



## Regression Estimation of Bongaart Indices from the Childbearing Indices: A Study of India/States/Districts

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### ABSTRACT

In a series of research articles El-khorazaty, Horne and Suchindran have showed how one can derive for any given population indirectly various childbearing and Bongaart fertility-inhibiting indices using only given information on the ASFRs, and the mathematical and regression models suggested by them. Very recently Bongaart revised his old model and suggested a set of new revised formulae to estimate various fertility-inhibiting indices. Following El-Khorazaty and Horne it is aimed to show in the present paper how one can derive various Bongaart revised fertility-inhibiting indices from the given information on various childbearing indices which were further seen derived from the only given information on TFR and a set of regression models that were earlier suggested by the first author and it is shown that the present study succeed in giving meaningful estimates for India its States, UTs, and Districts. Various regression models referring to estimation of childbearing indices used in this study were developed earlier by Ponnappalli using the state level time series of ASFRs overtime of the SRS of India and Horne et al., mathematical model. The regression models used in indirect estimation of the fertility-inhibiting indices from the TFR and also from the childbearing indices were developed by Ponnappalli using the Bongaart indices of the DHS surveys earlier given by Bongaart in his revised recent study.

**Keywords:** Fertility, Childbearing indices, Indirect Estimation, Bongaart Indices, ASFRs, TFR, TF, India.

### 1. INTRODUCTION

In an interesting study El-khorazaty (1992) proposed a ‘multivariate regression model’ to estimate Bongaart fertility-inhibiting indices of  $C_m$ ,  $C_c$ , and  $C_i$  from the information on childbearing indices. Horne and El-khorazaty (1996) further suggested a methodology to estimate childbearing and Bongaart indices from the ASFRs derived using the Coale-Trussell model fertility schedules. To be precise, in a series of research articles El-khorazaty, Horne and Suchindran showed a way how to derive indirectly various childbearing and Bongaart indices from the given information on ASFRs and the models derived by them.

In a recent study Ponnappalli (2016), following the above researchers, suggested a regression methodology to estimate the childbearing and Bongaart indices even from the total fertility rate (TFR), without the need of ASFRs. So far no researcher tried to provide and study district level variations in fertility using the estimates of childbearing and Bongaart indices due to obvious reasons. So the present study is such an attempt.

The two specific objectives of the present paper are:

- 1) For districts in India and states, for 1997 and 2011, to derive systematically various Bongaart revised indices indirectly, from the given set of childbearing indices using a regression approach earlier suggested by the first researcher.
- 2) To study the progress in the fertility transition in India during 1997 to 2011 using the estimate thus obtained and based on the study results to suggest some policy implications.

Details of the data used, methodology followed, analysis of the results, discussion of the results and conclusions brought out from this study followed by references are provided in the follow sections.

## 2. DATA

Data required for the present study are a set of childbearing indices for India, its states and 640 districts that refers to 1997 and 2011.

This study borrows the above information from another study made by the present authors (See Ponnappalli and Akash, 2019). To state, these childbearing indices were derived using a set of regression models. For convenience, the relevant regression models of the above study are presented here as Appendix Table 1. For details of the models one may refer the above study by Ponnappalli and Akash (2019). It is seen from Appendix Table 1 that given a value of TFR one may easily derive various childbearing indices from the regression models without much effort. For the present study childbearing indices relevant to the required years of 1997 and 2011 were derived using the TFR estimates of the relevant years earlier derived from the Reverse survival method (RSM) by the same researchers (See Ponnappalli and Akash, 2019). To state in simple, reverse survival method is one of the frequently used indirect technique by demographers to derive indicators like CBR, GFR and TFR using the simple census or survey information on age-sex distribution of data. In the recent past, Timaeus and Moultrie (2013) provided an extended version for RSM that which requires little more rigorous input data but provides somewhat reliable estimates of TFR, GFR, CBR, ASFRs for 15 years before the census period under consideration.

Thus said, the present researchers in their earlier studies (See Akash and Ponnappalli 2017, Ponnappalli and Akash, 2019) *at first*, using the age-sex distribution of population data of 2011 census of various Districts, States, UTs in India derived the TFR estimates for the years 1997 and 2011 from reverse survival method suggested by Timaeus and Moultrie (2013) and christened them as TFR (RSM) (See Akash and Ponnappalli, 2017). *Secondly*,

using this TFR (RSM) of 1997 and 2011 they derived the childbearing indices (See Ponnappalli and Akash, 2019). *Thirdly*, using these Childbearing indices of 1997 and 2011, in the present paper they derived a set of Bongaart indices for each of the State, UT, and 640 Districts in India for 1997 and 2011. Validity of the present indices obviously depends on the validity of the TFR (RSM) that was the main basic input for deriving the earlier childbearing and Bongaart indices here. To state, validity of the TFR (RSM) was tested by the researchers by comparing them with the another set of TFR estimates indirectly derived by Guilmo, and Rajan (2013) who further used a modified reverse survival method earlier suggested by Bhat (1996), christened here as (MRSM). It is seen that estimates made by both the methods were highly correlated with an R-Square value of 0.96. It is to state, the validity of the age-sex distribution data which was used in deriving the TFR (RSM) were further verified by means of calculating age-sex accuracy indices such as Whipple's Index, and Myers Index at district level in India. (See Akash and Ponnappalli, 2017).

*To emphasize further, the input used here in this paper to estimate various Bongaart indices from the suggested regression models is a set of childbearing indices that refer to two time periods 1997 and 2011. The childbearing indices used here are further noticed to be derived from the given TFR (RSM) estimates that refer to the said time periods of 1997 and 2011. The TFR (RSM) estimates are further seen to be derived from the age-sex distribution data of the 2011 census of India and the RSM method newly suggested by Timaeus, I.M. and Moultrie, T.A. (2013).*

El-khorazaty (1992) in his paper entitled “estimation of fertility-inhibiting indices using vital registration data” proposed a ‘correspondence model’ to derive the Bongaart indices. It uses Bongaart (1978, 1982, 1983) PD model (old version) and provided indices relevant to  $C_m$ ,  $C_c$  and  $C_i$ . However, Ponnappalli (2016) model proposed here to estimate Bongaart indices, unlike El-khorazaty (1992) model, uses the very recent modified version of the Bongaart (2015) model that allows even to estimate a value for the index  $C_a$ .

### 3. METHODS

#### 3.1. Brief Overview of Bongaart Original and Revised Aggregate and Age-specific PD Models

Information provided in this section of the paper is heavily borrowed from the Bongaart recent paper entitled “Modeling the fertility impact of the proximate determinants: Time for a tune-up” (See Bongaart, 2015).

As we know already, like mortality and migration, fertility is also determined by a number of factors. The factors that determine fertility are traditionally divided into background and proximate determinants. Background determinants (such as sociocultural, economic and environmental factors) are theorised to effect fertility only through their effect on proximate determinants (behavioural factors such as use of contraception and abortion, prevailing practices of marriage and breastfeeding). The interrelationship between these background and behavioural factors were first recognised by Davis and Blake (1956) and they proposed a set of 3 of behavioural factors which again consists of 11 variables in total. Davis and Blake (1956) christened these 11 variables as “Intermediate fertility variables” as background variables affects the fertility only through these selected variables. Several researchers further attempted to understand and simplify the process suggested by Davis and Blake. Fortunately, in late 1970s, Bongaart succeeded in suggesting a set of 7 intermediate variables which were christened by Bongaart as “proximate determinates (PDs)” of fertility (See Bongaart, 1978, 1982, 1983). Bongaart (1978) further developed a ‘simple’ model to quantify the effect of various PDs, especially of four crucial PDs, on fertility (TFR/CBR). His model was widely used in studying and understanding levels, trends and differentials in fertility in terms of proximate determinants and their effect of many a number of countries in the world (Bongaart, 2015).

Stover (1998) followed by other researchers made a number of attempts to revise this Bongaart late 1970s PD model. Certain drawbacks related to various assumptions made by Bongaart in the original model and the recent changes taken place in the factors that determine fertility with a progress in the demographic transition of world countries, genuinely led to the suggestions and modifications for the original model. Interestingly Bongaart (2015) himself made a further attempt to revise his original model incorporating ‘six adjustments’ and tried to show that his ‘new revised model provides an improved assessment of the roles of the proximate determinants. This was made possible through his experiments using the recent DHS survey data of 36 countries carefully chosen by him. (Bongaart, 2015, page 554).

Bongaart (1978) study suggested two different models namely ‘aggregate model’ and ‘age-specific model’. The aggregate model which is widely used is as given below:

Original aggregate model:  $TFR = C_m \times C_c \times C_i \times C_a \times TF$

Where, TFR = observed total fertility rate;  $C_m$  = Index of marriage

$C_c$  = Index of contraception;  $C_i$  = Index of postpartum infecundability

$C_a$  = Index of abortion; TF = Total fecundity rate

Bongaart (2015:537) states this model as a “multiplicative equation for a population at a given point of time” and “treats each PD as a factor that inhibits fertility.” Each of the index in the model developed in such a way that each of them vary from a value of ‘0’ to a value of ‘1’. For instance  $C_m$ ,  $C_c$ ,  $C_i$ , and  $C_a$  equals ‘1’: only when ‘all women are cohabitating’, only when all women ‘not using any contraception’, and ‘in the absence of lactational amenorrhea’, ‘in the absence of abortion’ respectively. Bongaart (2015, page 537) further states TF is recognised to be the same as the TFR but is a ‘hypothetical’ one that is assumed to be ‘around 15 births per woman’ seen in any population when  $C_m = C_c = C_i = C_a = 1$ .

Using the DHS survey information and the following formulae of  $C_m$ ,  $C_c$ ,  $C_i$ ,  $C_a$  earlier suggested by Bongaart (1978, 1982, 1983) further given in table 1 of Bongaart (2015, page 538) one may directly estimate the original aggregate model-based indexes. For convince of presentation Table 1 below is extracted from Bongaart (2015, page 538) and presented as it is.

Table 1. Original aggregate proximate determinants model and equations for Indexes.

<i>Index</i>	<i>Equations</i>	<i>Variables</i>
Original aggregate model	$TFR = C_m C_c C_i C_a TF$	TFR = total fertility rate TF = total fecundity rate
Marriage index	$C_m = \frac{\sum m(a) f_m(a)}{\sum f_m(a)}$	m(a) = proportion married by age f <sub>m</sub> (a) = age-specific marital fertility rate (a) = age
Contraception index	$C_c = 1 - 1.08 u e$	u = contraceptive prevalence (married women) e = average effectiveness
Postpartum infecundability index	$C_i = \frac{20}{18.5 + i}$	i = average duration of postpartum infecundability
Abortion index	$C_a = \frac{TFR}{TFR + b TAR}$ $b = 0.4 (1 + u)$	TAR = total abortion rate b = births averted per abortion

Source: Formulae extracted from Table 1, of Bongaart (2016).

Table 2. Original age-specific proximate determinants model and equations for Indexes.

<b>Index</b>	<b>Equations</b>	<b>Variables</b>
Original age-specific model	$f(a) = C_m(a)C_c(a)C_i(a)C_a(a)f_f(a)$	f(a) = age-specific fertility rate
		$f_f(a)$ = age-specific fecundity rate
		a = age
Marriage index	$C_m(a) = m(a)$	m(a) = proportion married
Contraception index	$C_c(a) = 1 - r(a)u(a)e(a)$	u(a) = contraceptive prevalence (married women)
		e(a) = average effectiveness
		r(a) = fecundity adjustment
Postpartum infecundability index	$C_i(a) = \frac{20}{18.5 + i(a)}$	i (a)= average duration of postpartum infecundability
Abortion index	$C_a(a) = \frac{f(a)}{f(a) + b ab(a)}$ $b = 0.4 (1 + u)$	ab(a) = abortion rate
		b = births averted per abortion

Source: Formulae extracted from Table 2, of Bongaart (2016).

Table 3. Revised age-specific proximate determinants model and equations for Indexes.

<b>Index</b>	<b>Equations</b>	<b>Variables</b>
Revised age-specific model	$f(a) = C_m^*(a)C_c^*(a)C_i^*(a)C_a^*(a)f_f^*(a)$	* = represents revised measures
Sexual exposure index	$C_m^*(a) = m(a) + ex(a)$	m(a) = proportion married/union
		ex(a) = extramarital exposure
Contraception index	$C_c^*(a) = 1 - r^*(a)(u^*(a) - o(a))e^*(a)$	u*(a) = contraceptive prevalence (exposed women)
		o(a) = overlap with postpartum infecundability
		e*(a) = average effectiveness
		r*(a) = fecundity adjustment
Postpartum infecundability index	$C_i^*(a) = \frac{20}{18.5 + i(a)}$	i (a)= average duration of postpartum infecundability
Abortion index	$C_a^*(a) = \frac{f(a)}{f(a) + b^* ab(a)}$	ab(a) = abortion rate
		$b^* = \frac{14}{18.5 + i(a)}$
		b = births averted per abortion

Source: Formulae extracted from Table 3, of Bongaart (2016).

Table 4. Revised age-specific proximate determinants model and equations for Indexes.

<b>Index</b>	<b>Equations</b>	<b>Variables</b>
Revised age-specific model	$TFR = \sum C_m^*(a)C_c^*(a)C_i^*(a)C_a^*(a)f_f^*(a)$ $= C_m^*C_c^*C_i^*C_a^*TF^*$	TF* = revised total fecundity rate f <sub>f</sub> <sup>*</sup> (a) = revised fecundity rate
Sexual exposure index	$C_m^* = \sum C_m^*(a)w_m^*(a)$ $w_m(a) = \frac{f_m^*(a)}{\sum f_m^*(a)}$ $f_m^*(a) = C_c^*(a)C_i^*(a)C_a^*(a)f_f^*(a)$	f <sub>m</sub> <sup>*</sup> (a) = fertility rate, exposed women a = age
Contraception index	$C_c^* = \sum C_c^*(a)w_c(a)$ $w_c(a) = \frac{f_n^*(a)}{\sum f_n^*(a)} \approx \frac{f_f^*(a)}{\sum f_f^*(a)}$ $f_n(a) = C_i^*(a)C_a^*(a)f_f^*(a)$ $C_i^* = \sum C_i^*(a)w_i(a) \approx C_i$	f <sub>n</sub> <sup>*</sup> (a) = natural exposed fertility a = age
Postpartum infecundability index	$C_a^* = \sum C_a^*(a)w_a(a) \approx \frac{TFR}{TFR+b^* TFR}$	

**Source:** Formulae extracted from Table 4, of Bongaart (2016).

A summary picture of the Bongaart age-specific PD model and relevant equations of the indexes originally proposed and given by Bongaart and Potter (1983) are shown below as table 2, that which is again extracted from Bongaart (2015, page 539). The age-specific PD model however is having an advantage over the aggregate model, its use is observed to be limited as it demands more detailed data to calculate various indexes. Bongaart (2015) realized that each of the above proximate determinants require a revision in their calculation and in certain issues relevant to each of them as highlighted by Bongaart in his recent article of 2015. For instance, Bongaart (2015, page 541) states “the original model assumes that the proximate determinants at a point in time affect fertility at the same time. In reality, there is a nine-month delay between a change in a proximate determinant and its impact on fertility.”

Bongaart (2015, pages 543-544) states that the revision proposed by him for his original PD model to a grate extent ‘overlap in a number of cases with those proposed by John Stover (1998).’ And states “in sum, JS and JB are in broad agreement on a number of issues”. Tables 3 and 4 extracted from Bongaart (2015, page 545-546) and given below for convenience summarily presents the revised age-specific PD model and aggregate PD model

and their equations for various indexes, respectively. For further details of the new models such as the six adjustments and other formulae relevant to the new models one may refer Bongaart (2015).

### 3.2. Regression Models for Indirect Estimation of Bongaart Revised Indices from the Childbearing Indices

After an understanding of the Bongaart original and revised models it is easy to understand and appreciate the indirect estimate procedure proposed by Ponnappalli, the first author, which is given below:

Model 1:  $\ln(C_m) = (-.153) + (.108) \times \ln(MAFB) + (-.169) \times \ln(MALB) + (-.176) \times \ln(VAFB) + (-.090) \times \ln(VALB) + (.382) \times \ln(MRLS)$

Model 2:  $\ln(C_c) = (-.005) + (.169) \times \ln(MAFB) + (-.266) \times \ln(MALB) + (-.277) \times \ln(VAFB) + (-.142) \times \ln(VALB) + (.602) \times \ln(MRLS)$

Model 3:  $\ln(C_i) = (-.576) + (-.052) \times \ln(MAFB) + (.082) \times \ln(MALB) + (.085) \times \ln(VAFB) + (.044) \times \ln(VALB) + (-.185) \times \ln(MRLS)$

Model 4:  $\ln(C_a) = (-.044) + (.031) \times \ln(MAFB) + (-.048) \times \ln(MALB) + (-.050) \times \ln(VAFB) + (-.026) \times \ln(VALB) + (.110) \times \ln(MRLS)$

The above regression models observed to have highest percent of variation explained (i.e., R-Square). These models were further seen to be derived using a set of regression models earlier derived by Ponnappalli (2016). Using the childbearing indices and the regression models 1 to 4 given above, a set of proximate determinants are derived for the years 1997 and 2011 (These estimates may be obtained from the researchers).

## 4. RESULTS

### 4.1. Understanding fertility transition in India at the state level during 1997 to 2011: Using various indirect estimates of Bongaart indices

Fertility transition taken place during 1997 to 2011 at the major state level is studied here by means of finding the relative contribution of a change in a particular PD over time from 1997 to 2011 to the overall change in the TFR during the same time period of 1997 to 2011.

The following formulae are used for the same:

It is realized that:  $AARG(C_m) + AARG(C_c) + AARG(C_i) + AARG(C_a) + AARG(TF) = AARG(TFR)$

Where  $AARG =$  Average annual rate of growth (or change), may be positive or negative.

Here it is realized  $TFR = C_m C_c C_a C_i TF$

$AARG$  of each PD, TF and TFR are computed as:

$$AARG (TFR) = (1/n) \times (\ln(TFR1997/TFR2011)), n = 2011 - 1997 = 14$$

$$AARG (C_m) = (1/n) \times (\ln(C_m1997/C_m2011)), n = 2011 - 1997 = 14$$

$$AARG (C_c) = (1/n) \times (\ln(C_c1997/C_c2011)), n = 2011 - 1997 = 14$$

$$AARG (C_i) = (1/n) \times (\ln(C_i1997/C_i2011)), n = 2011 - 1997 = 14$$

$$AARG (C_a) = (1/n) \times (\ln(C_a1997/C_a2011)), n = 2011 - 1997 = 14$$

$$AARG (TF) = (1/n) \times (\ln(TF1997/TF2011)), n = 2011 - 1997 = 14$$

Appendix Table 2 provides the details of the AARG of each of the above indices and a change (in %) in PD and TF for a change in TFR over time. While, figure 1 depicts the AARG in TFR 1997 to 2011, figure 2 depicts the relative contribution of  $C_m$ ,  $C_c$ ,  $C_i$ ,  $C_a$  and TF for a change in TFR during 1997 and 2011, for India and major states.

For convenience the AARG is shown in Figure 1 in positive terms for ease of presentation but when it is noticed in Appendix Table 2 the same is shown negatively as the formulae used gives it in negative terms. Both are observed to be the same except for the sign used and not to be confused.

After a keen observation of figure 1, figure 2 and from the results given Appendix Table 2 below panel, it is concluded that:

- 1) The AARG in TFR from 1997 to 2011 of the 5 states of : Uttar Pradesh, followed by West Bengal, Uttarakhand, Bihar, Assam seen to be more than the other states during the said period.
- 2) The AARG in TFR from 1997 to 2011 of the 2 states of: Kerala and Tamil Nadu observed to be very low, obviously it is seen that these are the two states with very low fertility during the study period. As fertility transition is almost completed we cannot expect much change over time in these and other low fertility states.
- 3) While the relative contribution of PD index  $C_i$  for a change in TFR overtime is observed to be negative the contribution of the other PD indexes observed to be positive.
- 4) When rank ordered the relative contributions for a decline in TFR over time:  $C_c$  comes first followed by  $C_m$ ,  $C_a$  and finally TF. It indicates that use of contraception and postponement of marriage perhaps due to major changes in the educational levels of the female population in India even at the district level might have contributed comparatively more than the other two PD indices.
- 5)  $C_i$  contribution is towards an increase in fertility as breastfeeding and postpartum abstinence period's declines with modernization.

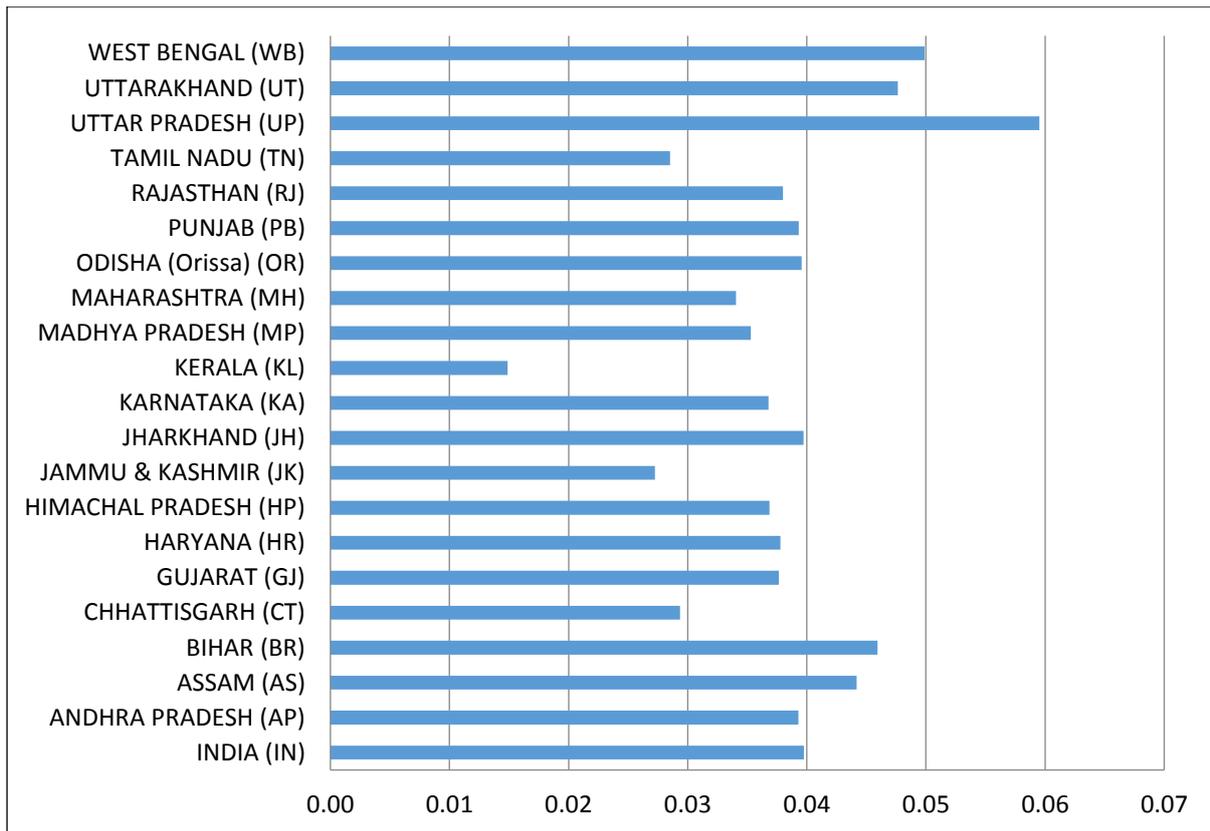


Figure 1. AARG in TFR 1997-2011, 20 states in India (Source Appendix Table 2).

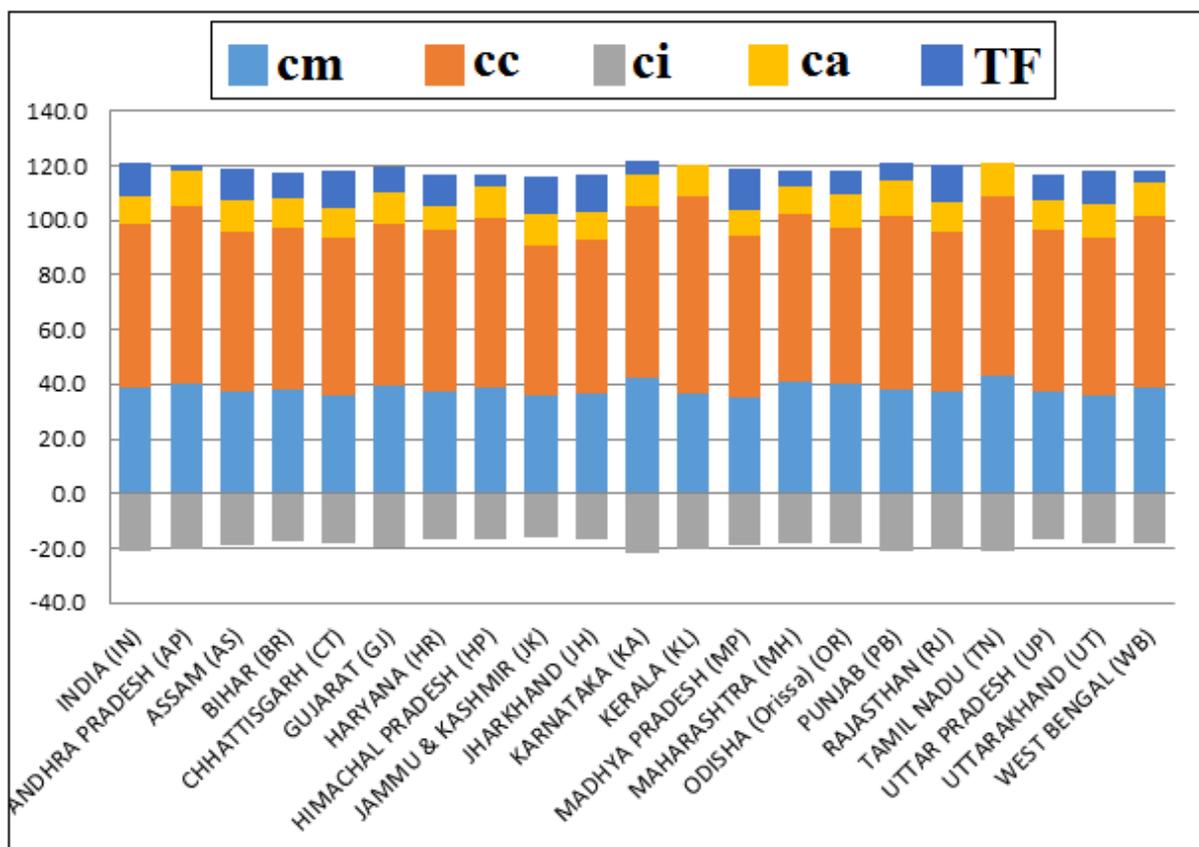


Figure 2. Relative contribution of  $C_m$ ,  $C_c$ ,  $C_i$ ,  $C_a$  and TF for a change in TFR during 1997 and 2011, India and major states (Source: Appendix Table 2).

One may have a better understanding of the same from figure 3 which shows by means of box-plots, a change in PDs from 1997 to 2011 of major states. Box plots in figure 3 summarize the distribution of PD indices  $C_m$ ,  $C_c$ ,  $C_i$  and  $C_a$  over time. In figure 3, Y-axis represents the index value and X-axis represents the time period. A change in TFR and TF not shown here along with the PDs as the scaling of these is very different difficult to show in the same figure.

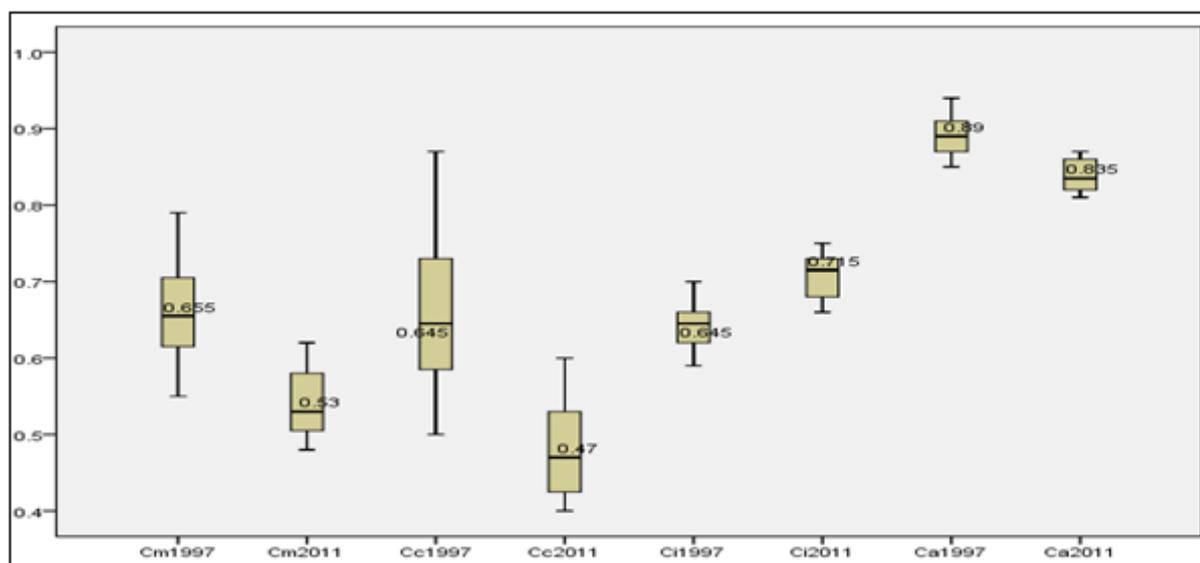


Figure 3. Indirect estimates of Bongaart Indices, 20 States in India, 1997 and 2011 (Source: Prepared by the researchers).

From figure 3, it is noticed that a box is a rectangle, the top and bottom of which mark the 75th and 25th percentiles, respectively, with the median observation (in this case, the median of state) as a cross-bar within the box (values of median depicted in the diagram for convince). The “whiskers” for each box are the lines protruding above and below, and indicate the range of the data above and below the upper and lower quartiles. Larger the whisker size, larger the number of values in that side. For further details of Box plot description, one may see any statistical text book.

For instance Black (2013, page 85) describes a box-and-whisker plot as a “diagram that utilizes the upper and lower quartiles along with median and two most extreme values to depict a distribution graphically.” It gives a five-number summary namely of the median (Q2), the lower quartile (Q1), the upper quartile (Q3), the smallest value in the distribution (minimum value), and the largest value in the distribution (maximum value) (Black, 2013, page 85).

#### 4.2. Understanding fertility transition in India at the district level during 1997 to 2011: Using various indirect estimates of Bongaart indices

We may summarize the district level analysis results in this section of the paper again by means of depicting the progress in PDs by box plots as shown in figure 4.

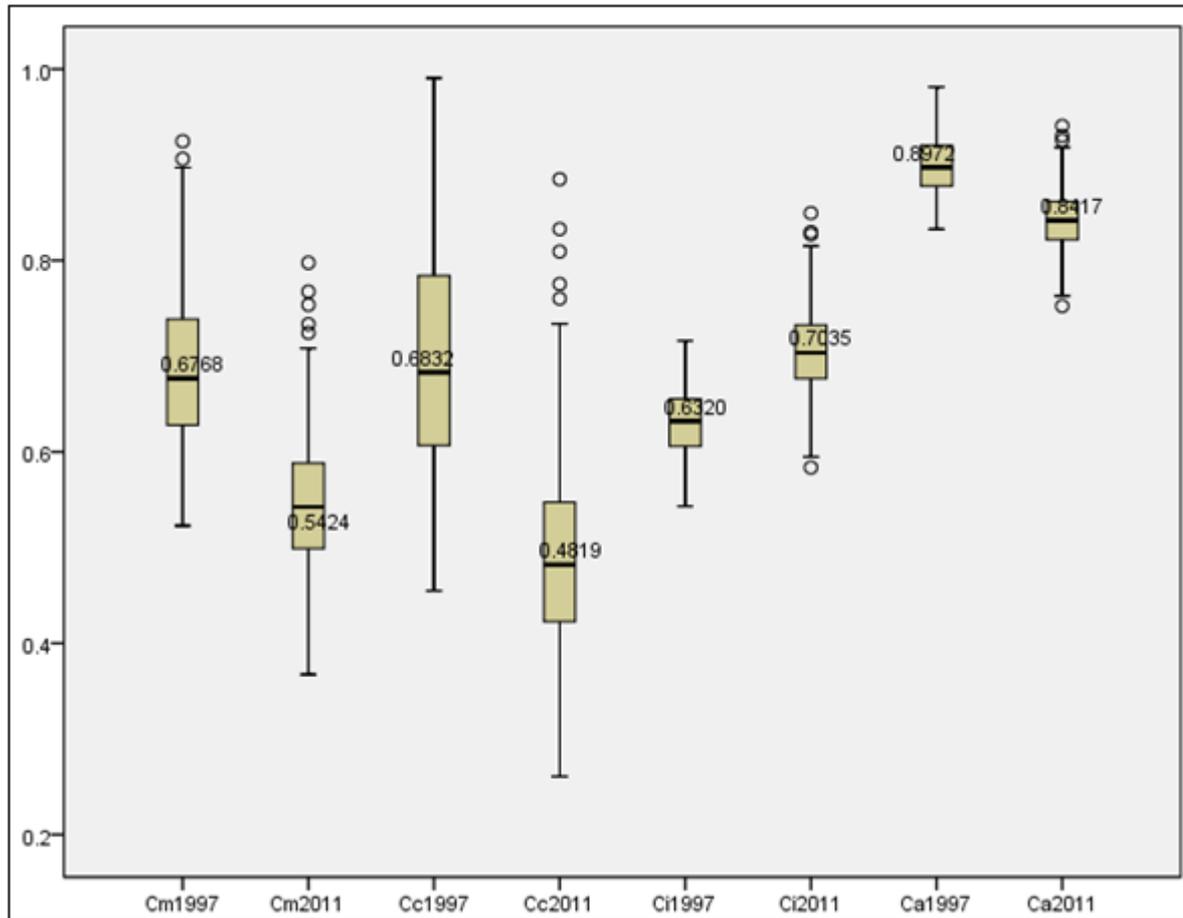


Figure 4. Indirect estimates of Bongaart Indices, 640 Districts in India, 1997 and 2011 (Source: Prepared by the researchers).

Figure 4 almost resembles the results given in figure 3 as that of the states, however, better representing the fertility variation in different states by means of changes overtime in their districts. Median values are observed to be declining in case of each PD except for C<sub>i</sub> as expected. As such district level analysis of changes in various PDs seems to corroborate the findings at the state level.

Above findings reached here by estimating indirect estimates of PDs and their further analysis said to be very similar to what theory states and furnished by Bongaart (2015). To be specific Bongaart (2015, page 549) states that “As expected, the indexes C<sub>m</sub>, C<sub>c</sub>, C<sub>a</sub> decline as countries move from high to low fertility and the inhibiting effects of these PDs become

stronger. In contrast,  $C_i$  rises as countries move through the transition because breastfeeding and postpartum abstinence decline.”

Thus said, the above two sections of the paper well proved the usefulness of the Bongaart indices derived indirectly and their validity as reliable estimates also as the results corroborate the finding from the study by Bongaart (2015).

## 5. CONCLUSIONS

In conclusion it may be stated that the Bongaart indices derived here, indirectly from the childbearing indices, seem to be quite acceptable and also found to be useful in an understanding of the fertility transition taking place in India and its sub-units. Thus this paper succeed in full filling the objectives of the present study earlier stated in the introduction. The new regression model/s used here may further be tested and modified with time at regular intervals of time as regression has certain methodological limitations as it depends on certain assumptions. In the policy point of view it is to state that there is a need to reduce fertility further in the most populous states of India namely Bihar, Madhya Pradesh, Rajasthan, Uttar Pradesh.

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**Appendix Table 1:** Regression models for estimating selected childbearing indices from TFR.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
<b>CONSTANT, INDEPENDENT VARIABLES, and R<sup>2</sup></b>	<b>DEPENDENT VARIABLE</b>						
	<i>Ln (PCW)</i>	<i>Ln (MRLS)</i>	<i>Ln (MALB)</i>	<i>Ln MACB)</i>	<i>Ln (VACB)</i>	<i>Ln (VALB)</i>	<i>Ln (VAFB)</i>
Constant	-.841	.685	2.958	-.394	1.656	-1.576	3.080
Ln (TFR)	-1.604	1.738	-.347	.101	-1.754	5.200	-2.125
Ln (TFR <sup>2</sup> )	.280						
Ln (TFR <sup>3</sup> )	-.553						
Ln (PCW)		.154	-.087	.041	-.137	.789	-.076
Ln (MRLS)			.285	-.148	1.616	-4.090	2.158
Ln (MALB)				1.163	.831	2.241	-7.342
Ln (MACB)					-.880	-2.198	11.341
Ln (VACB)						2.882	-.420
Ln (VALB)							.090
Ln (MAFB)							-4.215
R Square	1.000	.965	.948	.991	.998	.956	.988

**Source:** Table 1 of Ponnappalli and Akash (2019), models prepared by Ponnappalli.

**Note: (1):** All the coefficients of various independent variables and constant terms given in various models above are observed to be statistically significant having a t - statistic value of more than 2.0.

**Note: (2):** MAFB = MRLS -MALB; For instance: Model 3:  $\ln (MALB) = (2.958) + (-.347) * \ln (TFR) + (-.087) * \ln (PCW) + (.285) * \ln (MRLS)$ .

**Note: (3):** In the above models: ‘Ln’ indicates the natural logarithm;  
 TFR = Total fertility rate = Sum of ASFRs of ages 15 to 49;  
 PCW = Percent childless women;  
 MAFB = Mean age at first birth;  
 MALB = Mean age at last birth;  
 MRLS = Mean reproductive life span;  
 MACB = Mean age at childbearing;  
 VACB = Variance of age at childbearing;  
 VALB = Variance of age at last birth;  
 VAFB = Variance of age at first birth.

<b>Appendix Table 2:</b> Average Annual Rate of Growth (AARG) in $C_m$ , $C_c$ , $C_i$ , $C_a$ , TF and TFR and their relative contribution to a change in TFR, India and major states, 1997 and 2011. (Note: $TFR = C_m C_c C_i C_a TF$ ).						
<i>Average Annual Rate of Growth (AARG) in <math>C_m</math>, <math>C_c</math>, <math>C_i</math>, <math>C_a</math>, TF, India and major states</i>						
	<i>AARG(<math>C_m</math>)</i>	<i>AARG(<math>C_c</math>)</i>	<i>AARG(<math>C_i</math>)</i>	<i>AARG(<math>C_a</math>)</i>	<i>AARG(TF)</i>	<i>AARG(TFR)</i>
India and States	1997-2011	1997-2011	1997-2011	1997-2011	1997-2011	1997-2011
INDIA (IN)	-0.015	-0.024	0.009	-0.004	-0.005	-0.040
ANDHRA PRADESH (AP)	-0.016	-0.025	0.008	-0.005	-0.001	-0.039
ASSAM (AS)	-0.016	-0.026	0.009	-0.005	-0.005	-0.044
BIHAR (BR)	-0.018	-0.027	0.008	-0.005	-0.004	-0.046
CHHATTISGARH (CT)	-0.010	-0.017	0.005	-0.003	-0.004	-0.029
GUJARAT (GJ)	-0.015	-0.022	0.007	-0.004	-0.003	-0.038
HARYANA (HR)	-0.014	-0.022	0.006	-0.003	-0.004	-0.038
HIMACHAL PRADESH (HP)	-0.014	-0.023	0.006	-0.004	-0.002	-0.037
JAMMU & KASHMIR (JK)	-0.010	-0.015	0.004	-0.003	-0.004	-0.027
JHARKHAND (JH)	-0.014	-0.023	0.007	-0.004	-0.005	-0.040
KARNATAKA (KA)	-0.016	-0.023	0.008	-0.004	-0.002	-0.037
KERALA (KL)	-0.005	-0.011	0.003	-0.002	0.000	-0.015
MADHYA PRADESH (MP)	-0.012	-0.021	0.007	-0.003	-0.005	-0.035
MAHARASHTRA (MH)	-0.014	-0.021	0.006	-0.003	-0.002	-0.034
ODISHA (Orissa) (OR)	-0.016	-0.022	0.007	-0.005	-0.003	-0.040
PUNJAB (PB)	-0.015	-0.025	0.008	-0.005	-0.003	-0.039
RAJASTHAN (RJ)	-0.014	-0.022	0.008	-0.004	-0.005	-0.038
TAMIL NADU (TN)	-0.012	-0.019	0.006	-0.003	0.000	-0.029
UTTAR PRADESH (UP)	-0.022	-0.035	0.010	-0.006	-0.006	-0.060
UTTARAKHAND (UT)	-0.017	-0.027	0.009	-0.006	-0.006	-0.048
WEST BENGAL (WB)	-0.019	-0.031	0.009	-0.006	-0.002	-0.050
<i>Relative contribution of AARG in <math>C_m</math>, <math>C_c</math>, <math>C_i</math>, <math>C_a</math>, TF to the change in AARG of TFR, India and major states</i>						
	<i><math>C_m</math></i>	<i><math>C_c</math></i>	<i><math>C_i</math></i>	<i><math>C_a</math></i>	<i>TF</i>	<i>TFR</i>
India and States	1997-2011	1997-2011	1997-2011	1997-2011	1997-2011	1997-2011
INDIA (IN)	38.8	59.9	-21.5	10.4	12.4	100
ANDHRA PRADESH (AP)	40.6	64.4	-20.5	13.0	2.6	100
ASSAM (AS)	37.3	58.7	-19.3	11.2	12.2	100
BIHAR (BR)	38.2	59.4	-17.4	10.4	9.4	100
CHHATTISGARH (CT)	35.7	58.0	-18.3	11.2	13.4	100
GUJARAT (GJ)	39.4	59.7	-19.4	11.1	9.3	100
HARYANA (HR)	37.3	59.2	-16.9	8.7	11.8	100
HIMACHAL PRADESH (HP)	38.5	62.5	-16.6	11.5	4.1	100
JAMMU & KASHMIR (JK)	35.5	55.0	-16.4	11.8	14.1	100
JHARKHAND (JH)	36.4	56.7	-16.6	10.2	13.4	100
KARNATAKA (KA)	42.6	62.7	-22.2	11.5	5.5	100
KERALA (KL)	36.3	72.4	-20.2	11.4	0.0	100
MADHYA PRADESH (MP)	35.1	59.2	-18.7	9.2	15.2	100
MAHARASHTRA (MH)	41.0	61.5	-18.2	9.9	5.9	100
ODISHA (Orissa) (OR)	40.3	56.8	-18.5	12.6	8.8	100
PUNJAB (PB)	38.4	63.5	-21.1	12.8	6.4	100
RAJASTHAN (RJ)	37.4	58.3	-20.4	10.6	14.0	100
TAMIL NADU (TN)	43.1	65.7	-20.9	12.1	0.0	100
UTTAR PRADESH (UP)	37.1	59.5	-17.0	10.7	9.8	100
UTTARAKHAND (UT)	36.2	57.7	-18.2	12.0	12.3	100
WEST BENGAL (WB)	38.9	62.8	-18.6	11.9	5.0	100
<b>Source:</b> Prepared by the researchers						
<b>Note 1:</b> For instance $AARG(TFR) = (1/n) * (\ln(TFR_{1997}/TFR_{2011}))$ , $n = 2011 - 1997 = 14$ ;						
<b>Note 2:</b> $AARG(C_m) + AARG(C_c) + AARG(C_i) + AARG(C_a) + AARG(TF) = AARG(TFR)$						