

Extended Abstract submitted to IPC 2021

Probabilistic projection of subnational total fertility rate in India and its 15 major states, 1950-2100

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Population prediction is a mathematical effort to look at the future population situation based on certain hypotheses and historical evidence present. The assumptions made and their likelihood of being correct in the future are important inputs in this mathematical endeavour. Predicting the future path of human reproduction and mortality is difficult, especially when looking back in time. Fertility rates in India have declined sharply, from nearly 6 children per woman in 1950 to 2.6 children per woman in 2010. India has more births than any other contemporary nation, with approximately 24 million births each year. Fertility varies dramatically across India. A contemporary map of India's total fertility rate (TFR) by state reveals a wide variety of fertility rates. While many southern states have TFRs that look like European fertility rates, other states have rates that look more closely like fertility in sub-Saharan Africa. State level TFRs range from 1.37 in Tripura to 3.57 in Bihar. This is a wide range of fertility, even for a country as large as India. For comparison, state-level TFR in the U.S. ranges from 1.4 to 2.2, and Chinese provinces range from 0.9 to 2.2. The main objective of this paper is to project fertility rates for the sub-national level in India using the UN's Bayesian probabilistic approach in order to compare with the most recent fertility information population projections of India and States (2011-2036), a report prepared by a 'Technical Group on Population Projection' with the deterministic projection. Results show that technical group projections systematically underestimated the TFR in 2018, since the pace of acceleration of the fertility decline in the 2000s is bit slow compared to them. Social advances observed in this decade might have influenced such fertility decline. For projections with starting point in 2018, technical group's estimations still present lower figures than those projected by the Bayesian model (TFR by technical group, 2.13 in 2016-2020; Bayesian estimated TFR 2.24 in 2018), in addition to a different convergence pattern in 2030. As per our

projection result, TFR is expected to decline from 2.24 during 2018 to 1.97 during 2033 to 1.73 in 2058. The results of the fertility projections show a continued decline in Indian fertility. By 2050, almost every Indian state is expected to have fertility levels below replacement. Several checks were carried out for deciding the minimum number of iterations needed to have best estimates of parameters, which concluded with the final result of 70,000 iterations of three chains. The trace plot and diagnostics test suggested convergence of parameters. Once the TFR starts to decline, there reaches a time where two consecutive increases above two children are observed which is the start of phase III. In India, Bayesian approach projections are a promising alternative to sub-national level projections, providing point estimates and calculate uncertainty. However, some changes, such as the inclusion of age-specific fertility rates and fertility-related covariates, such as educational attainment, may be made to the model.

Table 1: TFR Trajectories for India starting from 2018 to 2098, with median, 75%, 80%, 95% confidence interval based on Bayesian hierarchical approach.

Year	Mean	SD	2.5%	5%	10%	25%	50%	75%	90%	95%	97.5%
2018	2.24	0.00	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24
2023	2.14	0.18	1.78	1.84	1.91	2.02	2.14	2.26	2.37	2.43	2.47
2028	2.05	0.24	1.58	1.65	1.74	1.88	2.05	2.22	2.36	2.45	2.53
2033	1.97	0.28	1.43	1.52	1.60	1.79	1.98	2.16	2.33	2.43	2.52
2038	1.91	0.31	1.29	1.40	1.51	1.70	1.91	2.11	2.29	2.42	2.50
2043	1.85	0.32	1.21	1.30	1.42	1.63	1.86	2.06	2.24	2.37	2.47
2048	1.80	0.34	1.12	1.22	1.36	1.58	1.81	2.01	2.21	2.34	2.43
2053	1.76	0.34	1.06	1.16	1.30	1.54	1.78	1.98	2.18	2.31	2.43
2058	1.73	0.35	1.00	1.12	1.27	1.52	1.75	1.95	2.15	2.28	2.39
2063	1.70	0.34	0.98	1.09	1.24	1.50	1.73	1.92	2.12	2.25	2.35
2068	1.69	0.35	0.91	1.07	1.24	1.49	1.71	1.91	2.10	2.21	2.31
2073	1.68	0.34	0.93	1.05	1.21	1.48	1.71	1.89	2.07	2.19	2.31
2078	1.67	0.33	0.92	1.08	1.23	1.48	1.70	1.88	2.05	2.17	2.30
2083	1.67	0.33	0.93	1.08	1.23	1.48	1.70	1.86	2.04	2.16	2.29
2088	1.67	0.32	0.94	1.08	1.24	1.49	1.70	1.86	2.04	2.16	2.29
2093	1.67	0.32	0.95	1.09	1.25	1.51	1.70	1.86	2.03	2.16	2.28
2098	1.68	0.31	0.96	1.11	1.29	1.52	1.70	1.86	2.02	2.14	2.23

Source: Author's calculation

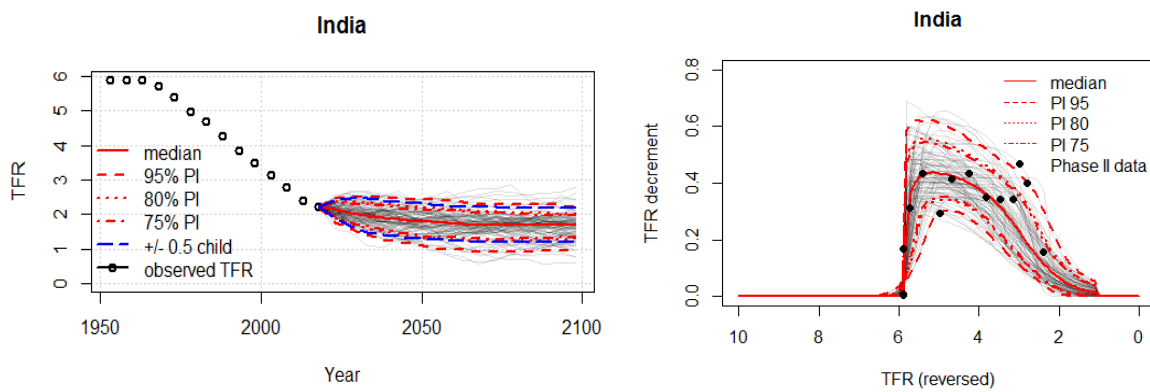
Table 2: Technical group projection of TFR, India 2011-2035	
Year/Period	Period level of TFR
SRS 2009-11	2.50
SRS 2011-15	2.37
2016-2020	2.13
2021-2025	1.94
2026-2030	1.81
2031-2035	1.73
Source: Statement 2 projected levels of TFR, India, 2011-2035; technical group report on population projections, census of India July, 2020	

Table 3: Projected mean TFR for 15 major Indian states, 2008-2098

Sl. No.	States	Year									
		2008	2018	2028	2038	2048	2058	2068	2078	2088	2098
1	Andhra Pradesh	1.92	1.64	1.59	1.53	1.49	1.48	1.48	1.49	1.52	1.55
2	Assam	2.70	2.18	2.00	1.86	1.76	1.69	1.66	1.64	1.64	1.66
3	Bihar	4.03	3.09	2.71	2.43	2.21	2.07	1.97	1.91	1.87	1.85
4	Gujarat	2.69	2.17	1.99	1.86	1.76	1.70	1.66	1.64	1.65	1.66
5	Haryana	2.64	2.13	1.97	1.84	1.74	1.68	1.64	1.63	1.63	1.64
6	Karnataka	2.09	1.75	1.67	1.61	1.55	1.53	1.52	1.53	1.55	1.58
7	Kerala	1.72	1.51	1.47	1.45	1.43	1.43	1.43	1.45	1.48	1.52
8	Madhya Pradesh	3.43	2.68	2.39	2.18	2.01	1.91	1.83	1.79	1.77	1.76
9	Maharashtra	2.03	1.71	1.64	1.58	1.53	1.51	1.50	1.52	1.54	1.57
10	Odisha	2.44	1.99	1.86	1.76	1.67	1.63	1.60	1.60	1.61	1.63
11	Punjab	1.98	1.68	1.61	1.56	1.52	1.50	1.50	1.51	1.53	1.56
12	Rajasthan	3.45	2.68	2.39	2.18	2.02	1.91	1.84	1.80	1.78	1.77
13	Tamil Nadu	1.69	1.48	1.45	1.44	1.42	1.41	1.42	1.44	1.48	1.52
14	Uttar Pradesh	3.98	3.05	2.68	2.41	2.20	2.06	1.96	1.90	1.86	1.84
15	West Bengal	1.97	1.67	1.60	1.55	1.51	1.49	1.49	1.50	1.53	1.55

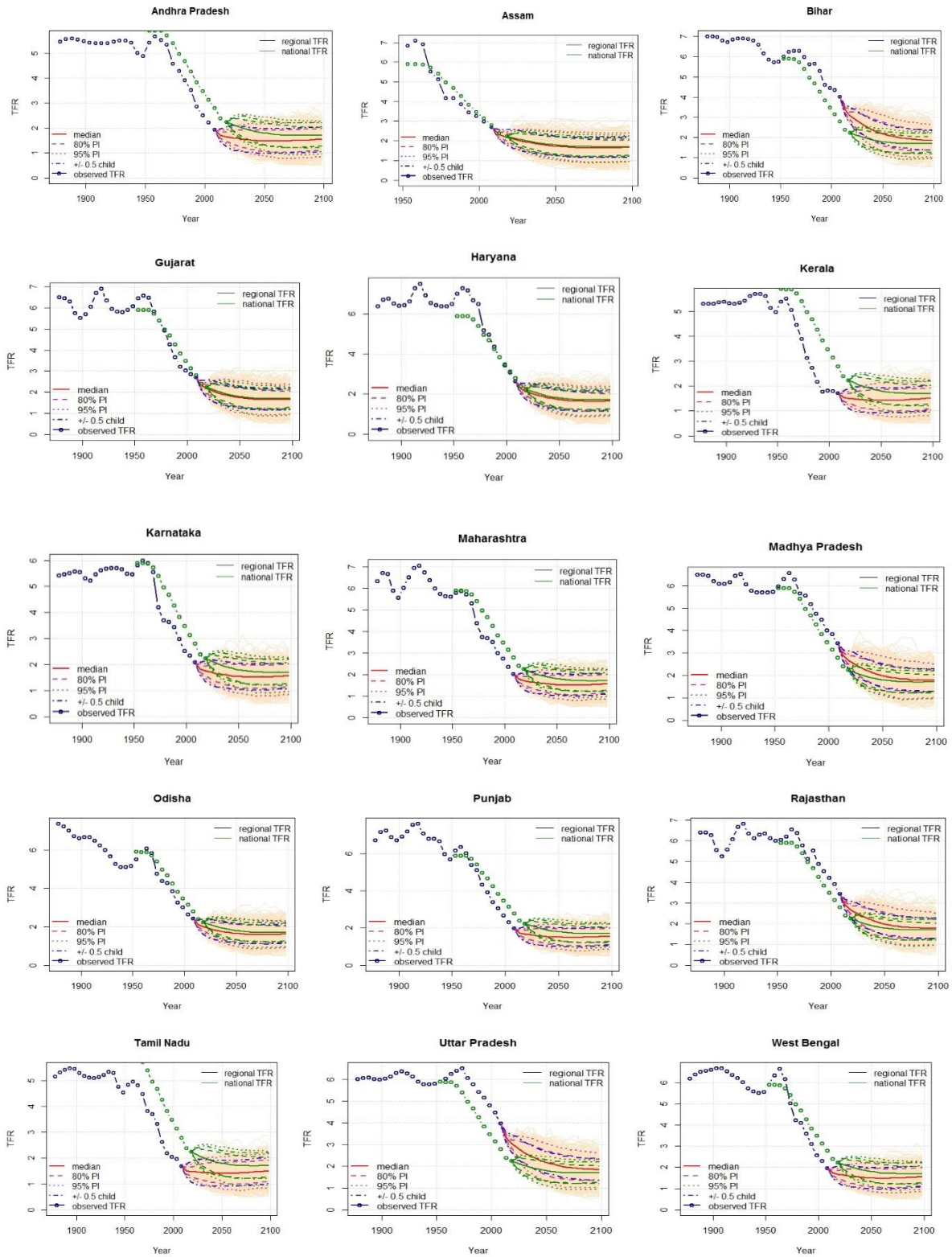
Source: Author's calculation

Figure 1: Graphs showing national trajectories for projected TFR, 1950-2100 and Double Logistic Curve,



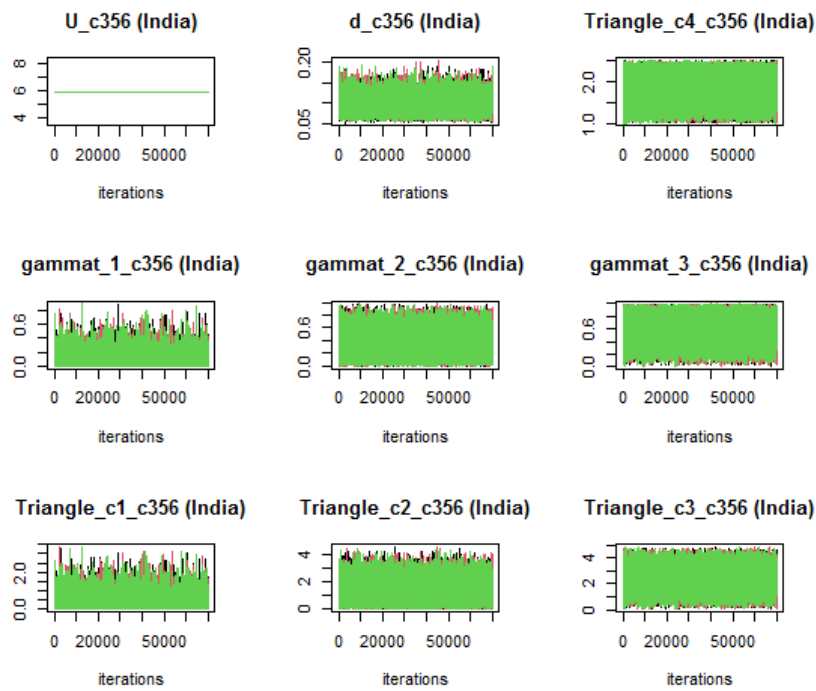
Source: Author's calculation

Figure 2: Comparison of TFR trajectories at national (India) and regional level based on data from India for its 15 major regions, 1950-2100



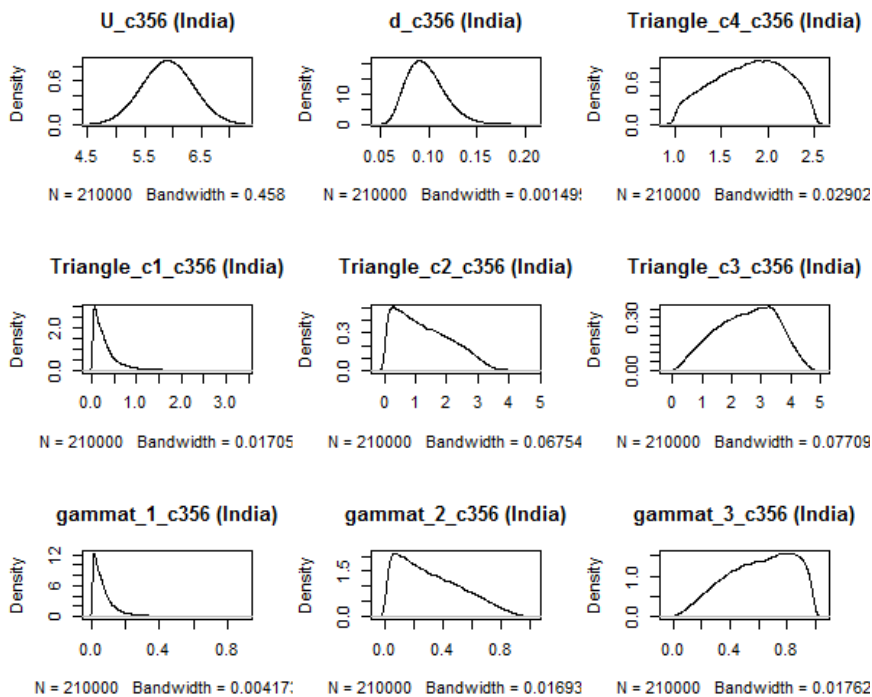
Source: Author's calculation

Figure 3: Trace Plots of parameters i) U_c , ii) d_c , iii) c_i ; $i = 1; 2; 3; 4$, iv) p_{c_i} ; $i = 1; 2; 3$



Source: Author's calculation

Figure 4: Density Plots of parameters i) U_c , ii) d_c , iii) c_i ; $i = 1; 2; 3; 4$, iv) p_{c_i} ; $i = 1; 2; 3$ (gammat) for India.



Source: Author's calculation