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Original Paper

An Adjustment of Indian Age Data: Some Empirical Approach

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Abstract

Adjustments of raw age data of Indian censuses are essential because of huge amount of errors. As a result, RG office of India publishes adjusted data based on elaborate techniques at different times (e.g., Chari, 1977, 1974; Jain, 1954 etc.). However, the present work using 5-year raw grouped data is a simple technique under some assumption at two major steps, firstly, cumulation and secondly, fitting polynomials with appropriate degrees.

The adjusted data are found appropriate based on two very essential criteria, i) the goodness of fit with the raw data and ii) smoothness of the series as mentioned by Jaffe (1966). Moreover, the adjusted data depict a close correspondence with the Chari's (1977) (which was published under the auspices of the Office of the Registrar of India, GOI) adjusted data excepting two sectors, one very early age and very aged persons for whom different techniques are discussed.

Keywords: raw grouped data, adjusted data, GOI, Chari's (1977), cumulation, data, Jaffe (1966)

1. Introduction

Adjustment of census age distribution either it is single year or grouped one is very essential because of many errors particularly in country like, India. The corrected age distribution is quite useful in many studies of population research, in particular, even in other branches of social sciences, physical sciences etc. Sometimes Market researchers require an age distribution of the consumer etc. As observed by experts, an age distribution that is smooth and as close to correct as possible is still useful, particularly as a basis for population projection (UN, 1983).

Now, the present paper tries to adjust age distribution particularly from age one to sixty nine, without paying attention to population aged zero year and advanced ages like 70 and above, where special type of error creeps in. The adjustments to these two sections of population may be made using data from sample registration system (SRS) and life tables. Here it may be mentioned that Jain (1954) while adjusting Indian 1951 census age distribution left unadjusted 0-4 population. Because of this, some attempt was ushered in separately to estimate 0-4 population (very young) from models based on fertility and mortality schedules of the country in a recent past at the time of adjustment being made (Mukhopadhyay, 2006; Mukhopadhyay, 1986). The important and single most item affecting the remaining age distribution, particularly single year is the age and/or digit preference error. Digit preference error is the tendency of persons reporting their ages ending in some preferred digits. However, there are some other kind of errors such as shifting errors, recall lapse error (Som, 1973) etc. which may be adjusted through the present methodology. A mention may be made here that earlier authors as a result tried to justify by saying that very good adjusted smoothed data are constructed only above age 10 years where the major obstacles are like age and/or digit preference error(e.g., Chari, 1974).

2. Methodology and Results

Smoothed and adjusted age data at a prima facae stage are usually obtained simply by cumulation of age distribution that is, to the number of persons or proportion of persons under given ages, that is, less than type since the process of cumulation removes the effect of errors that do not result in a net transfer of people across each of the age boundaries used (UN, 1983). In the present technique cumulation of the population of 5-year raw census age distribution of 1971 census of India (as reference data for

testing the present methodology), not in less than type, rather more than type is done. The raw 5-year grouped distribution by two sexes are given below .

Table 1. 5-year Raw Grouped Distribution of Ages by Two Sexes Separately, 1971 Census (India)

Age group	**Population**		**Person**
	Male	Female	
(1)	**(2)**	**(3)**	**(4)**
0-4	39,355,600	79,559,516	40,203,916
5-9	39,796,175	82,007,472	42,211,297
10-14	32,274,530	68,767,834	36,493,304
15-19	23,246,454	47,468,232	25,221,778
20-24	21,527,935	43,101,354	21,573,419
25-29	20,481,079	40,820,420	20,339,371
30-34	17,867,076	36,188,417	18,321,341
35-39	15,661,954	32,898,302	17,236,348
40-44	13,229,867	28,287,984	15,058,117
45-49	10,417,273	22,884,783	12,467,510
50-54	9,415,037	20,530,924	11,115,887
55-59	5,951,965	12,828,389	6,876,424
60-64	6,891,311	14,376,032	7,484,721
65-60	3,356,877	7,001,249	3,644,372
70+	5,745,232	5,579,218	11,324,450
A.N.S.	60,025	116,264	56,239
Grand Total	284,049,276	264,110,376	548,159,652

Sources: Census of India, 1971, Series-1, Paper 3 of 1977, Age Tables (Chari, 1977)

The above distribution clearly points out some significant inconsistencies. The population aged 0-4 is under enumerated for both the sexes. However, it is known that 0-year population is mostly under counted, the one-year is slightly less etc. Apart from this, there are some fluctuation of the data, e.g., the population aged 55-59 are always lower than the adjacent higher age group of 60-64 which may indicate a age preference and/or shifting error. Moreover, there are a wide gap between the figures of male and female populations in the advanced age group of 70 and above population. These are some kind of vital errors in the raw data usually encountered in the Indian census age distribution. The Table 2 below gives the more than type cumulated distribution with growth rates for each group based on the assumption of exponential pattern, assuming the population being closed with respect to migration. The exponential function is as usual

$$P_t = P_0 e^{-rt}$$

where P_t and P_0 are populations at ending and initial points of each cumulated age data in Table 2, r is the growth rate between each age interval and the value of each one varies from one interval to another and t is the time interval, i.e., 5 years The negative growth rates in the equation above is because of usual pattern of age distribution to progress smoothly from one age to another unless it is depleted

drastically by large scale calamities like wars, epidemics, famines or by heavy age-selective migration. The subsequent steps of analysis are conducted using main frame computer, Sun with FORTRAN (90) language and some software packages (SPSS, versions: 12 and 7.5) and S.Plus(2000). The last two columns are obtained using the procedure as explained above.

Table 2. Raw Cumulated Census Population by 5-year Ages and Sexes, India, 1971 and Estimated Growth Rates for Each 5-year Period

Age	Population		**Exponential growth rates** $\mathbf{r = (\log P_t/P_0) / t}$	
	Male	Female	Male	Female
(1)	**(2)**	**(3)**	**(4)**	**(5)**
0+	283993037	264050351	-0.030529225	-0.032279397
5+	243789121	224694751	-0.038025612	-0.038987076
10+	201577824	184898576	-0.039943589	-0.038365951
15+	165084520	152624046	-0.033159211	-0.031508577
20+	139862742	130377592	-0.033505602	-0.036093431
25+	118289323	108849657	-0.037735371	-0.041690236
30+	97949952	88368578	-0.041416638	-0.045176487
35+	79628611	70501502	-0.048786437	-0.050244480
40+	62392263	54839548	-0.055241867	-0.055215750
45+	47334146	41609681	-0.061140310	-0.057631624
50+	34866636	31192408	-0.076783263	-0.071860665
55+	23750749	21777371	-0.068364166	-0.063850955
60+	16874325	15825406	-0.117238023	-0.114303586
65+	9389604	8936095	-0.098246565	-0.094210013
70+	5745232	5579218		

After getting the different 5-year period growth rates for different cumulated ages such as 0+, 5+, 10+ … 70+ the estimated cumulated figures for each individual ages like 0+, 1+, 2+, … 70+ are obtained using the figures corresponding to growth rates as obtained for male and female populations in columns (4) and (5) in the above table and applying these to the initial ages of 0+, 5+, 10+, and so on up to 70+. The following table, as such, gives the cumulated figures for male and female populations separately for individual cumulated single ages.

Table 3. Estimated Cumulated Figures in Each Individual Ages, 0+, 1+, 2+, … 70+

Age >	Estimated Population		**Age >**	Estimated Population	
	Male	Female		Male	Female
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
0+	283993037	264050351	36+	75837055	67046710
1+	275453959	255663061	37+	72226036	63761213
2+	267171632	247542186	38+	68786957	60636715
3+	259138339	239679261	39+	65511632	57665328
4+	251346589	232066094	40+	62392263	54839548
5+	243789121	224694751	41+	59039069	51893620
6+	234692431	216103129	42+	55866088	49105945
7+	225936135	207840024	43+	52863635	46468021
8+	217506070	199892874	44+	50022545	43971804
9+	209390545	192249597	45+	47334146	41609681
10+	201577824	184898576	46+	44526817	39279440
11+	193684770	177939123	47+	41885986	37079698
12+	186100779	171241619	48+	39401781	65003147
13+	178813750	164796204	49+	37064910	33042888
14+	171812055	158593390	50+	34866636	31192408
15+	165084520	152624046	51+	32289662	29029544
16+	159700211	147890052	52+	29903151	27016652
17+	154491513	143302894	53+	27693025	25143332
18+	149452700	138858017	54+	25646249	23399908
19+	144578229	134551009	55+	23750749	21777371
20+	139862742	130377592	56+	22181307	20430328
21+	135254194	125755729	57+	20715573	19166606
22+	130797500	121297709	58+	19346694	17981052
23+	126487656	116997726	59+	18068270	16868831
24+	122319824	112850177	60+	16874325	15825406
25+	118289323	108849657	61+	15007577	14116058
26+	113908802	104404983	62+	13347341	12591342
27+	109690501	100141798	63+	11870771	11231315
28+	105628413	96052693	64+	10557549	10018188
29+	101716754	92130559	65+	9389604	8936095
30+	97949952	88368578	66+	8510975	8132665
31+	93976055	84465230	67+	7714564	7401470

32+	90163382	80734297	68+	6992677	6736016
33+	86505391	77168164	69+	6338340	6130392
34+	82995808	73759552	70+	5745232	5579218
35+	79628611	70501502			

The adjusted single year data then are obtained by subtracting one step lower single year cumulated figure from one step higher figure and son for further ages and accordingly the entire single year age distribution is obtained and given below.

Table 4. Estimated Single Year Age Distribution, Census of India, 1971

Age	Estimated Population		**Age**	Estimated Population	
	Male	Female		Male	Female
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
0	8539078	8387290	36	3611019	3285497
1	8282328	8120875	37	3439079	3124498
2	8033292	7862925	38	3275325	2971387
3	7791750	7613167	39	3119369	2825780
4	7557468	7371343	40	3353194	2945928
5	9096190	8591622	41	3172981	2787675
6	8756796	8263105	42	3002453	2637924
7	8430065	7947150	43	2841090	2496217
8	8115525	7643277	44	2688399	2362123
9	7812721	7351021	45	2807329	2330241
10	7893054	6959453	46	2640831	2199742
11	7583991	6697504	47	2484205	2076551
12	7287029	6445415	48	2336871	1960259
13	7001695	6202814	49	2198274	1850480
14	6727535	5969344	50	2576974	2162864
15	5384309	4733994	51	2386511	2012892
16	5208698	4587158	52	2210126	1873320
17	5038813	4444877	53	2046776	1743424
18	4874741	4307008	54	1895500	1622537
19	4715487	4173417	55	1569442	1347043
20	4608548	4621863	56	1465734	1263722
21	4456694	4458020	57	1368879	1185554
22	4309844	4299983	58	1278424	1112221
23	4167832	4147547	59	1193945	1043425

24	4030501	4000520	60	1866748	1709348
25	4380521	4444674	61	1660236	1524716
26	4218301	4263185	62	1476570	1360027
27	4062088	4089105	63	1313222	1213127
28	3911659	3922134	64	1167945	1082095
29	3766802	3761981	65	878539	893439
30	3973897	3903348	66	796411	731195
31	3812673	3730933	67	721887	665454
32	3657991	3566133	68	654337	605624
33	3509583	3408612	69	593108	551174
34	3367197	3258050	70	5745232	5579218
35	3791556	3454792			

After preliminary checking and scrutiny the distribution of single year ages in Table 4 showed some irregularities at some points particularly of multiples of 5 and 10 where intervals start. As a result, further cumulation is thought to be done again in order to smooth the series. The cumulation is done now in ten year interval so that every digit has been included in each age cycle. Here it may be mentioned that while adjusting single year age data, Zelnik (1961) used some 10-point moving average considering all the ten digits from 0 to 9 in ten year interval.

Table 5. Cumulated Distribution (Less than Type) for Ten Year Intervals, 1971

Age up to	**Population**	
	Male	Female
(1)	**(2)**	**(3)**
9	83601000	78823782
19	142005368	135034325
29	187903875	176860903
39	222923330	207855863
49	248690545	231571529
59	266832328	251560242
69	278975491	271374337

In order to get finally the adjusted single year age distribution, an attempted is made to fit some polynomial equation of suitable degree. As third degree polynomial is suitable for demographic data (Shryock, et al, 1971), the equation below is taken and fitted in the above data for male and female populations separately using SPSS package.

$$u = a + bt + ct^2 + dt^3$$

The estimated polynomial equations for male and female populations are, as such, obtained and given below,

$$u = 1.9E+07 + 7857783t - 77984t^2 + 271.135t^3 \quad \text{for male,}$$

and $u' = 2.0E + 07 + 7234353t - 69236t^2 + 210.861t^3$ for femalue

and the coefficient of determination measured by R^2 for both the cases have been found to be highly significant ($p<0.01$). Using these fitted polynomials separately for male and female populations, the cumulated (less than type) distributions were obtained. The final adjusted single year population for single year ages starting from 1 to 69 were obtained simply by subtracting one step lower figures from one step higher ones repeatedly up to the last figure is achieved. The following table gives the final adjusted single year age distribution for 1971 census of India.

Table 6. Finally Adjusted Census Single Year Age Data for Male and Female Population, India, 1971

Age	Adjusted Population		**Age**	Adjusted Population	
	Male	Female		Male	Female
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
1	7780072	7165326	36	3346096	3115840
2	7625728	7028122	37	3248688	3022912
3	7473012	6892180	38	3152880	2931296
4	7321928	6757504	39	3058752	2840896
5	7172468	6624088	40	2966240	2751728
6	7024628	6491948	41	2875312	2663904
7	6878428	6361064	42	2786080	2577264
8	6733848	6231448	43	2698432	2491968
9	6590888	6103096	44	2612416	2407856
10	6449568	5976016	45	2528000	2325088
11	6309864	5850184	46	2445264	2243520
12	6171784	5725648	47	2364128	2163280
13	6035344	5602352	48	2284592	2084256
14	5900528	5480312	49	2206752	2006496
15	5767344	5359568	50	2130480	1930032
16	5635760	5240064	51	2055872	1854816
17	5505824	5121840	52	1982816	1780864
18	5377528	5004872	53	1911488	1708176
19	5250816	4889176	54	1841744	1636784
20	5125776	4774744	55	1773616	1566592
21	5002336	4661568	56	1707104	1497728
22	4880544	4549664	57	1642256	1430096
23	4760352	4439040	58	1579024	1363744
24	4641808	4329664	59	1517376	1298640
25	4524880	4221552	60	1457424	1234848
26	4409584	4114704	61	1399056	1172240

27	4295920	4009136	62	1342336	1110976
28	4183856	3904800	63	1287200	1050896
29	4073456	3801776	64	1233728	992192
30	3964656	3699849	65	1181880	934672
31	3857504	3599472	66	1131680	878448
32	3751952	3500208	67	1083040	823440
33	3648032	3402240	68	1036096	769744
34	3545776	3305504	69	990720	717312
35	3445120	3210080			

The adjusted single year distributions of population according to two sexes from ages 1 to 69 give a monotonically decreasing series with male figures always being greater than females. It indicated a true age data in single year with consistent nature. However, the task is not over. In theory two things are yet to be tested, i.e., smoothness and fit as is suggested elsewhere (Jaffe, 1960). For the former, the figures should show a smooth series, and this was tested by forming difference table in which the values of third differences were quite small and are tending towards constant values at higher orders. The following showed the two difference tables.

Table 7. Difference Table for Adjusted Single Year Male Age Data, Census of India, 1971

AGE (t)	**Population (u)**	**Δu**	**Δ^2u**	**Δ^3u**
(1)	**(2)**	**(3)**	**(4)**	**(5)**
1	7780072	154344	1628	-4
2	7625728	152716	1632	8
3	7473012	151084	1624	4
4	7321928	149460	1620	-20
5	7172468	147840	1640	20
6	7024628	146200	1620	0
7	6878428	144580	1620	-20
8	6733848	142960	1640	24
9	6590888	141320	1616	-8
10	6449568	139704	1624	-16
11	6309864	138080	1640	16
12	6171784	136440	1624	-8
13	6035344	134816	1632	32
14	5900528	133184	1600	-48
15	5767344	131584	1648	8
16	5635760	129936	1640	56
17	5505824	128296	1584	-88

18	5377528	126712	1672	72
19	5250816	125040	1600	-48
20	5125776	123440	1648	48
21	5002336	121792	1600	-48
22	4880544	120192	1648	32
23	4760352	118544	1616	-16
24	4641808	116928	1632	0
25	4524880	115296	1632	32
26	4409584	113664	1600	-64
27	4295920	112064	1664	64
28	4183856	110400	1600	-48
29	4073456	108800	1648	48
30	3964656	107152	1600	-32
31	3857504	105552	1632	-32
32	3751952	103920	1664	64
33	3648032	102256	1600	-32
34	3545776	100656	1632	16
35	3445120	99024	1616	16
36	3346096	97408	1600	-80
37	3248688	95808	1680	64
38	3152880	94128	1616	32
39	3058752	92512	1584	-112
40	2966240	90928	1696	112
41	2875312	89232	1584	-48
42	2786080	87648	1632	32
43	2698432	86016	1600	-80
44	2612416	84416	1680	80
45	2528000	82736	1600	0
46	2445264	81136	1600	-96
47	2364128	79536	1696	128
48	2284592	77840	1568	-96
49	2206752	76272	1664	112
50	2130480	74608	1552	-176
51	2055872	73056	1728	144
52	1982816	71328	1584	-32
53	1911488	69744	1616	0

54	1841744	68128	1616	-48
55	1773616	66512	1664	48
56	1707104	64848	1616	32
57	1642256	63232	1584	-112
58	1579024	61648	1696	112
59	1517376	59952	1584	-64
60	1457424	58368	1648	64
61	1399056	56720	1584	-80
62	1342336	55136	1664	32
63	1287200	53472	1632	0
64	1233728	51840	1632	64
65	1181888	50208	1568	-128
66	1131680	48640	1696	128
67	1083040	46944	1568	
68	1036096	45376		
69	990720			

Table 8. Difference Table for Adjusted Single Year Female Age Data, Census of India, 1971

AGE (t)	**Population (u)**	**Δu**	**Δ^2u**	**Δ^3u**
(1)	**(2)**	**(3)**	**(4)**	**(5)**
1	7165326	137204	1262	-4
2	7028122	135942	1266	6
3	6892180	134676	1260	-16
4	6757504	133416	1276	20
5	6624088	132140	1256	-12
6	6491948	130884	1268	4
7	6361064	129616	1264	-8
8	6231448	128352	1272	24
9	6103096	127080	1248	-48
10	5976016	125832	1296	56
11	5850184	124536	1240	-16
12	5725648	123296	1256	-40
13	5602352	122040	1296	56
14	5480312	120744	1240	-40
15	5359568	119504	1280	24
16	5240064	118224	1256	-16
17	5121840	116968	1272	8

18	5004872	115696	1264	8
19	4889176	114432	1256	-16
20	4774744	113176	1272	-8
21	4661568	111904	1280	32
22	4549664	110624	1248	-16
23	4439040	109376	1264	0
24	4329664	108112	1264	-16
25	4221552	106848	1280	48
26	4114704	105568	1232	-80
27	4009136	104336	1312	80
28	3904800	103024	1232	-48
29	3801776	101792	1280	32
30	3699984	100512	1248	-48
31	3599472	99264	1296	64
32	3500208	97968	1232	-80
33	3402240	96736	1312	128
34	3305504	95424	1184	-128
35	3210080	94240	1312	0
36	3115840	92928	1312	96
37	3022912	91616	1216	-16
38	2931296	90400	1232	-112
39	2840896	89168	1344	160
40	2751728	87824	1184	-160
41	2663904	86640	1344	160
42	2577264	85296	1184	-160
43	2491968	84112	1344	144
44	2407856	82768	1400	-128
45	2325088	81568	1328	112
46	2243520	80240	1216	-48
47	2163280	79024	1264	-32
48	2084256	77760	1296	48
49	2006494	76467	1248	-16
50	1930032	75216	1264	300
51	1854816	73952	0964	-932
52	1780864	72988	1896	996
53	1707876	71092	900	-428
54	1636784	70192	1328	96
55	1566592	68864	1232	-48
56	1497728	67632	1280	32

57	1430096	66352	1248	-64
58	1363744	65104	1312	128
59	1298640	63792	1184	-160
60	1234848	62608	1344	160
61	1162240	61264	1184	-192
62	1110976	60080	1376	192
63	1050896	58704	1184	-112
64	992192	57520	1296	80
65	934672	56224	1216	-96
66	878448	55008	1312	48
67	823440	53696	1264	
68	769744	52432		
69	717312			

The fitness of the estimated data separately for male and female populations with the observed (raw) series have been done by finding multiple correlation coefficient (ρ) between the raw and the adjusted figures. In the present case, the ρ values for the two cases were found to be significant ($p < 0.01$). The following tables have been presented here for the significance tests of the ρ values for different data set. The Figures 1 and 2 show the best fitted curves for male and female population single year age distributions separately.

Table 9. Multiple Correlation Coefficients between Different Categories, Single Year Age Data, Census of India, 1971

Male			
Categories	**Raw**	**Adjusted**	**Chari (1977)**
Raw	1.000	.716**	.720**
Adjusted	.716**	1.000	.993**
Chari (1977)	.720**	.993**	1.000

** Correlation is significant at the 0.01 level.

Table 10. Multiple Correlation Coefficients between Different Categories Single Year Age Data, Census of India, 1971

Female			
Categories	**Raw**	**Adjusted**	**Chari (1977)**
Raw	1.000	.695**	.700**
Adjusted	.695**	1.000	.992**
Chari (1977)	.700**	.992**	1.000

** Correlation is significant at the 0.01 level.

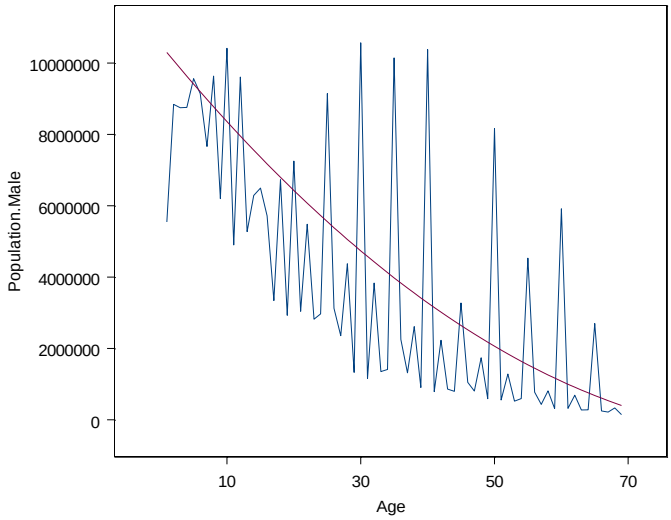

Figure 1. Observed and Fitted Values for Male Population

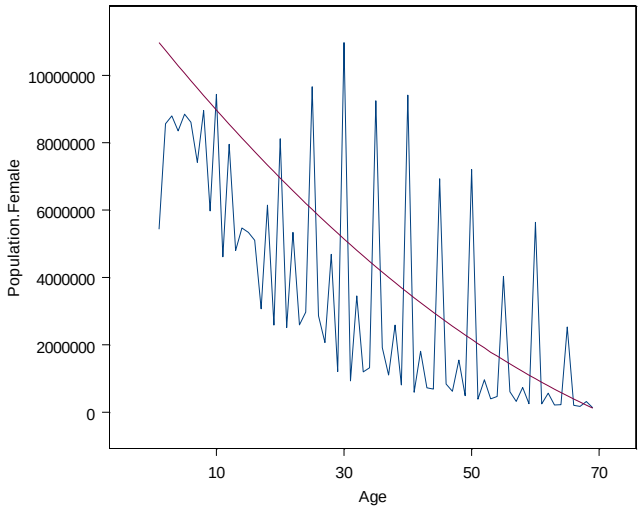

Figure 2. Observed and Fitted Values for Female Population

3. Concluding Remarks

The methodology adopted in the paper based on a few assumptions although encounters a number of steps but they are simple in the sense that except the raw age-group data there are no other inputs necessary. Contrary Chari (1977, 1974) used single year raw data experimenting with different type of age groupings like, 0-4, 1-5, 2-6, 3-7 and 4-8. Then choosing a suitable one and graduating the series by some graduating formula. Having obtained the adjusted grouped data, single year data have been arrived at by means of Karup-King's third order osculatory interpolation formula (Bogue et al., 1993).

From the point of view of actuaries there is no absolute graduation or adjustment technique. Rather different graduator adopts different techniques. The only criterion is the optimum course between the smoothness and the closeness (fitness) with the raw data. In this respect, the two criteria are quite vividly shown in the last section of the paper. In the same section there is also a close matching between the two adjusted data, one from the present technique and another from Chari (1977) which simply shows the validity of the present technique (as the method adopted by Chari was published under the Office of the Registrar General, Government of India).

The present methodology, henceforth may be applied in countries, particularly where data deficiencies are well known both in terms of quality as well as delay in publishing the census report. From the two graphs, one for males and another for females it is obviously clear that in the very young ages under one year under-counting is very common which is why there is low pick in the diagram in addition to other errors. Hence for adjustment of entire single year data graduator applies different method to estimate the same only except for other ages. Similarly in the higher ages people are used to exaggerate their high age to show more higher to pose themselves more senior persons in the family they belong. The corresponding graphs for both the male and female are clear in this respect.

Finally, in the event of completing the present adjusted age data of India, the two more data points are to be estimated, i) the 0 year and ii) the 70+ year populations which could not be estimated from the present technique. However, they may be obtained in a very simple way. For the former one, survival factor may be used for adjusting birth data from sample registration system of India to get the 0 year population and for the latter UN's method (1955) may be used. After all these for the entire adjusted data prorating may be done These things have not been done here since the main purpose of the paper was to apply some new methodology based on some assumption for the adjustment of the overall census single year age data from 5-year grouped data which are generally obtained within a short time after the completion of the national census.

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