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A Method for Estimating Expectation of Life at Birth at Sub-National Level

Introduction

LIFE expectancy represents an important indicator of the level of mortality in a population. It has been used to assess the level of public health facilities as well as quality of life in a population. The conventional way to obtain life expectancy, however, is through the construction of a life table, which has rigorous data requirements and often entails agreat deal of personnel time, A life table provides a model that assesses solely the effect of age-specific mortaility rates. Regrettably, the construction of a life-table requires age-specific deaths and the population by the age. From the actual data pertaining to mortality, it is easy to obtain a measure of mortality rate but not the measure to probability of dying. Further, in many developing countries, demographic data are often severely defective or incomplete. Thus, it is impossible to obtain reliable age-specific death rates directly from the recorded number of deaths and population count. More so, at the subnational levels age-specific deaths and the population by age are hardly available and hence it is not possible to determine life-expectation at birth by constructing a life-table. It may be noted here that if age-distribution of deaths is not available for any region than also one can construct life tables by using census age-distribution at one or two point of time by assuming that total number of annual births and annual deaths are constant over time and population is closed to migration (R.G.I., 1977; Arriaga, 1968). There are several methods to estimate life expectancy for a population. We have divided them into five groups, which are based on stable population concepts, biological theories of aging, age-distribution of population, widowhood status and regression approach (Swanson, 1989; Swanson and Palmore, 1976; Swanson, Palmore and Sundarum, 1977; Gunasekaran, Palmore and Gardner, 1981; Mazur, 1969a, 1969b, and 1972, Carrier and Hobcraft, 1971; Mccann, 1976; Coale and Demeny, 1983; United Nations, 1983; Siler, 1979; Preston and Bennett, 1983; Malaker and Crook, 1989; Hill, 1977; Hill and Trussell, 1977).

The regression based method is well suited for estimating life expectation at birth at the sub-national level. In this paper, an attempt is made to develop new regression models to estimate expectation of life at birth without utilizing any model life tables. The method is

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illustrated at the regional as well as district level for the state of Uttar Pradesh. In the absence of any direct check on such estimates their consistency has been established by considering the infant mortality rate and probability of survival of the children up to the age of five years of the various regions, divisions and districts under study.

Model

Generally, when mortality falls from high to low levels, the changes in mortality rates are more at the very young as well as at the older ages, relative to the ages between the two extremes. First, we tried to establish the relationship of a mortality variable, probability of survival of the children up to the age of five years and the percentage of population aged 65 years and over or ratio of old population (65 years and over) to child population (up to 15 years) with the expectation of life at birth in stable populations. We found very strong relationship of probability of survival of the children up to age of five years ($_5l_0$) and the percentage of population aged 65 years and over (P65+) with expectation of life at age x (e^0_x x = 0,1, 5, 10, 15, 20,...) while using Coale-Demany life table and United Nations model life table for developing countries. Also, similar findings were found, where SRS based abridged life tables for India and its states were used. Then we have taken children surviving in the age-group 30-34/children even born in the age-group 30-34 (S_4) data in place of probability of survival of the children up to age of five years ($_5l_0$) and the percentage of population aged 65 years and over (P65+) data from Census of India, 1981 and expectation of life at age x (e^0_x :x = 0, 1, 5,10,15 ....) from SRS based abridged life table, 1976-80. We find high association of 54 and P65+ with e_0. On the basis of these observations we can conclude that, we can get estimate of e^0_0 , e^0_1, e^0_5, e^0_{10} and e^0_{15} with the help of S_4 and P65+ at the district level also. We have tried to find out a regression equation with expectation of life at birth as the dependant variable and children surviving in the age-group 30- 34/children ever born in the age-group 30-34 (S_4) and the observed percentage of population aged 65 years and above (P65+) or ratio of old population (65 years and over) to the child population (up to age 15 years) [OCR] as independant variable. These data are available in Demographic Year Book. Here it may be noted that one can use S_3 in place of probability of survival of the children up to the age five. The regression models are as follows :

$$e^0_0 = -19.062 + 88.568 * S_4 + 0.142 * OCR$$

$$S.E. = 0.89 \quad R^2 = 0.99, \text{ n=15} \qquad 1)$$

and

$$e^0_0 = -15.335 + 7.641 * S_4 + 4.728 * P65 +$$

$$SE. = 0.23, R^2 = 0.98, n = 15 \qquad 2)$$

Finally, we have developed new regression equation from the empirical observations using India's data, with state as a unit for estimation of expectation of life at birth at sub-national level, which requires only two data elements : (S_4) and the percentage of

population aged 65 years and over (P65+). The Proposed regression models for estimation of expectation of life at birth for all area are given below :

$$e_0^0 \text{ (person)} = -61.670 + 125.663^* S_4 + 1.888^* P_{65+}$$

$$S.E. = 2.06,\ R_1^2 = 0.88,\ n = 12 \qquad (3)$$

$$e_0^0 \text{ (Male)} = -43.399 + 100.142^* S_4 + 2.912^* P_{65+}$$

$$S.E. = 1.87,\ R^2 = 0.88,\ n = 12 \qquad (4)$$

and

$$e_0^0 \text{ (Female)} = -68.510 + 130.568^* S_4 + 2.736^* P_{65+}$$

$$S.E. = 2.39,\ R^2 = 0.88,\ n = 12 \qquad (5)$$

Application and Discussions

We apply the proposed model to the regions (5), divisions (12) and districts (56) of Uttar Pradesh circa, 1981. Resulting estimate of expectation of life at birth are given in Tables 1, 2 and 3. We would, however, like to mention that estimate of expectation of life at birth at the district level may not be as reliable as the estimates at the state and national levels. The consistency of the estimates across the districts is of greater importance. In absence of any direct check on such estimates, their consistency has been established by considering the infant mortality rate and probability of survival of children up to the age of five year *(Is)* of the various regions, divisions and districts understudy. If we take estimate of infant mortality rate and probability of survival of children up to the age of five years as obtained by Pathak, Ram and Singh (1988 and 1989), it is observed that expectation of life at birth in Uttar Pradesh and its regions, divisions and districts are consistent with IMR and /5. It be may mentioned here that the rank correlation coefficient of IMR and *Is* with expectation of life at birth are -0.88 and 0.88 respectively.

It may be observed from Table 2 that the expectation of life at birth varies from 55.4 years for the Hill region to 46.5 years for the Bundelkhand region. The Hill region has the highest expectation of life at birth in case of males as well as females, the estimated value of expectation of life at birth for the state of Uttar Pradesh is 48.7 years, which lies in the range of 43.8 and 56.9 for Bareilly division and Garhwal division respectively.

There is a wide variation in the estimates of the expectation of life at birth between the various districts of Uttar Pradesh. From the analysis it is found that expectation of life at birth varies from 40.3 for Hardoi to the maximum of around 59.9 for Ballia followed by Dehradun (59.0) and Garhwal (58.7). On the otherhand, the expeclation of life at birth for males varies from 44.9 for Hardoi to 60.4 for Bailia and in the case of females, it varies from 36.2 for Budaun to 59.5 for Ballia. There are only four districts, namely Ballia, Almora, Garhwal and Dehradun where the expectation of life is more than 55 years. Only ten districts namely Budaun, Shahjahanpur, Fatehpur, Lalitpur, Hardoi, Rae Bareili, Bahraich, Gonda, Sultanpur and Basti have an expectation of life at birth which is lower than 45 and in other 42 districts the expectation of life at birth is between 45 and 55.

TABLE 1: EXPECTATION OF LIFE AT BIRTH, IMR AND PROBABILITY OF SURVIVAL OF CHILDREN UP TO AGE FIVE YEARS *(Is)* FOR INDIA AND MAJOR STATES, CIRCA 1981

Region				*IMR*	I_5
	Male	*Female*	*Total*		
India	53.0	52.4	52.8	110	0.8685
Andhra Pradesh	52.7	54.6	53.8	104	0.8776
Bihar	54.6	52.5	53.8	105	0.8760
Gujarat	54.3	56.2	55.5	92	0.8936
Haryana	56.2	51.6	55.0	105	0.8781
Kamataka	53.8	55.2	54.3	100	0.8804
Kerala	61.7	66.4	64.0	40	0.9382
Madhya Pradesh	47.8	47.3	47.6	145	0.8281
Maharastra	52.9	54.5	53.7	98	0.8775
Orissa	49.0	49.9	49.3	145	0.8360
Punjab	61.7	59.9	60.3	92	0.8973
Rajaslhan	49.5	47.8	48.3	135	0.8435
Tamil Nadu	54.8	55.2	55.0	89	0.8874
Uttar Pradesh	51.4	46.1	48.7	137	0.8343
West Bengal	53.7	55.5	55.1	94	0.8912

TABLE 2: EXPECTATION OF LIFE AT BIRTH, IMR AND PROBABILITY OF SURVIVAL OF CHILDREN UP TO AGE FIVE YEARS (I_5) FOR REGIONS AND DIVISIONS OF U.P., CIRCA 1981

Region! division				*IMR*	*Is*
	Male	*Female*	*Total*		
Region					
Bundelkhand	49.8	43.4	46.5	146	0.8271
Central	48.7	43.9	46.8	145	0.8241
Eastern	55.6	47.5	48.5	135	0.8359
Hill	56.9	55.1	55.4	101	0.8827
Western	52.6	44.3	47.8	136	0.8320
Division					
Agra	50.2	40.1	46.0	139	0.8272
Allahabad	50.2	45.1	47.6	132	0.8401
Bareili	47.9	41.4	43.8	156	0.8037
Faizabad	49.9	44.0	45.6	156	0.8106
Gorakhpur	51.5	47.3	48.0	128	0.8463
Garhwal	57.3	56.6	56.9	93	0.8843
Jhansi	49.8	43.4	46.5	146	0.8271
Kumoun	56.4	53.7	54.6	99	0.8832
Lucknow	48.9	44.1	45.7	160	0.7890
Meerut	54.8	48.4	51.4	126	0.8445
Moradabad	52.7	45.0	48.0	115	0.8565
Varanasi	55.2	52.1	53.0	115	0.8642

TABLE 3: EXPECTATION OF LIFE AT BIRTH, IMR AND *Is* FOR DISTRICTS OF U.P., CIRCA 1981

Districts	*Expectation of life at birth*			*IMR*	I_5
	Male	*Female*	*Total*		
Uttar Kashi	54.3	54.0	54.1	115	0.8644
Chamoli	54.5	52.3	52.8	107	0.8693
Tehri Garhawal	56.2	54.4	54.5	115	0.9642
Dehradun	58.5	59.0	59.0	77	0.9094
Garijwal	59.6	58.3	58.7	88	0.8844
Pithoragarh	58.5	52.9	54.9	108	0.8777
Almora	59.7	56.3	56.9	89	0.8936
Nainital	53.5	52.2	53.0	100	0.8793
Saharanpur	56.7	50.9	53.8	106	0.8679
Muzaffamagar	55.3	47.8	51.5	120	0.8553
Bijnor	54.5	47.3	50.2	134	0.8349
Meerut	56.0	49.3	52.3	110	0.8617
Ghaziabad	53.8	47.2	50.8	104	0.8655
Bulandshahar	53.5	45.6	49.2	132	0.833
Moradabad	51.8	43.4	46.9	141	0.8231
Rampur	52.2	45.1	48.0	64	0.9034
Budaun	47.0	36.2	40.7	193	0.7753
Bareilly	49.5	44.9	46.5	138	0.826
Pilibhit	47.8	45.1	45.8	143	0.8229
Shahjahanpur	46.5	40.0	42.2	174	0.7902
Aligarh	50.3	41.8	45.5	142	0.8186
Mathura	51.2	41.7	46.6	131	0.8308
Agra	49.4	43.1	47.2	122	0.8471
Etah	50.5	40.4	45.0	166	0.8061
Mainpuri	50.7	41.0	45.9	150	0.8235
Farukhabad	49.8	43.4	46.7	143	0.8301
Etawah	50.9	42.0	46.5	137	0.8315
Kanpur	52.3	49.7	51.4	99	0.8712
Fatehpur	47.1	41.9	43.6	162	0.8086
Allahabad	49.2	44.7	46.7	143	0.8326
Jalaun	50.5	43.9	47.4	145	0.8331
Jhansi	50.2	45.4	47.7	135	0.8366

Table 3 *(contd. on page* 272)

Table 3 *(contd. from page* 271)

Districts	Expectation of life at birth			*IMR*	*Is*
	Male	*Female*	*Total*		
Lalitpur	45.6	39.4	42.1	171	0.8016
Hamiipur	50.4	40.9	45.0	159	0.8121
Banda	50.4	45.7	47.9	138	0.8364
Kheri	51.7	47.4	49.1	135	0.8375
Sitapur	50.7	44.4	46J	158	0.8103
Hardoi	44.9	37.4	40.3	203	0.7671
Unnao	48.5	43.9	45.3	152	0.8145
Lucknow	51.9	50.9	51.5	105	0.8674
Rae Bareili	47.0	42.5	43.0	185	0.7907
Bahraich	48.5	42.0	44.5	154	0.8082
Gonda	47.4	39.8	42.4	176	0.7896
Barabanki	51.0	46.9	47.5	149	0.8183
Faizabad	53.1	48.4	49.5	136	0.8344
Sultanpur	48.7	43.0	44.3	167	0.8016
Pratapgarti	51.8	46.1	47.3	146	0.8196
Basti	46.8	39.3	41.1	180	0.7669
Gorakhpur	50.8	47.8	48.2	148	0.8344
Deoria	51.8	50.0	50.0	122	0.8477
Azamgarh	56.3	53.2	53.3	114	0.8609
Jaunpur	53.3	47.7	49.4	135	0.8395
Ballia	60.4	59.5	59.9	79	0.9402
Ghazipur	57.2	53.7	54.2	113	0.8643
Varanasi	55.3	52.8	53.7	113	0.8683
Mirzapur	52.4	48.9	50.4	123	0.8529

Following the procedures outlined above, we have prepared Table 4, which shows life expectancy at birth for population with children surviving in the age-group 30-34/children ever born in the age-group 30-34 (S_4) between 0.70 and 0.95 and percentage of population aged 65 years and over (P_{65+}) between 2.0 percent to 6 percent. Owing to space limitations increments of 0.5 for P_{65+} and 0.01 for S_4 were used for both parameters. This table provides an easily used reference to estimate expectation of life at birth for India. We can also see the effect of error in data on S_4 and P_{65+} on the estimate of expectation of life at birth. Effect of error in P_{65+} is much less as compared to error in S_4. If S_4 is *p* percent over estimate/underestimate then estimate of expectation of life at birth will be about (3)* *p* percent overestimated/ underestimated.

TABLE 4 : ESTIMATED EXPECTATION OF LIFE AT BIRTH ACCORDING TO 5_q AND P+

$S4/P65+$	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
0.70	30.1	31.0	32.0	32.9	33.8	34.8	35.7	36.7	37.6
0.71	31.3	32.3	33.2	34.1	35.1	36.0	37.0	37.9	38.9
0.72	32.6	33.5	34.5	35.4	36.4	37.3	38.2	39.2	40.1
0.73	33.8	34.8	35.7	36.7	37.6	38.6	39.5	40.5	41.4
0.74	35.1	36.0	37.0	37.9	38.9	39.8	40.8	41.7	42.7
0.75	36.4	37.3	38.2	39.2	40.1	41.1	42.0	43.0	43.9
0.76	37.6	38.6	39.5	40.4	41.4	42.3	43.3	44.2	45.2
0.77	38.9	39.8	40.8	41.7	42.6	43.6	44.5	45.5	46.4
0.78	40.1	41.1	42.0	43.0	43.9	44.8	45.8	46.7	47.7
0.79	41.4	42.3	43.3	44.2	45.2	46.1	47.0	48.0	48.9
0.80	42.6	43.6	44.5	45.2	46.4	47.4	48.3	49.2	50.2
0.81	43.9	44.8	45.8	46.7	47.7	48.6	49.6	50.5	51.4
0.82	45.2	46.1	47.0	48.0	48.9	49,9	50.8	51.8	52.7
0.83	46.4	47.4	48.3	49.2	50.2	51.1	52.1	53.0	54.0
0.84	47.7	48.6	49.6	50.5	51.4	52.4	53.3	54.3	55.2
0.85	48.9	49.9	50.8	51.8	52.7	53.6	54.6	55.5	56.5
0.86	50.2	51.1	52.1	53.0	54.0	54.9	55.8	56.8	57.7
0.87	51.4	52.4	53.3	54.3	55.2	56.2	57.1	58.0	59.0
0.88	52.7	53.6	54.6	55.3	56.5	57.4	58.4	59.3	60.2
0.89	53.9	54.9	55.8	56.8	57.7	58.7	59.6	60.6	61.5
0.90	55.2	56.1	57.1	58.0	59.0	59.9	60.9	61.8	62.8
0.91	56.5	57.4	58.3	59.3	60.0	61.2	62.1	63.1	64.0
0.92	57.7	58.7	59.6	60.5	61.5	62.4	63.4	64,3	65.3
0.93	59.0	59.9	60.9	61.8	62.8	63.7	64.6	65.6	66.5
0.94	60.2	61.2	62.1	63.1	64.0	65.0	65.9	66.8	67.8
0.95	61.5	62.4	63.4	64.3	65.3	66.2	67.2	68.1	69.0

Concluding Remarks

The Conventional way to obtain expectation of life at birth, however, is through construction of life table, which has rigorous data requirements. The selection of model life table is very subjective and arbitrary. In the present paper, a regression model is proposed to estimate the expectation of life at birth from the CEB and CS data without using any model life table.

The proposed regression model is illustrated at the regional as well as district level for the state of Uttar Pradesh. Hill region (55.4) and Garwhal division (56.9) and Kumaun division (54.6) are having expectation of life at birth higher than other regions and divisions repectively by using proposed regression model.

References

Amaga, E E , 1968, New Life Tables for Latin American Population in the Nineteeth and Twentieth Centimes, Population monographs, Series No 3, University of Califomia, Berkeley Carner, N and Hobcraft, J, 1971, *Demographic Estimation for Developing Societies,* Population Investigation Committee, London

Census of India, 1971 Social and Cultural Tables, *India,* Senes-1, Part-EC ____, Social and Cultural Tables, *Uttar Pradesh,* Senes-21, Part-II C Census of India, 1981 Fertility Tables, *India and its major slates,* Part-VI A and B _____, Social and Cultural Tables, *India,* Senes-1, Part-IV A _____, Social and Cultural Tables, *Uttar Pradesh,* Series-22, Part-IV A _____, General Population Tables, *Uttar Pradesh,* Senes-22, Part IIA Coale, A J and Demeny, P , 1983, Regional model life table and stable poplattons, Second edition, Academic Press, New York Gunashekaran, S , Palmore, J A and Gardner, R W , 1981, Regression estimates of mortality from incomplete death registration, *Asian and Pacific Census Forum,* 7(4) 5-9 Hill, K , 1977, Estimating adult mortality levels from information on widowhood, *Population Studies,* 31(1) 75-84 Hill, K and Trussell, J , 1977, Further developments in indirect mortality estimation, *Population Studies,* 31(2} 313-333 Malakar, C R and Crook, N R 1989, The use of widowhood data for investigation of mortality differentials in West Bengal— A district level analysis, *Demography India,* 18(1&2) 121- 129 Mazur, D P, 1969a, Expectancy of life at birth in 36 nationalities of Soviet Union 1958 60, *Population Studies,* 23 225246 _____, 1969 b, Techniques for estimating basic demographic measures from limited data for the U S S R 1959 60, IUSSP Conference London, 1 219-229 ., 1972 Using regresion models to estimate the expectation of life for USSR, *Journal of the American Statistical Association, 67 :* 31-36. Mccann, J. C, 1976, A technique for estimating life expectancy with crude vital rates, *Demography, 13 :* 259-272. Pathak, K. B., Ram, F. and Singh, B. S., 1988, A new method of estimating infant and child mortality from the CEB and CS data, *Janasamkhya, 6 (2):* 159-168. Pathak, K.B., Ram, F. and Singh, B. S., 1989, Some new approaches to estimating the vital rate at sub-national levels. In: K. Srinivasan and K. B. Pathak (eds.), *Dynamics of Population and Family Welfare,* pp. 247-267, Himalaya Publishing House, Bombay. Preston, S. H. and Bennett, N. G., 1983, A census based method for estimating adult mortality, *Population Studies,* 37(1) .-91-104. Registrar General of India, 1977, *Life Tables,* Census of India 1971, Series I, Paper I, Ministry of Home Affairs, New Delhi. Registrar General of India, 1985, SRS Based Abridged life tables 1976-80, Census of India, Occasional Paper No. 1 of 1985, Ministry of Home Affairs, New Delhi.

Siler, W., 1979, A Competing risk model for animal mortality, *Ecology,* 60 : 750-757. S wanson, D. A., 1989, A state based regression model for estimating substate life expectancy, *Demography, 26(1):* 161-170. Swanson, D. A. and Palmore, J. A., (1976) Two parameter regression estimates of current life expectancy at birth: Part I, *Asian and Pacific Census Newsletter,* 3(2): 5-10. Swanson, D. A., Palmore, J. A. and Sundarum C., 1977. twoparameter regression estimates of currentlife regression estimates of current life expectancy at birth : Part n, *Asian and Pacific Census Fourm,* 3(4) : 5-10.

United Nations, 1979, Demographic Year Book, 1978, *Special issue : Historical supplement,* New York. United Nations, 1982, Model life tables for developing countries, *Population StudiesNo.77,* New York. United Nations, 1983, Indirect Techniques for demographic estimation, *Manual X,* Population studies No. 81, New York.

Appendix Table

Regions, Divisions and Districts of Uttar Pradesh

Region/Division	
REGION	
Bundelkhand	Banda, Hamirpur, Jalaun. Jhansi, Lalitpur (5)
Central	Bara Banki, Fatehpur, Hardoi, Kanpur, Kheri Lucknow, Rai Bareilly, Sitapur, Unnao(9)
Eastern	Allahabad, Azamgarh, Ballia, Baharaich, Basti, Deoria, Faizabad, Gazipur, Gonda, Gorakhpur, Jaunpur, Mirzapur, Pratapgarh, Sultanpur, Varanasi. (15)
Hill	Abnora, Chamoli, Dehra Dun, Garhwal, Nainital, Pithorgarh, Tehri Garhwal, Uttarkashi. (8)
Western	Agra, Aligarh, Bareilly, Bijnor, Badaun, Bulandshahar, Etah, Etawah, Farrukhabad, Ghaziabad, Mainpuri, Mathura, Meerut, Moradabad, Muzaffamagar, Pilibhit, Rampur, Saharanpur, Shahjanpur. (19)
DIVISION	
Agra	Agra, Aligarh, Etah, Mathura, Mainpuri (5)
Allahabad	Allahabad, Etawah, Fatehpur, Farrukhabad, Kanpur (5)
Bareilly	Bareilly, Badaun, Pilibhit, Shahjahanpur (4)
Faizabad	Baharaich, Bara Banki, Faizabad, Gonda, Pratapgarh, Sultanpur (6)
Gorakhpur	Azamgarh, Basti, Deoria, Gorakhpur (4)
Garnwal	Chamoli, Dehra Dun. Garhwal, Tehri Garwal, Uttar Kashi (5)
Jahnsi	Banda, Hamirpur, Jalaun, Jhansi, Lalitpur (5)
Kumaun	Almora, Nainital, Pithorgarh (3)
Lucknow	Hardoi, Kheri, Lucknow, Rai Bareilly, Sitapur, Unnao (6)
Meerut	Bulandshahar, Ghaziabad, Muzaffamagar,
Muradabad	Bijnor, Muradabad, Rampur (3)
Varanasi	Ballia, Gazippur, Jaunpur, Mirzapur, Varanasi (5)

' Figures in parentheses represent the number of districts belong to division/region.