A MODEL OF POPULATION GROWTH INVOLVING MORTALITY FERTILITY INTERACTIONS: PROJECTIONS FOR INDIA

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A population growth model investigating the implications of exogenous continuously improving mortality experiences in low-income world for sequential fertility changes as lagged response to mortality disturbances and for future population growth and structure was presented at the 1976 Annual Meetings. [See 1976 Proceedings of the Social Statistics Section, pages 501-06]. Some tentative results for India were also presented.

More extensive computer simulation results for several values of the lag parameter are now presented. Additionally, lag parameter values based on relevant population census and other demographic statistics for India have been tentatively estimated and population projections made for the years 1991 and 2011. The future course of important population structural characteristics like dependency ratio, proportion in labor force age-groups, proportion of children in the population, proportion of females in childbearing age-groups, total fertility rate, and long-term stable population growth rate up to year 2011 has been calculated.

It may be worthwhile to restate the basic elements of the analysis underlying this study. Mortality changes are assumed exogenous. The initial population is regarded as a stable population at time t=o. This population becomes subject to exogenously determined rates of mortality improvement of varying magnitude over the next several periods. The central hypothesis is that birth rates may respond in downward fashion to declines in death rates. The main elements of the hypothesis pertain to household family formation behaviour and are: (a) the concept of Desired Family Size; (b) household response to past mortality changes via lagged adjustment in planned fertility; (c) 'myopic' expectations about future mortality improvements; (d) possible changes in (i) desired family size, (ii) preferred child-spacing pattern and (iii) household behaviour parameters reflecting degree of risk-aversion in response to mortality improvements and the historical consistency of this process. The expectations hypothesis involves distributed lags and myopic expectations. Mathematically the hypothesis used is written as:

$$E\,y\,(t + c/t) = M\,(t + c/t).\ E\,y\,(t/t) \quad \ldots.(1)$$

where

$$E\,y\,(t/t) = L\ E\,y\,(t - 1/t - 1) + (1 - L)\,y\,(t - 1) \quad \ldots.(2)$$

where L = lag parameter lying between 0 and 1;

$E\,y\,(t + c/t)$ = expected change in the force of mortality in the period $(t + a)$, expectations formed at time t; and

$y\,(t - 1)$ = actual change in the force of mortality observed in the time period $(t - 1)$.

$M\,(t + c/t)$ = Myopia factor at time t for time period $(t + c)$ in the future.

Changes in mortality rates play an important role in this model on account of the concept of the Desired Completed Family Size and its fixity in the face of changes in mortality. Declining mortality rates and the taking into account of mortality improvements in the decision-making process for determining planned fertility rates imply that planned fertility rates respond to changes in mortality via number of currently living children and expected survival rates. Decline in mortality rates will induce declines in planned fertility rates in order to achieve the goal of a fixed DCFS.

A simplified formulation is developed for the purpose of gaining qualitative insights into the role played by model parameters and for throwing into sharp focus the relationship between fertility and mortality rates in determining age composition structure and rate of population growth. The population is divided into four equal age groups 0, 1, 2 and 3. Age group 0 relates to children and age group 1 consists of all adults in childbearing period of life. Children are born to females in age group 1 only. Since all children are born in one time period, myopia is absent. The myopia parameter $M\,(t + c/t + c)$ is equal to unity.

Family formation behaviour assumptions are: (i) The family is aiming at a Desired Completed Family Size (DCFS) which is assumed given and fixed and does not change as mortality rates change. DCFS is defined as the number of children born who are desired to survive to adulthood, say age 1. (ii) The family has a fixed preferred child-spacing pattern which does not change as mortality and fertility changes occur. (iii) Families respond to mortality improvements by lagged adjustments in planned fertility. Since a single period covers the whole child-bearing time span, it will be unrealistic to ignore completely mortality changes currently under way

whose impact on emerging profile of children living at various ages of the mother's child-bearing span could easily be visible.

Empirical Results for India

For reasons of space, a detailed discussion of the choice of parameter values and of the assumptions underlying the projections is not given here. The following information based on results of 1951, 1961 and 1971 Population Censuses of India is, however, important in making judgments about these assumed values.

(a) The percent growth rates of India's population during 1941-50, 1951-60 and 1961-70 decades were 13.4%, 21.64% and 24.57%. Between 1951 and 1971, India's population increased by 51.1 percent.

(b) If it is assumed that no significant mortality improvements occurred in India in the few decades prior to 1951 so that stable population condition could be taken as a reasonably rough approximation, the long-run stable population one period (20 years) growth factor G may be assumed at $(1.134)^2 = 1.286$. This means that on average, in the absence of significant mortality improvements that actually occurred in India during the fifties and to a much lesser extent during the sixties, India's population between 1951 and 1971 would have increased by 28.6%. The difference of 22.5% may be attributed to mortality and fertility shifts that may have taken place during the 20-year period 1951-71.

(c) Analyses of India's census data suggests that there is little evidence of significant fertility declines occurring during 1951-70 in response to very significant mortality declines underway in that period. This means that the value of lag parameter L in relation (3) is very close to unity.

(d) Based on India's Official Life Tables, the survival rates from birth to age 20 are as follows:

Period	Male	Female
1941-50	.58	.57
1951-60	.72	.71
1961-70	.77	.75

Thus, between 1946 and 1956 (mid-points of the decades), the female's 20-year survival rate increased by 24.56 percent; the percentage for period between 1956 and 1966 was only 5.92 percent. For the 20-year period 1946 to 1966, the 20-year female survival rate increased by 31.93 percent. Evidence is very clear that mortality declines which were very significant during the fifties had considerably slowed down during the sixties. Mortality gains reflected in the above survival rate were of the order of 2.2 percent per year in fifties, but only of 0.6 percent per year in the sixties.

(e) Life expectancy at birth for females was 35 years based on 1941-50 Life Table, 40.0 on 1951-60 Life Table, and 45.6 years on 1961-70 Life Table. Thus, over the 20-years between 1951 and 1971 Censuses, female life expectancy at birth increased by over 10 years, or by nearly 30 percent.

The following assumptions have been made in making population projections:

(i) Calculations have been made for females only. It is assumed that similar orders of magnitude will emerge for males and total population. 50% of children born are assumed female.

(ii) Mortality disturbance is assumed to start at time t=o in 1951. Three different sets of assumptions regarding future mortality improvements over the 3 time periods are used in making projections: a(t) means that forces of mortality at all ages decline on average during time period t to t+1 by amount a(t).

(a) $a(o) = .2820$; $a(1) = 0$; $a(2) = 0$ [once-for-all disturbance case]. [Low Mortality gains case]

(b) $a(o) = .30$; $a(1) = .10$; $a(2) = .05$; [Intermediate mortality gains case]

(c) $a(o) = .32$; $a(1) = .16$; $a(2) = .08$; [High mortality gains case]

Future mortality gains are assumed to be smaller since existing cheap sources of mortality declines are assumed to have been, by and large, almost entirely used up, and further gains are likely to depend on improvements in diet, nutrition, etc.; that is, factors which depend on gains in per capita income.

(iii) For making population projections Model Life Tables West-Females for Life Expectancy at Birth equal 35 years given in Coale and Demeny have been used. [Page 38; r = .10; Mortality Level 7.]

(iv) Tentative analysis of census data and other relevant population statistics for India for the period 1950 to 1970 indicate that the value of the lag parameter relevant for India is close to unity, may be around .90. But there is some evidence that significant fertility reductions as a result of a vigorous Government policy for population control may be underway. Hence, we may use the values of lag parameter as .75 and .9 for population projection purposes. Besides projections are also made for the case of no fertility response L = 1.0 and a value of L = .6 to show the population growth and structure implications of more intensified population control efforts to accelerate fertility response to the lag parameter value of L = .6.

Simulation Results

The main results for the Intermediate

Summary Table

Projections for Female Population for India for Years 1991 and 2010
and Estimation of Important Population Parameters.
Intermediate Mortality Gains Case, a(o) = .30; a(1) = .10; a(2) = .05
(Initial 1971 census figure assumed at 1000)

	Actual 1971	Projected Population							
		1991				2011			
		L=.6	L=.75	L=.9	L=1.0	L=.6	L=.75	L=.9	L=1.0
A. Female Population by age-group									
0 (0-20)	506	543	557	575	589	664	685	718	748
1 (20-40)	286	507	514	518	521	679	696	716	731
2 (40-60)	148	320	314	311	309	572	577	583	584
3 (60-80)	60	122	121	120	118	235	230	226	224
4 Total	1000	1492	1506	1524	1537	2150	2188	2243	2287
B. Proportion age group 0.	.506	.364	.370	.377	.383	.309	.313	.320	.327
C. Proportion age group 1.	.286	.340	.341	.340	.339	.316	.318	.319	.320
D. Proportion "labor force" (=age groups 1 and 2)	.434	.554	.550	.544	.540	.582	.582	.579	.575
E. Dependency Ratio. [(0)+(3)] / [(1)+(2))]	1.304	.804	.818	.837	.853	.717	.720	.728	.739
F. (i) Estimated total fertility (female children only)	2.53 (1951)	1.771	1.780	1.845	1.870	1.624	1.634	1.664	1.695
(ii) Fertility as proportion of 1951 fertility	1	.700	.711	.727	.741	.642	.646	.658	.670
G. Projected Population given actual 1971 total population (millions)	458	683	690	698	704	985	1002	1027	1047
H. Rate of Population Increase (%)									
(i) over period	-	49.2	50.6	52.4	53.7	44.1	45.3	47.2	48.8
(ii) annualized rate	-	2.02	2.07	2.13	2.17	1.84	1.89	1.95	2.01
I. Projected Population for year 2001	-	-	-	-	-	820	832	847	859

Future Mortality Gains case (Case (b)) are given in the Table below. The results based on High and Low cases (cases (a) and (c)) are given in the Table below. The discussion below is based on Case (b).

Important results are:

(i) If the hypothesis that households' fertility behavior takes no account of mortality gains during the current period is true, i.e., L = 1.0, then India's expected population is expected to be 704 million by 1991, 859 million by 2001, and 1047 million by 2011.

(ii) India's population increased by 51.6 percent during 1951-71; it is projected to grow by 49.2 percent if L = .6, 50.6 percent if L = .75, and 52.4 percent if L = .9. The projected rates of growth for the period 1991-2011 are 44.1% (L = .6), 45.3% (L = .75), and 47.2% (L = .90).

(iii) India's child population age group (0-20) which formed 50.6% in 1971 is projected to fall to 36.4% in 1991 and 30.9% in 2011 if L = .6; to 37.7 in 1991, and 32.0% in 2011 if L = .9.

(iv) Total fertility, i.e., number of children born per potential mother, is expected to fall to 70.0% of its 1951 level by 1991 and to 64.2% of its 1951 level by 2011 if L = .6. These work out to 30 percent decline in fertility by 1991 and 36 percent decline by 2011. For L = .9, the fertility declines by 1991 and 2011 are projected to be 27.3 percent and 34.2 percent below 1951 levels.

(v) The proportion of the female population in the child bearing ages is expected to increase from 28.6 percent in 1961, to 34.0 percent in 1991, and to 31.6 percent in 2011 if L = .6. This proportion remains fairly stable for different values of L being around 34 percent for 1991, and 32 percent for 2011.

(vi) The proportion of population in labor force age groups 1 and 2 is expected to rise from 43.4 percent in 1971, to between 44 to 45 percent in 1991, and to 58 percent in 2011. This proportion shows minor variations for different values of L.

(vii) The dependency ratio is projected to decline from 1.3 in 1971 to between .80 and .84 in 1991, and to about .72 in 2001.

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Annexe A
Table 2
Projections for Female Population for India for Years 1991 and 2011
and Estimation of Important Population Parameters.
High Mortality Gains Case- a(0) = .32; a(1) = .16; a(2) = .08
(Initial 1971 census figure assumed at 1000)

	Actual 1971	Projected Population							
		1991				2011			
		L=.6	L=.75	L=.9	L=1.0	L=.6	L=.75	L=.9	L=1.0
A. Female Population by age-group									
0 (0-20)	506	546	563	584	601	661	687	729	766
1 (20-40)	286	529	535	540	544	743	766	792	813
2 (40-60)	148	333	329	325	322	650	654	659	662
3 (60-80)	60	129	127	126	124	267	263	258	254
4 Total	1000	1537	1554	1575	1591	2321	2370	2438	2495
B. Proportion age group 0.	.506	.355	.362	.371	.378	.285	.290	.299	.307
C. Proportion age group 1.	.286	.344	.344	.343	.342	.320	.323	.325	.326
D. Proportion "labor force" (=age groups 1 and 2)	.434	.561	.556	.549	.544	.600	.599	.595	.591
E. Dependency Ratio. [(0)+(3)] / [(1)+(2)]	1.304	.781	.798	.820	.838	.666	.669	.680	.692
F. (i) Estimated total fertility (female children only)	2.53 (1951)	1.713	1.748	1.796	1.837	1.478	1.493	1.528	1.566
(ii) Fertility as proportion of 1951 fertility	1	.677	.691	.710	.726	.584	.590	.604	.619
G. Projected Population given actual 1971 total population (millions)	458	704	712	721	729	1063	1085	1117	1143
H. Rate of Population Increase (%)									
(i) over period	-	53.7	55.4	57.5	59.0	51.0	52.5	54.8	56.8
(ii) annualized rate	-	2.17	2.23	2.30	2.35	2.08	2.13	2.21	2.27
I. Projected Population for year 2001	-	-	-	-	-	865	879	897	913

Annexe A
Table 1

Projections for Female Population for India for Years 1991 and 2010
and Estimation of Important Population Parameters.
Low Mortality Gains Case - (once-for-all mortality disturbance). a(o) = .2820; a(1) = 0; a(2) = 0.
(Initial 1971 census figure assumed at 1000)

	Actual 1971	Projected Population							
		1991				2011			
		L=.6	L=.75	L=.9	L=1.0	L=.6	L=.75	L=.9	L=1.0
A. Female Population by age-group									
0 (0-20)	506	534	547	557	566	665	681	696	715
1 (20-40)	286	481	489	490	493	590	603	611	622
2 (40-60)	148	300	298	293	291	478	486	488	487
3 (60-80)	60	116	116	113	113	195	193	188	189
4 Total	1000	1431	1450	1453	1463	1928	1963	1983	2013
B. Proportion children [age group 0] .	.506	.373	.377	.383	.387	.345	.347	.351	.355
C. Proportion women child-bearing age [age group 1] .	.286	.336	.337	.337	.337	.306	.307	.308	.309
D. Proportion "labor force" (=age groups 1 and 2)	.434	.546	.543	.539	.536	.554	.555	.554	.551
E. Dependency Ratio. [(0)+(3)] / [(1)+(2)]	1.304	.832	.840	.854	.865	.804	.802	.806	.813
F. (i) Estimated total fertility (female children only)	2.53 (1951)	1.844	1.860	1.885	1.908	1.870	1.870	1.887	1.908
(ii) Fertility as proportion of 1951 fertility	1	.729	.735	.745	.754	.739	.739	.746	.754
G. Projected Population given actual 1971 total population (millions)	458	655	664	665	670	883	899	908	922
H. Rate of Population Increase (%)									
(i) over period	-	43.1	45.0	45.3	46.3	34.7	35.4	36.5	37.6
(ii) annualized rate	-	1.81	1.88	1.89	1.92	1.50	1.53	1.57	1.61
I. Projected Population for year 2001	-	-	-	-	-	760	773	777	786