1. Introduction

Modelling mortality for any population is important because of health planning issues. Modelling mortality can also enable mortality comparisons between populations, within populations, between regions, between the sexes and according to many other demographic characteristics. Identification of regional patterns of mortality transition is also another important area of study as the pace of mortality decline varies across regions and sub-population groups residing in various regions.

Modelling mortality can be done mainly in three ways: by model life tables, relational models and by the laws of mortality. As model life tables serve only as aggregated mortality schedules according to 'some defined standard', they may not incorporate the mortality experience of various regions of the country under study; they are useful for countries where data on mortality are either unavailable or scanty. Brass logit and Brass relational models of mortality also serve in the case of limited data but they suffer from the lack of fit at both ends of the mortality curves. The most appropriate way to model human mortality is by means of the laws of mortality. The parameters themselves serve as sources of information apart from representing overall mortality.

In the present study, an attempt has been made to model mortality patterns for India and its 15 major states on the one hand and to regionalize the patterns of mortality transition for the same by using the data on age-specific mortality rates from the Sample Registration System (SRS) from 1970-2000. It has also been tried to find out whether
there is any linkage between the changes in the socio-economic conditions and patterns of mortality decline in various regions.

2. Model fitting

As discussed above, models depicted by laws of mortality serve best to represent human mortality. A literature survey of various attempts to model human mortality and to test different options revealed that the eight-parameter model developed by the Heligman and Pollard (1980) was usable for the present study. However, the model has some limitations regarding over-parametarization and convergence of the parameters. The estimation of the parameters of the model requires age-specific death rates in single years whereas generally data in five-year age groups are available for India and other developing countries of the Asia and the Africa and hence the model requires simplification (with some suitable assumptions) to apply to the grouped data on the one hand and to achieve more parsimonious model on the other.

In this work, the model has been simplified by dropping the middle term and has then been fitted to the Indian grouped data by sex. Non-linear regressions with unweighted ordinary least square principle have been employed to fit the model with certain simplifying assumptions. The simplified model effectively needs to estimate five parameters instead of the eight parameters of the complete model. In most of the cases, the observed and the estimated values closely follow each other as squared sum of deviations is found to be sufficiently low. All the parameters also converge simply after finite number of iterations.
3. Results of fit

The trends of estimates of the parameters provide considerable information on representation of mortality in India and its states for both the sexes. If the overall trend of the estimates is considered, it can be established that the parameters representing early-life mortality, i.e., A, B, and C declined in India and its states over the period for both the sexes. This indicates a reduction in the level of mortality (reduction in A), a narrowing age-displacement of infant mortality (the decline in B), and a corresponding reduced rate of decrease of childhood mortality (reduction in C).

In cases of adult and old-age mortality, random fluctuations of estimates of the parameters G and H have been observed for both sexes and hardly any clear trend can be depicted for almost all the states.

For both the sexes, all the north-central Indian states viz, Madhya Pradesh, Uttar Pradesh, and Rajasthan, including Gujarat follow high mortality regime up to 1980 in case of infant and child mortality since estimates of all the three parameters A, B and C were higher in these states compared to the other states. After 1982, Bihar (data for this state is available only from 1982) joined this group, whereas Gujarat has started showing declining trend. The estimates for Assam also demonstrated an upward trend from 1982 and remained consistently high for the rest of the period. It has also been observed that the estimates for Orissa have been fluctuating; lower during 1976-80 and relatively higher during 1982-85. It has been noticed that southern states such as Kerala and Tamil Nadu and the northern state of Punjab follow the low mortality regime throughout the period, except some periods. Maharashtra and Andhra Pradesh can be included in this regime during late eighties and early nineties respectively. In these states the level of
early age mortality was relatively lower, age-displacement of infant mortality was narrow and the pace of reduction of child mortality was faster during the above mentioned periods. Other states follow medium mortality regime as estimates of all the three parameters indicate.

In addition to the Indian data, the model was tested with the data from three other developing countries viz. Sri Lanka, Mexico and Venezuela. Though the simplified five-parameter model did not fit as accurately to these data as complete eight-parameter model did, nevertheless the simplified model produced good results fitted to these data. However, fitted to the India and its states the simplified model produce excellent fits and hence can be used for further applications.

4. Regionalizing patterns of mortality decline

The values of the estimated parameters for various periods of 15 major states were then used to regionalize the patterns of mortality decline in India. Estimates of A, B and C have been used in this exercise since only these estimates show substantial variations over the period and estimates of the other two parameters, namely, G and H did not show any considerable variations. By plotting the estimates of A, B and C in 3-dimensional axis and by joining the points successively for each time period, starting from 1970-75 to 1996-2000 the patterns have been recognized for each state and for both the sexes. Since the values for the Kerala females could not be available beyond 1990 due to very low mortality, this state has been excluded from this exercise. Broad commonality in the characteristics of the pattern of declining trend has been culled out. For example, whether the decline has been smooth throughout the period or it was stalled somewhere during the period of study.
It has been observed that the north-central Indian states of Gujarat, Rajasthan, Punjab (for female), Haryana (for male), Uttar Pradesh and Orissa follow similar pattern of mortality decline (termed as decline-stall-decline). On the other hand, the states located more or less in the middle part of India ranging from the west to the east, i.e., Maharashtra, Andhra Pradesh, Bihar and West Bengal follow similar pattern of decline (termed as decline-stall) for both the sexes over the years. It has also been found that Karnataka and Tamil Nadu, the adjacent states located in southern India, follow similar pattern of mortality decline (termed as stall-decline-stall) for both the sexes. Haryana also shows similar pattern of decline to these states only for females. Madhya Pradesh and Assam are not so geographically contiguous states, but follow a similar pattern of decline only for females (stall-decline). Kerala, Punjab, Assam and Madhya Pradesh have their own pattern of decline for males.

An attempt has also been made to find whether those states, which follow similar patterns of mortality transition, have some sort of linkages with the similarity in the changes of the socio-economic conditions over the years with the help of some macro-level developmental indicators. Altogether seven indicators, which might have significant influence in mortality transition, have been selected for the analysis. These are: per capita Net State Domestic Product, percentage population living below poverty line, literacy rate, household health expenditure per event of hospitalization, state’s health expenditure as percentage of total expenditure, bed-population ratio and status of child immunization.

Tamil Nadu and Karnataka, which follow similar pattern of mortality decline, also follow similar pattern of socio-economic development as the aforementioned indicators suggest. Some broad similarities with regard to these indicators have also been observed
for the states of Maharashtra, Andhra Pradesh and West Bengal, which follow similar pattern of mortality decline. Though Bihar follows the pattern of mortality decline similar to that of Maharashtra, Andhra Pradesh and West Bengal, it does not show similarity to these states as far as the developmental indicators are concerned. It has also been seen that though the states of Uttar Pradesh, Rajasthan, Gujarat, Punjab (for females), Haryana (for males) and Orissa follow similar pattern of mortality decline, the aforementioned indicators do not behave similarly in these states. Similar is the case for Assam and Madhya Pradesh.

It must be mentioned that the present evidences with limited data are only indicative and not conclusive, suggest that the patterns of mortality decline may or may not always be linked with the socio-economic development; in some cases the association can be determined and in some cases it did not. Given that the number of units for which mortality data are available, i.e., states, is small, more detailed analysis was not possible.

5. Future research prospects

The parameters of the simplified model can be used for forecasting mortality. The model demonstrated the utilities such as removing awkward irregularities of data and providing a comparable set of parameters which can be used for forecasting as recommended by Keyfitz (1982).

The present simplification and the fitting procedure of eight-parameter Heligman-Pollard model are based on certain simplifying assumptions including the use of model life tables. A system of simultaneous estimation of mortality parameters may provide a better landscape for mortality modelling. Independent estimation of all the parameters in a model yields values which are the outcome of the model but may not be appropriate as
measures of the phenomenon and the regionalization based on these parametric values may not produce precise results. A simultaneous estimation system may provide solutions for the mortality curves that are coherent with the requirements. Multivariate ARIMA models could be used to this, but caution must be taken with the multivariate ARIMA method, as the prerequisite of knowledge of the covariance structure and joint error structures could be crucial to the process (Chauhan, 2002).

Socio-economic linkages with regional mortality transition could not be established in a concrete manner because of lack of data on a number of macro level socio-economic indicators, especially during 1970s and 1980s and more research is called for in this area. This means to create a firm data base of the socio-economic indicators among various sub-population of the country. The regional analysis of patterns of mortality decline must also take into the cognizance of the level of socio-economic conditions, access and opportunities to the marginalized sections of the society. It would be extremely useful to consider these in light of the emerging concept of “divergence and convergence in life expectancy” (Vallin and Meslé, 2005) in which it has been argued that: “... each major improvement in matter of health is likely to first lead to a divergence in mortality since the most favoured segments of the population benefit most from the improvement. When the rest of the population access the benefit of the improvement (through improved social conditions, behavioural changes, health policies, etc.), a phase of convergence begins and can lead to homogenization until a new major advance occurs. The entire health transition process thus breaks down into successive states, each including a specific divergence-convergence sub-process” (p-85). They have
also argued that from the eighteenth century to the present, at least two and even perhaps three of these successive stages have occurred or are developing.

Availability of cause-of-death data in time series manner for all the states of India would enable a more thorough assessment of the regional pattern of mortality decline and could strengthen the findings of the thesis. Ghosh and Kulkarni (2004) have argued that the pace of epidemiologic transition is not similar among all sections and sub-population groups in the society and thus the regional analysis of epidemiologic transition is a basic need for studying mortality in India. Data collection in this area must be strengthened to see the regional mortality transition in a more meaningful way. Recent inclusion of the collection of causes of death data to the Sample Registration System is a noteworthy step in strengthening the system, but a long way to go to obtain a sound statistical data base on causes of death.

Though the SRS provides a good source of demographic data in India, there is an urgent need to strengthen the vital registration system. Even in the SRS the sample size should be increased to get more accurate estimate of mortality and fertility, especially for the urban areas. A systematic data collection on morbidity is also needed. An integrated approach to the collection of morbidity data, registration of deaths and their medical certification might be initiated by an independent institution through the support of medical and population research institutions and statistical organizations.

To sum up, the present work first tried to simplify the eight-parameter Heligman-Pollard model of age pattern of mortality by reducing the number of parameters on one hand and to fit the model to the grouped age-specific mortality rates on the other. The simplified five-parameter model produces satisfactory fit for India and its major states for
most of the occasions. Thus, this work shows that it is possible to simplify the Heligman-Pollard model and that such a model can satisfactorily describe the age pattern of mortality in Indian states. This enables researchers to model mortality in India even when data on death rates are available only in five-year age groups as is the case with the SRS estimates. Further, the values of the estimated parameters have been used to regionalize the patterns of mortality decline. Three distinct patterns of decline for males and four different patterns for females have been identified. While some geographic contiguity is seen in these patterns, there are discontinuities as well. This is a contribution to the available literature in the field of mortality studies in India, which so far have basically been focused on the level of mortality and not on the pattern of decline as such. In addition, an attempt has been made to find the plausible linkage between the nature of the pattern of decline and the character of socio-economic development in the states or the regions. The available indications suggest that there is no clear concordance with the pattern of decline and the state of development in cases of some states. Further research would have to examine whether analysis for regions within states would reveal such association. At this stage, since the limitations on data on age specific death rates, such an exercise has not been possible. However, it is expected that once mortality information is available at lower level of aggregation further exploration in this direction would be possible. Thus, there has been a clear understanding on mortality changes in various states and regions in India as the present work has shown. But the factors associated with the decline need to be well understood before clear linkages can be established.