Chapter-1
Introduction

1. Background of the study

Up to the beginning of the twentieth century, the rates of population growth in Asia were low and fluctuating. From 1920 onwards, however, they began to rise, and this rise persisted up to 1970, after which they began to decline in many countries. The rates of population growth in the later half of the twentieth century have been moderate in East Asia, very high in South Asia and the highest in Western South Asia.

India witnessed unprecedented growth in population during the twentieth century. From a population of 238 million in 1901, the population has crossed one billion mark in 2000; an increase of slightly more than four fold. This rapid increase in population was mainly due to remarkable decline in mortality after 1921, particularly after independence. Decline in fertility started mainly after 1971 in most of its states but it accelerated during 1981-91 and gained momentum during 1991-2001. From the demographic transition theory one can argue that now India’s position lies somewhere between the ‘late expanding stage’ and the ‘low stationary stage’. The life expectancies were 22.6 years for males and 23.3 years for females during 1901-10, but increased to 61.6 years for males and 63.3 years for females during 1998-2002 (Office of the Registrar General, India; 1999, 2005a); correspondingly the crude death rate declined from 42.6 per thousand population per year during 1901-11 to 8.0 in 2003 (Office of the Registrar General, India; 2005b).

It is worth mentioning that the levels as well as the age and sex pattern of
mortality prevailing at any time in a country are invariably linked with the structure of causes of death and with the levels and causes of morbidity. Following the notion of demographic transition, which used to explain population growth, based on changes in fertility and mortality, Omran’s 1971 essay on “Epidemiologic Transition” sought to elucidate the determinants of changing patterns of mortality. According to Omran, all societies experience the “ages” in the process of modernization. The first is the “age of pestilence and famine”, during which mortality is high and fluctuating with an average life expectancy under 30 years. Infectious and parasitic diseases and nutritional and reproductive health problems predominate in this “age”. During the second age, the “age of receding pandemics”, mortality declines considerably with steady increase in the life expectancy to around 50 years and sustained population growth begins. Finally, during the “age of degenerative and man-made diseases” (the third “age”), the pace of the mortality decrease slackens, the infectious diseases disappear and the degenerative diseases like cancers, cardiovascular diseases and accidents become more common and frequent. The model proposed by Omran was unidirectional but later studies found that there is not a unique path from high to low mortality, but many; there is multiplicity of stages and multiplicity of transits between them (Palloni, 1990). Other researches in this field have observed that there are deviations from the general pattern and possibility of “counter transition” due to advent of HIV/AIDS in various parts of the world (Frenk et al., 1989a, b; Gaylin and Kates, 1997; Caselli, 2002).

Elsewhere, McKeown’s (1976, 1979) classic works on the history of mortality change in England and Wales provided a longitudinal examination of changes in the causes of death over nearly a century. McKeown computed the proportion of the decline
in standardized mortality rates due to specific causes. Three-fourths of the decline in mortality was due to the reduction in infectious diseases; the remainder attributable to non-infectious causes was mostly in the category of nephritis, diseases of early infancy and old age, and other diseases. Over the same period, age-standardized mortality rates for cardiovascular disease increased by 250 per cent, and rates for neo-plasms increased nearly fourfold. Other works on the plausible reasons of mortality decline (McKeown, 1965; 1979; Mckeown and Brown, 1955; Mckeown, Brown and Record, 1972; Mckeown and Record, 1962) suggested that the ultimate constraints on mortality decline are those of material resources, and hence of economic living standard, which Malthus discerned some two centuries back.

It is well established that the mortality transition took place in the more developed countries largely due to the transition from nomadic to agricultural to industrial society and also due to the transition from rural to urban population concentration. In the more-developed countries, these changes mostly took place in the eighteenth century and accompanied an increase in the per capita income of each country. Unlike the more-developed countries, the mortality transition in the less developed countries were not a function of an increase in per capita income - many of less developed countries have yet to see much of an increase in this area - but more a function of multiplicity of other factors.

Work of Caldwell (1986) titled "routes to low mortality in poor countries" has dealt with how multiplicity of socio-economic factors and state intervention brought about mortality transition in the Third World countries, especially the success in mortality reduction in four poor populations, those of Kerala of India, Sri Lanka, Costa
Rica, and China.

Studying history of mortality decline in the Indian sub-continent is a difficult task because of lack of reliable statistics (Davis, 1951). Analyzing the deficient statistics, Davis argued that mortality in Indian area had started to decline since 1920 as evident by the reduction in crude death rate, infant mortality rate, decrease in the proportion of widows, and the increase in life expectancy. According to him basically three plausible reasons of mortality decline can be identified: elimination of war and banditry during the British rule, the control over famine through the change in certain social conditions such as establishment of rail, road networks and irrigation system, and the control over epidemic disease through medical intervention by the state.

A few studies on age pattern of mortality in India are available. Bhat (1989) has tried to estimate mortality and fertility in India for the period 1881-1961 from census age distribution by using the 'variable-r' method (modification of Preston and Coale method, 1982). The analysis suggested that previous other estimates have exaggerated the levels of fertility and mortality during the aforesaid period. The estimates also implied that the age pattern of mortality is quite different from those contained in the Coale and Demeny models. According to the estimates the levels of child mortality for the beginning of the twentieth century were substantially lower than the previous estimates but levels of adult mortality were generally higher; possibly due to the fact that at higher levels of adult mortality has mostly to do with the correction which has been incorporated in the study for the effects of age misstatement. Lastly, it was concluded that Coale and Demeny model life tables may give an erroneous picture of the age pattern of mortality at very low levels of life expectancy.
Clark (1989) tried to find out the regional mortality levels in India during the pre-independence period. He found that the difference in the levels of mortality by region is quite pronounced, with Madras showing far better survival probabilities than United Provinces and Bombay.

By and large the mortality transition in independent India was largely due to public health and disease control measures, which were imported from the developed countries and, therefore, have been independent of economic development (Bhende and Kanitkar, 1999). These include DDT spraying, the use of antibiotics like penicillin and vaccines like the B.C.G. etc. The assistance provided by the World Health Organization to eradicate such mass killers as malaria, smallpox etc. has been helpful.

However, the level of mortality, especially infant and child mortality in India is still much above that in the developed world and also above that in many Asian countries. Besides, there are substantial regional variations. The level of overall mortality (infant mortality as well) is still substantially higher in the North-Central states of India than many other states.

Mortality as a negative aspect of health depicts the status of population through various measures such as expectation of life at birth, infant mortality rate, crude death rate etc. These measures have some limitations in describing the age pattern of mortality. Expectation of life at birth basically corresponds to the ‘level’ of mortality and not with the ‘pattern’ as such. Infant mortality depicts the experience of mortality of certain age group, whereas crude death rate is highly influenced by age-sex structure of the population.

Typically, the age pattern of mortality is a combination of three defined
continuous curves. These three curves depict the childhood, adolescent and early adulthood, and senescent mortalities. Heligman and Pollard (1980) have devised an 8-parameter model to describe the age pattern of mortality; this model has been widely accepted by the demographers and actuaries in the recent past. The first three parameters of the model describe mortality pattern in infant and early childhood years, the second three parameters refer mostly to ‘accident hump’ among males and to maternal mortality among females in the middle ages, and finally, the last two parameters describe the near geometric rise in mortality in older ages. This model adequately describes the age pattern of mortality but not the pattern of mortality decline or transition as such. Regional analysis of the pattern of mortality decline is also another important aspect to study for the purpose of regional health policy and planning.

After depicting the trends and variations of mortality in India and its 15 major states, this thesis attempts to fit the Heligman-Pollard model to grouped data by modifying it suitably with some assumptions. The present study also tries to regionalize the pattern of mortality decline in India by using the values of the parameters as obtained from the modified Heligman-Pollard model after fitting it to the data from 1970 to 2000.

2. Need of the study

In India, the studies in the field of mortality are basically limited to the analyses of levels and trends of various measures of mortality such as expectation of life at birth, infant mortality rates and crude death rates etc. of states and at the country level. As mentioned earlier that the Heligman-Pollard model depicts the age pattern of mortality adequately and has been adopted by many researchers to model age pattern of mortality of various developed countries; it is worth mentioning that the existing models, including
the Heligman-Pollard with many parameters and tested with good quality data from industrially advanced countries may not be appropriate in the Indian case. In India like other developing countries, age-specific mortality rates are available for age groups and not for the single year. But fitting the Heligman-Pollard model requires single year age specific death rates. Thus, it is necessary to modify the existing model with suitable assumptions so that it can be fitted to grouped data on the one hand and reduce number of parameters to achieve parsimony on the other.

The health profile of India at the beginning of the twenty-first century appears promising. Impressive improvements have been made in the socioeconomic, nutrition and health status of people after independence, especially from the 1980s. Successful eradication, elimination and control of the major killer diseases have contributed largely to the resultant epidemiological and demographic transition observable in the country. But there are wide variations in the transition according to the regions and among the sub-population groups. As mentioned earlier, the levels of fertility and mortality are higher in the North-Central states than many other states, especially than the Southern states of India. These are also higher among the marginalized sections of the society across the regions. Another important issue to be acknowledged is that the pattern of mortality transition may not be similar for the whole country; there may be substantial variations in the routes of mortality decline from state to state and from region to region. In the Indian context, regionalizing patterns of mortality transition is very much needed because very wide variations not only in the pattern of mortality but also in social and cultural norms, traditional beliefs, level of living standard and degree of social and economic progress have been observed in different parts of the country.
3. Present research

3.1 Objectives

The general objectives of this thesis are to simplify the 8-parameter Heligman-Pollard model (1980) so that it can be fitted to the grouped data for India and its states and also to regionalize the patterns of mortality transition in India by using the values of the parameters of the simplified Heligman-Pollard model. The specific objectives are:

1) To assess the trends and variations of mortality in India and its major states by sex.

2) To simplify the Heligman-Pollard model pattern of mortality with suitable assumptions in such a way that it can be fitted to grouped data to describe age pattern of mortality by sex in India and its major states and also to reduce the number of parameters to achieve a more parsimonious model.

3) To estimate the parameters of the simplified Heligman-Pollard model by sex for various states of India and at the all India level at different time periods.

4) To identify the regional patterns of mortality transition by sex by observing the values of the parameters of the simplified model over the period (from 1970 to 2000) and to examine whether these correspond to socio-economic conditions.

3.2 Data sources

In the absence of dependable data from the Civil Registration System (CRS) in India, the Sample Registration System (SRS) has been the main source of information on fertility and mortality indicators at state and national levels for the last three decades or so. The SRS mechanism involves collection of data through two different procedures viz., continuous enumeration and retrospective half-yearly surveys followed by a process
of matching of the two records and subsequent field verification of unmatched and partially matched events. The methodology provides a cross-check on the correctness and completeness of events of births and deaths listed in both the records.

The SRS was started in 1964 on a pilot basis and first gave national and subnational estimates for 1970. Since then the SRS has been an annual source of data on births and deaths in India. This thesis will mainly use data from the SRS from 1970 to 2000 for various analyses. In particular, age-specific death rates for the annual time series will be analyzed. Data sets for males and females and for persons are available in the SRS. Further, data are available for rural and urban residential areas. In this thesis, the main analysis will be carried out for the male and female populations of India. Data for recently created states of Uttaranchal, Chattisgarh and Jharkhand have been included in their parent states of Uttar Pradesh, Madhya Pradesh and Bihar respectively. A discussion of quality of data, coverage and their use in mortality analysis is given in Chapter-2.

Life-tables for the various periods from 1970-2000 published by Office of the Registrar General, India will also be used in the analysis.

3.3 Methodology

As stated earlier, the Heligman and Pollard formula is represented as a combination of three continuous mathematical curves. Mathematically, the formula can be written as

\[ \frac{q_x}{p_x} = A^{(x+B)^c} + D \exp \left\{ -E \left( \log \left( \frac{x}{F} \right) \right)^2 \right\} + GH^x \] .......... (1)

or, alternatively

\[ q_x = A^{(x+B)^c} + D \exp \left\{ -E \left( \log \left( \frac{x}{F} \right) \right)^2 \right\} + \frac{GH^x}{(1+GH^x)} \] .......... (2)
where \( q_x \) is the probability of dying within 1 year for a person aged \( x \) exactly, and \( p_x = (1 - q_x) \). \( A, B, \ldots, H \) are parameters to be estimated.

Here the first term of the equation, a rapidly declining exponential, reflects the fall in mortality during the early childhood years; \( A \) measures the level of infant mortality, \( C \) measures the rate of mortality decline in childhood (the rate at which a child adopts to its environment). \( B \) is an age displacement to accident for infant mortality. The third term in the formula, the well-known Gompertz exponential, reflects the near geometric rise in mortality at adult ages-senescent mortality. The parameter \( G \) represents the base level of senescent mortality while \( H \) reflects the rate of increase of that mortality. The remaining term represents the mortality pattern with increased rates for the young adult population. These increased rates are sometimes called 'accident hump’ for males and 'excess female mortality’ for maternal deaths.

This model is valid for the single year value of \( q_x \). As 'accident hump' and 'maternal mortality' (its location, spread and severity) are localized phenomena and mainly concentrated in the 20-35 age range, to fit the Heligman and Pollard model to explain accident hump (represent by the middle term of the equation 2) the requirement of single year data is a necessary condition. Thus, to fit the above equation (2) to grouped data the middle term has been excluded from the equation and the equation becomes

\[
q_x = A^{(x+B)} + GH^x/(1+GH^x)..............................(3)
\]

where the interpretations of the parameters are similar to that of the equation (2).
Equation (3) is the governing equation of the simplified model. To hold the equation (3) true and to make fitting possible to the grouped data certain assumptions are made, as incorporated in the methodology section of the chapter-4 of the thesis. Data for the periods 1970-75, 1976-80, 1982-85, 1986-90, 1991-94 and 1996-2000 for India and its states were fitted in the equation. The parameters of the curve were then estimated by non-linear regression with ordinary least squares using Levenberg-Marquardt iteration scheme, a modified version of Gauss-Newton iteration and the values of the parameters thus obtained for the periods.

The obtained results have then been compared with the fit of original 8-parameter model in the grouped data as obtained by using MORTPAK-LITE software. In addition to Indian data, the reduced model has been fitted to the grouped datasets of some other developing countries to evaluate the performance of this simplified model.

To obtain the regional pattern of mortality decline the values of the parameters A, B and C have been plotted in 3-dimentional scale for each period viz. 1970-75, 1976-80, 1982-85, 1986-90, 1991-94 and 1996-2000 for both sexes and for all the 15 states and also at all India level. 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 sexes. Those states, which broadly follow similar pattern over the years, have been grouped into a category through visual comparison and thus the regions of similar mortality decline have been identified.
4. Organization of the thesis

The thesis is divided into six chapters. Chapter 1 provides the introduction and background including specific objectives, sources of data used in this thesis, and related methodology in brief.

Chapter 2 discusses basic details of mortality levels, trends and variations in India and its 15 major states from the period 1970-2000 and includes a detailed discussion on data sources and their quality in studying mortality in India and its states.

Chapter 3 provides a detailed review of important outcomes of previous studies in the field of mortality research. To start with, a few important concepts and definitions are discussed. Three categories of mortality models are discussed: model life tables, relational models and mortality laws. The viability of these models is determined in the methodological context and their validity in case of India has also been discussed. This chapter ends with critically examining the applicability of the Heligman and Pollard model (1980) in the Indian context.

In Chapter 4 the simplified Heligman-Pollard model has been fitted to grouped data of India and its 15 major states. The methodology of fitting in detail and the related assumptions, and the results of fit for India and its states have been discussed in this chapter. In addition, the applicability of the simplified model to the data sets of some other developing countries has also been discussed at the end of this chapter and the comparison has been made with the results of the fit of 8-parameter model by employing the MORTPAK-LITE.

Regionalization of the pattern of mortality decline by sex has been done in chapter 5. After discussing the previous works in the field of regionalization such as
model life tables and their methodology, this chapter describes the methodology used in
the present study. Then the regions which have experienced similar patterns of mortality
decline over the period separately for males and females have been identified. Male­
female similarity in the pattern of decline has also been noted in this chapter. The linkage
between the socio-economic factors and the patterns for mortality of various regions has
been discussed in the concluding part of this chapter.

Chapter 6 discusses what has been achieved from the study and further research
areas are outlined at the conclusion of this chapter.