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Mortality Trends, Differentials and Modeling for Mortality Forecasting in Bangladesh

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MORTALITY TRENDS, DIFFERENTIALS AND MODELING FOR MORTALITY FORECASTING IN BANGLADESH

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Submitted by

Abu Sayeed Md. Ripon Rouf
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Department of Population Science and Human Resource Development
Faculty of Science
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February 2017

Dedicated to

my respected Parents,

Beloved Sons

&

Wife

MORTALITY TRENDS, DIFFERENTIALS AND MODELING FOR MORTALITY FORECASTING IN BANGLADESH

PhD Thesis

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Declaration

I declare that the thesis entitled "MORTALITY TRENDS, DIFFERENTIALS AND MODELING FOR MORTALITY FORECASTING IN BANGLADESH" embodies the findings of original research work carried out by myself under the supervisions of Dr. Dilip Kumar Mondol, Professor, Department of Population Science and Human Resource Development and Dr. Md. Jahanur Rahman, Professor, department of Statistics, University of Rajshahi. This thesis is submitted to the Department of Population Science and Human Development, University of Rajshahi for the Degree of **Doctor of Philosophy** in Population Science and Human Resource Development. No part of this thesis has ever been submitted anywhere for any Degree.

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Certificate

This is to certify that the thesis entitled "**MORTALITY TRENDS, DIFFERENTIALS AND MODELING FOR MORTALITY FORECASTING IN BANGLADESH**" is an original research work carried out by Abu Sayeed Md. Ripon Rouf under our direct supervision and submitted to the Department of Population Science and Human Development, University of Rajshahi for the Degree of **Doctor of Philosophy** in Population Science and Human Resource Development. This work has never been submitted anywhere for any Degree. Mr. Ripon Rouf has fulfilled all the terms and conditions for the PhD degree including presentations of the findings of the research work in two seminars held in the Department of Population Science and Human Resource Development, University of Rajshahi.

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Abstract

Mortality is one of the most important vital events and it is a crucial indicator of socio-economic development in any nation. It is said that socio-economic development should be measured in terms of mortality. Bangladesh, a developing country of South Asia, is experiencing significant decline in fertility and mortality in the last few decades. Along with remarkable decline in early aged mortality, senescence mortality also declined in the last decade. But, practically, the pace of socio-economic development is not satisfactory compared with the pace of mortality decline. Though, a common concept regarding mortality is that mortality decline is the consequence of socio-economic development and conversely low mortality is also a cause of ageing population problem. This study attempts to examine the trends, differentials of mortality and modeling for mortality forecasting in Bangladesh. It has also projected population using forecasted mortality to know its impact on population in future.

Present study has revealed that female mortality declined somewhat faster than that of male in both rural and urban areas. Initially male life expectancy at birth (e^0) was greater than that of female, later on it changes and female life expectancy at birth becomes greater than that of male. A sharp decline in childhood mortality and old age mortality is happened in last two decades. Similar declining trend of mortality has evident in both rural and urban areas. Sensitivity analysis of life expectancy at birth has shown that the childhood mortality and old age mortality have more effect than other age group mortality to increase life expectancy. Decomposition analysis of difference of mortality rate between different census periods has indicated that age specific mortality rate effect is generally more attributable than age composition population effect. Using mortality data from Bangladesh Bureau of Statistics (BBS), this study forecasted life expectancy at birth for 40 years (2012-2051). The life expectancy at birth will increased to more than 82 years for male and more than 86 years for female. During the whole projection period life expectancy at birth for female is higher than that of male. The increasing pattern of life expectancy at birth is similar in rural and urban areas. Population projection demonstrates that working age population (15-59 or 15-64) will increase till 2021 and then decrease very slowly

(almost stagnant) towards the rest of the period. In spite of a slow decline in working age people after 2021, still there will be a huge number of working age people until 2051. The percentage of young age population (0-14) will decrease during the whole projection period and the percentage of old age population (60+ or 65+) will increase during the whole projection period which results a large number of elderly people.

In spite of remarkable decline in childhood mortality, it is still high compared to developed countries. Finally, this study suggests that the increasing number of elderly people would create ageing population problem in near future. Moreover, proper steps should be needed to create job opportunity to employ the huge number of working age population in various sectors of country's economic development. Otherwise, they will be the burden of the society and create social problems. At the same time, proper health policy should be taken to provide healthcare facilities for the growing number of population. The country also needs to think about suitable steps like pension scheme, various allowances etc. for the elderly people.

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In fine, I am alone responsible for the shortcomings and the errors if there be any, I am sorry for that.

University of Rajshahi, **Author**

Bangladesh

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List of Acronyms

AFM	:	Age at First Marriage
ARIMA	:	Autoregressive Integrated Moving Average
ASDR	:	Age-specific Death Rate
BBS	:	Bangladesh Bureau of Statistics
CBR	:	Crude Birth Rate
CDR	:	Crude Death Rate
CPR	:	Contraceptive Prevalence Rate
e^{0}	:	Life Expectancy at Birth
e^{60}	:	Life expectancy at age 60
e^{65}	:	Life expectancy at age 65
IMR	:	Infant Mortality Rate
MAFM	:	Mean Age at First Marriage
ODR	:	Old Dependency Ratio
SVD	:	Singular Value Decomposition
SVRS	:	Sample Vital Registration System
TDR	:	Total Dependency Ratio
TFR	:	Total Fertility Rate
U5MR	:	Under 5 Mortality Rate
YDR	:	Young Dependency Ratio

Chapter I

Background of the Study

1.1 Introduction

Mortality is a key indicator of socio-economic development in any Nation. It is one of the most important vital events among three vital events fertility, mortality and migration in demography. It has two opposite impacts on human beings and nations. First, the high mortality rate, which is still the most daunting challenge for many developing countries, is the cause of short life span, poor socio-economic condition and inadequate health facility. Mortality has started to decline dramatically in all developing countries in last few decades. On the other hand, totally opposite situation is apparent in developed countries as they experience very low mortality rate due to improved socio-economic condition and health facility. According to Olshansky et al. (2012), life expectancy changes by education. They found that life expectancy is lower among the people who have less than high school education and higher among those have more than high school education. John Bound et al. (2014) categorized more specifically that increase of life expectancy depended on increase of years of education. Cutler et al. (2006) showed that the pleasure of life is worth nothing if one is not alive to experience them. They have also shown by comparing between rich and poor countries, health improving as to provide adequate health facilities and political willingness. They have further observed that the mortality rate is much higher among low income countries than high income countries, Preston (2007) mentioned that the socio-economic development should be measured in term of mortality. He suggested that mortality declines with socio-economic development. Yet, Cutler et al. and Preston's publications are still factual for those countries that are facing high mortality. On the other hand, a few countries with sharply declining mortality rate over the last few decades have already started to face its inverse impacts. Although it is a common phenomenon that the mortality decline is the consequence of socio-economic development and inversely low mortality is also a cause of ageing population problem (Lee and Carter, 1992). It is also important to find the root cause and effective solution to reduce high infant & child mortality as high infant & child mortality is positively correlated with high fertility as well as with high population growth (Islam et al., 2003; Bairagi and Datta, 2001; Khuda and Hossain, 1996; Mahmood, 2005; Randall and LeGrand, 2003; El-Ghannam, 2005).

The aim of this study is to examine the mortality trend, differentials and modeling for mortality forecasting to get a clear idea regarding future course of mortality as well as future life expectancy at birth in Bangladesh. The population of Bangladesh has increased from 42 million in 1941 to 150.6 million in 2011 (BBS, 2012) and approximately 160 million in 2015. It is noteworthy that Bangladesh is one of the densely populated countries in the world except some of the island and city based countries. Containing 150.6 million citizens of which 77.1 million are males and 73.5 million are females. However, the crude birth rate of Bangladesh declines from 48 per thousand in 1970 to 19.2 in 2011 and crude death rate from 21 per thousand in 1970 to 5.5 in 2011. In the same period, the total fertility rate (TFR) declined from 7.0 children per woman in 1970 to 4.24 in 1991 and 2.11 in 2011 (SVRS, 2012), the annual growth rate of population decreased from 2.61% in 1974 to 1.37% in 2011 and infant mortality declined from 128 per thousand in 1974 to 92 in 1991 and 35 in 2011 (Mitra et al., 1997 and SVRS, 2012). The working-age (age group 15-59) population was 92 million (61.1% in total population) in 2011 with 46.4 million males and 45.6 million females. In 1981 and 1991, the working-age population were 42.9 million (47.70% in total population) and 52.6 million (49.5% in total population) respectively and with 21.96 million males and 20.92 million females in 1981 and 26.72 million males and 25.9 million females in 1991. The size of male to female working-age population are steady during all census periods and the comparative percentage of working-age population among three census periods has increased in Bangladesh and will continue in future. Apart from this, while the percentage of young-age (age group 0-14) population in the total population has been showing a decreasing trend, the number of young-age population is still showing an increasing trend. The young-age population was about 31.91% (48.05 million) in 2011, about 45.15% (47.99 million) in 1991 and about 46.62% (41.9 million) in 1981. The life expectancy at birth increased from 56.63 years in 1981 to 68.63 years in 2011 for males and from 56.56

years in 1981 to 69.81 years in 2011 for females and expected to 82.97 years for males and 86.04 years for females in 2051.

Owing to these demographic changes, Bangladesh is likely to face population ageing problem in the future as to it's over population burden and without sufficient socio-economic development. In 1981, only 6.07% male and 5.28% female of the population of Bangladesh was 60+ years old and it increased to 7.21% for male and 6.68% for female in 2011. This proportion is expected to increase to 19.80%[1] for male and 23.89%[1] for female and also to 23.14%[2] for male and 27.25%[2] for female in 2051. However, little attention is paid to the unpleasant consequence of this increasing ageing population and their social, economic and health implications in Bangladesh. Though at present the ageing situation is not so serious, the policy makers should pay attention in this respect to meet up the future adverse condition.

This study tries to deal with mortality trends, differentials and future course of mortality in Bangladesh. Very few studies on trends and determinants on mortality are there in Bangladesh and other South Asian countries (Alam et al., 2005; Hurt and Saha, 2004; Rahman, 2000; Rahman, 1999; Mostafa and Ginneken, 2000; Souza and Bhuiya, 1982; Mcintosh et al., 1986; Rahman, 1997; Soares; 2007) which demonstrates further studies on the issues. . Numerous studies have been done on the future mortality forecasting in developed countries (Tujapurkar, Li and Boe, 2000; Booth, Maindonald and Smith, 2001, 2002; Carter and Prskawetz, 2001; Hollmann, Mulder and Kallan, 2000; Li, Lee and Tuljapurkar, 2004; Hyndman and Ullah, 2005; Wang and Lu, 2005; De Jong and Tickle, 2006; Booth et al., 2006) but there is no mentionable study regarding future course of mortality in Bangladesh. Some of the researchers have focused on infant & child and old-age mortality in developing countries but studies on complete mortality situation in developing countries is still lacking. So this is the prime time to study on age-specific mortality modeling and forecasting to investigate the future course of life expectancy at birth. Therefore, we intend to study on such an issue. It will also use age-specific mortality forecasting depending on the present pace of mortality change and differentials males and females

[1] Population projection by Cohort Component Method in scenario-I
[2] Population projection by Cohort Component Method in scenario-II

separately. Under these circumstances, this study uses the experiences of developed countries since there is no mentionable study on age-specific mortality modeling and forecasting in developing countries.

1.2 Importance of the study

As the literature shows an extensive research has already taken place in developed countries but in Bangladesh only a limited research is done on the topic. This issue is extremely important from developed countries point of view as well as Bangladesh for taking future plan of action on ageing population due to future mortality decline. So this research is very important that examines age-specific mortality modeling and forecasting to investigate the future course of life expectancy at birth. It will also find age-specific mortality forecasting depending on the present pace of mortality change and differentials males and females separately. Under these circumstances, this study uses the experiences of developed countries since there is no mentionable study on age-specific mortality modeling and forecasting in developing countries.

Hope, this study will provide a good message regarding this situation through the investigation of mortality trends and differentials. Again, the modeling and forecasting of age-specific mortality will be able to provide a concept regarding future age-specific mortality course and life expectancy at birth depending on the present trend of age-specific mortality. It will also be helpful message regarding mortality to make an effective proposal for Bangladesh population with the focus of our findings.

Since Bangladesh is a developing country, our findings may help the authority to take proper steps to economic development for future population of the country. We also believe that Bangladesh will be benefited through this research as we would like to use proper mortality forecasting model and to use appropriate methodological techniques to analyze the data.

1.3 Rationality of the study

As the world’s most densely populated country, the person-land ratio in Bangladesh is getting narrower day by day and creating negative impacts on its socio-economic development with highly over population burden. The country needs a stable population policy to deal with the challenge successfully. But unfortunately after achieving independence in 1971, it never gets stable political situation as well as stable government to mitigate such challenge. In most of the cases the government does not carry on the continuation of the policies taken by the previous government. As a consequence, it does not achieve sustainable development in any aspect. After nineties in the last century the situation started to somewhat improve in many aspects with a slightly democratic environment, though the pace of development is not satisfactory. Like many other issues population policy is not yet taken properly to meet up the growing challenges. That’s why our study will help the authority to take proper plan of action to handle the future huge working age population as well as additional elderly people, as we deal with trends, differentials and modeling for mortality forecasting in Bangladesh. So, our findings and suggestions will be policy oriented which help the planners to take proper steps regarding population.

1.4 Objectives of the study

In Particular, the basic objectives are as follows:

i) to examine the magnitude of the change of mortality trends and differentials by age and sex-specific;

ii) to investigate the sensitivity of life expectancy at birth (e^0) by age-specific mortality change;

iii) modeling and forecasting of mortality in Bangladesh and

iv) to gain an idea about the impact of forecasted mortality on future population in Bangladesh.

1.5 Hypothesis and its tests of the study

Is mortality affected demographic composition and socio-economic development? This study tries to find out the effect of mortality on demographic composition and socio-economic development of Bangladesh. We investigate the trends and differentials of mortality and also modeling for mortality forecasting to provide helpful message to the policy makers to take necessary steps for future planning regarding population. To do so it is very important to take proper hypotheses to test the effect of mortality on demographic composition and socio-economic development.

In this regards, this study has taken the following hypotheses:

Hypothesis-I

If age-specific mortality rate effect has more contribution than age composition population on differences of crude death rates between different census populations.

Hypothesis-II

If present mortality trend continues in future it may cause more adverse impacts on the future demographic composition and socio-economic development in Bangladesh

To justify the hypothesis-I, decomposition method of crude death rates between different census periods is used to investigate which effect has more contribution in the differences of crude death rates.

For hypothesis-II, we forecast the mortality rate by Lee-Carter method to know the future course of mortality and population is projected by Cohort Component method to know the future population age distribution. These projected results are used to investigate the demographic composition and its impact on socio-economic development.

1.6: Organization of the study

This thesis consists of eight chapters, of which first one is Background of the study (Chapter-I) that contains introduction, that is a complete overview of the study and also description of some previous studies. Importance of the study, rationality of the study, objectives of the study and research hypotheses are also discussed in Chapter-I.

Review of literature is in Chapter-II, which has a brief introduction, discussion of some previous studies related to trends, differentials and modeling for forecasting of mortality.

Data sources and Methodology are discussed in Chapter-III which contains an introduction, description of study area, data sources and analytical techniques, conceptual definition of some important topics, and also quality of data along with limitations of the data.

Chapter IV provides Socio-economic development and demographic change in Bangladesh, which has an introduction that describes briefly about many aspects of Bangladesh. This chapter also discuss about trend of literacy rate, contraceptive prevalence rate, population trends and differentials according to sex and broad age group, trends and differentials of labour force participation, trends of GDP growth rate, total population, median age, overall mortality, infant and child mortality, total fertility rate and mean age at first marriage.

Pattern of mortality trends and differentials in Bangladesh are discussed in Chapter-V, which has a brief introduction along with the trends of percentage change of life expectancy at birth, age-specific mortality, sex-specific mortality, sensitivity analysis of life expectancy at birth and decomposition of changes in mortality trends.

Chapter VI contains modeling and forecasting of mortality in Bangladesh. With an introduction this chapter has discussed about Lee-Carter model, its advantage and dis-advantage, description of data for Lee-carter model, Lee-Carter model fitting methodology, estimation of mortality index, age-specific death rates and life expectancy forecasting procedure, Lee-Carter model parameter estimates, 40 years forecasting of morality index, ARIMA model diagnostic procedure and 40 years projection of age-specific death rates and life expectancy at birth.

Impact of forecasted mortality on future population is discussed in Chapter VII. This chapter provides an introduction which is a short overview of the chapter. Population projections are done by Cohort Component method in two scenarios for the next 40 years on the basis of mortality forecasting done in the Chapter VI. This chapter has also discussed about projected mortality impact on future broad age group population and projected mortality impact on old age population and its consequence of ageing population in Bangladesh. Total population trend, age distribution of population, broad age group population, dependency ratios and median age are focused in this chapter. And finally Chapter VIII contains summery, discussion and recommendations. Discussion of the whole study, summarizing the findings and recommendations are provided in this chapter.

Chapter II

Review of Literature

2.1 Introduction

Now-a-days the discussions on human life span continue strongly. Some researchers argue this belief that life expectancy is now approaching a top limit has been established to be wrong (Wilmoth, 2001; Oeppen and Vaupel, 2002). They oppose Fries's idea that the limits of human life expectancy are fixed in conditions of life expectancy, around 85 years (Fries, 1980). One of the widespread visions shared by many demographers today analyzing the mortality changes over time in developed countries (e.g. G7 countries including Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) is that most of the increase in life expectancy was due to large reductions in mortality early in life before the 1960's and 1970's. Nevertheless, in future, most of the gain in the length of people's lives will be due to a mortality decline among the elderly (Wilmoth, 1998; Vaupel, 1998; Tuljapurkar, et. al. 2000; Horiuchi, 2000; Oeppen and Vaupel, 2002). Using life expectancy at birth to examine whether there is an upper limit to the human life span becomes questionable. Wilmoth (1998) states "trends in life expectancy are deceptive because they reflect age patterns of human morbidity and mortality as well as declines in underlying death rates." In the same year Vaupel comments "life expectancy is heavily influenced by mortality early in life. Furthermore, life expectancy is a synthetic measure of current mortality condition in a particular year. It is calculated by fixing age-specific death rates at prevailing level. Hence, it is useful to examine other measures of longevity of human life" (Vaupel, 1998). His petition, coinciding with Wilmoth's analysis on trends in life expectancy, draws a significant attention of this thesis, not only on the 'value' of the limits of human life expectancy and mortality forecasting, but also trends and differentials of mortality. This chapter includes the review of a number of studies regarding trends, differentials and forecasting of mortality which is discussed in section 2.2.

2.2 Review of literature

Sociologists decide what questions to ask on the basis of a review of the literature in the field. Good researcher look to see what is already known about the subject that they want to study (Light et al. 1989: pp. 30). Reviewing the literature is surviving the existing theories and researches on the subject (Zanden, 1990: pp. 17). The subject in the present study "Mortality Trends, Differentials and Modeling for Mortality Forecasting in Bangladesh" was never a subject of proper research in Bangladesh. It is only from recent past that we find studies and researches done on the subject. To carry out this research we have reviewed a number of studies done by various researchers in different countries. Some of the reviews are expressed below:

Ricardo F. N. (1995) observed that Mongolia is experiencing deep economic and social transformations, whose implications for the health care system are discussed. An economic crisis whose end is nowhere in sight, emergent social inequalities, a vague health insurance model with unclear financing sources, and lack of concern by most policy-makers in strengthening the preventive component of the health system, are not positive factors for substantial infant and child mortality decline in the near future. A clear advantage is, however, the fact that there is a wide space for major improvements with existing internal and external resources.

Hans-Peter K. and Iliana K. (2000) proposed a modified DeMoivre hazard function that is suitable for the application of frailty models to adult and old ages. The proposed hazard increases faster than exponential, and when combined with unobserved frailty it can capture a broad range of patterns encountered in the analysis of adult mortality. They suggested that the stronger selection process in the male population, caused by an overall higher level of mortality, may constitute a primary mechanism leading to the convergence of male and female mortality at higher ages.

Mostafa G. and Ginneken J. K. (2000) examined the determinants of mortality in a sample of about 10,000 elderly persons. They used information on several social and economic variables derived from the 1982 census and mortality data of this population which was followed prospectively in 1982 to 1992. They showed that marital status was the single most important determinant: widows and widowers had

1.5 to 2 times higher risk of death compared to couples where both husbands and wives were alive. Social support in old age by children also plays a role, especially for women: women living with at least one son or daughter had 18% lower mortality than women living in a household without sons or daughters.

Kannisto V. (2000) showed that the secular transition from high to low mortality has been accompanied by general and massive compression of mortality. In recent decades, however, this development has come close to stagnation even when life expectancy continues to increase. This has happened at a level where compression is still so incomplete that the shortest age interval, in which 90 percent of deaths occur, is more than 35 years. He seems unrealistic to expect human mortality ever to be compressed into so narrow an age interval that the survival curve would be even approximately rectangular.

Juhee V. S. (2001) revealed that infant mortality has reached a low stable rate in developed countries while it is still high and on a slow decline in developing countries. Although credit for contributing to the lowering of infant mortality has been given to health programs by public health personnel and to the improvement in socio-economic status by social scientists, in a traditional and agricultural country such as Nepal, both these factors are found to influence infant mortality. He suggests that among all the variables analyzed in the study, parity, place of residence, immunization, and ethnicity influence infant mortality the most.

Brendan Kennelly et al. (2003) analyzed that econometric model of population health in 19 countries in the Organization for Economic Co-operation and Development countries using panel data covering three different time periods. They found that very little statistically significant evidence that the standard indicators of social capital have a positive effect on population health. By contrast, per capita income and the proportion of health expenditure financed by the government are both significantly and positively associated with better health outcomes.

Núria Calduch Verdiell (2003) investigated that the main socio-economic and geographic determinants of infant mortality in Spain over the period 1975-2000. He suggested that among all the variables analyzed in the study income inequality, maternal employed, fertility rate, maternal education and the availability and access to health services appeared to be the most significant predictors of infant mortality for Spain and for other developed and less developed countries.

Alberto Minujin and Enrique Delamonica (2004) observed that increasing in equity combined with improvements in the national average are maintained, expanded and accelerated, and then U5MR may be reduced faster and more equitably in the next 10-15 years than it has proven possible during the last decade.

Iain D Currie et al. (2004) used a penalized generalized linear model with Poisson errors and showed how to construct regression and penalty matrices appropriate for two dimensional modeling. They illustrated their methods with two data sets provided by the Continuous Mortality Investigation Bureau, a central body for the collection and processing of UK insurance and pensions data. They observed that the failure to predict accurately the fall in mortality rates has had far reaching consequences for the UK pensions and annuity business.

The influence of individual and contextual socioeconomic variables on mortality is compared in two Canadian provinces, Manitoba and Nova Scotia from the period 1996-97 to 2002; Leslie L. Roos et al. (2004) analyzed that well-educated and higher income individuals were less likely to die during follow-up. No significant direct effect was found between neighborhood socioeconomic characteristics and mortality. They showed that an increased importance of individual income vis-"a-visa mortality in advantaged neighborhoods relative to disadvantaged neighborhoods. Additional Manitoba analyses showed a ‘‘healthy mover’’ effect among respondents changing place of residence, regardless of whether they moved to more advantaged or more disadvantaged neighborhoods.

Marc Luy (2005) showed that tempo-adjustments in life expectancy can provide a very different picture of current mortality conditions compared to conventional life expectancy. An application of the Bongaarts and Feeney method to the analysis of the mortality gap between western and eastern Germany. He showed that the differences in survival conditions between the two regions still are considerably higher than generally expected, and the survival gap between the two entities began to narrow some years later than trends in conventional life expectancy suggest.

Nan Li and Ronald Lee (2005) showed that mortality patterns and trajectories in closely related populations are likely to be similar in some respects and differences are unlikely to increase in the long run. And it should be possible to improve the mortality forecasts for individual countries by taking into account the patterns in larger group. They forecasts also allow divergent patterns to continue for a while before tapering off.

Rob J Hyndman and Md Shahid Ullah (2005) demonstrated that the method on fertility and mortality data, and showed that it achieved better forecasting results than other approaches to mortality forecasting. This superior performance arises for several reasons: (1) we allow more complex dynamics than other methods by setting $K > 1$, thus allowing higher order terms to be included; (2) nonparametric smoothing reduces the observational noise; (3) the use of robust methods avoids problems of outlying years, especially around the world wars. It has the added advantage of providing interesting historical interpretations of dynamic changes by separating out the effects of several orthogonal components.

Siu-Hang Li and Wai-Sum Chan (2005) showed that a systematic outlier detection process to ascertain the timing, magnitude, and persistence of any outliers present in historical trends of the mortality index. They also tried to match the identified outliers with important events that could possibly justify the vacillations in human mortality levels. Further they were try to adjust the effect of the outliers for model re-estimation. The empirical results indicate that the outlier-adjusted model could achieve better fits and more efficient forecasts of variables such as the central rates of death and the life expectancies at birth.

Claudia Pedroza (2006) showed that the Bayesian prediction intervals to be appropriately wider than those obtained from the Lee–Carter method, correctly incorporating all known sources of variability. An extension to the model is also presented and the resulting forecast variability appears better suited to the observed data.

David Cutler et al. (2006) observed that the prediction of acceleration in the production of new knowledge and new treatments is likely to make the health gradient steeper, with increasing gaps across educational and social class groups, and possibly race as well. They showed that there was no gradient in infant mortality between the children of physicians and non-physicians prior to an understanding of the germ theory of disease. More educated people quit smoking faster after the health consequences were understood.

Samuel H. Preston and Haidong Wang (2006) demonstrated that the changes in sex mortality differentials in the United States have been structured on a cohort rather than a period basis, a feature that has previously escaped attention. Furthermore, they showed that the cohort imprint is closely related to a cohort's history of cigarette smoking. Rather than attempting to extrapolate from epidemiologic studies to the national level, as previous studies have done, we achieve these results through a difference-of-differences design that directly reveals the impact of smoking on mortality. The different smoking histories of women and men provide a telling vantage point from which to view the havoc that smoking has wrought on national mortality patterns.

Kenneth Harttgen and Mark Misselhorn (2006) found that the determinants of child mortality and under nutrition differ significantly from each other. Access to health infrastructure is more important for child mortality, whereas the individual characteristics like wealth and educational and nutritional characteristics of mothers play a larger role for anthropometric shortfalls. Although very similar patterns in the determinants of each phenomenon are discernable, there are large differences in the magnitude of the coefficients. Besides regressions using a combined data set of all six countries show, that there are still significant differences between the two regions although taking account of a large set of covariates.

Peter Wohlfart (2006) considered the issue of predicting future mortality and using non-parametric counting process approach combined with a kernel smoothing- and a bias correction technique for estimation of the past mortality. He used the Lee-Carter method for adapting a mortality model and generating forecasts of the future mortality. He also evaluating the consequences of varying the length of the estimation period in the Lee-Carter model, and it appears that it may have a great impact on the predictions.

Antoine Delwarde et al. (2006) observed that the human mortality globally declined during the course of the 20th century. These mortality improvements pose a challenge for the pricing and reserving in life insurance. They analyzed the pattern of mortality decline in the G5 countries (France, Germany, Japan, UK and US). They revealed that the prediction of the index of mortality decline obtained for male and female separately. If correctly implemented this may be used as a reference indicator of mortality improvements of a wide geographical and economic area.

Nurul Alam et al. (2007) examined that infant mortality among multiple birth (MB) was more than five times higher than among singletons in Matlab, Bangladesh. Mortality among MB declined by 27% in 1975–2002, considerably less than the 51% mortality decline among singletons in the same period. They also revealed that infant mortality among twins and triplets was particularly high among children who were born to young mothers (<20 years), who were the first live birth, who were born after a short birth interval (<24 months) and whose mothers were unschooled. Mortality of MB was lower in the area with easy access to high-quality maternal and child-care services.

Booth H. and Tickle L. (2008) showed that significant developments in mortality forecasting since 1980 are reviewed under three broad approaches: expectation, extrapolation and explanation. Expectation is not generally a good basis for mortality forecasting, as it is subjective; expert expectations are invariably conservative. Explanation is restricted to certain causes of death with known determinants and most of the developments have been in extrapolative forecasting, and make use of statistical methods rather than models developed primarily for age-specific graduation.

Continuing increases in life expectancy beyond previously-held limits have brought to the fore the critical importance of mortality forecasting. Significant developments in mortality forecasting since 1980, Heather Booth and Leonie Tickle (2008) reported that decomposition by cause of death poses problems associated with the lack of independence among causes and data difficulties. They included comparative evaluations of methods in terms of the accuracy of the point forecast and its uncertainty, encompassing a wide range of mortality situations.

Julian P. Cristia (2009) indicated that a consistent increase in mortality differentials across sex and age groups. The study also found that a substantial increase in life expectancy differentials: the top-to-bottom quintile premium increased around 30 percent for men and almost doubled for women. These results complement recent research to point to almost five decades of increasing differential mortality in the United States.

Andrew J.G. Cairns et al. (2011) revealed that the suitability of six stochastic mortality models for forecasting future mortality and estimating the density of mortality rates at different ages. An important, though unsurprising that a good fit to historical data does not guarantee sensible forecasts. They also discuss the issue of model risk, common to many modeling situations in demography and elsewhere. They find that even for those models satisfying our qualitative criteria, there are significant differences among central forecasts of mortality rates at different ages and among the distributions surrounding those central forecasts.

Abdulraheem I.S et al. (2011) observed that the interaction of genetic and environmental risk factors and socialization are responsible for longevity difference by gender. A sex-specific consideration of risk behavior and quality of life suggests that a healthy lifestyle, relevant information and preventive measures particularly in males must be initiated before puberty if they are to have a positive effect on mortality and morbidity during the course of a person's life.

Rising Mortality and Life Expectancy Differentials by Lifetime Earnings in the United States trends, differentials and key proximate determinants of infant and under-five mortality in Ethiopia based on the data from 2000, 2005 and 2011 Ethiopia Demographic and Health Surveys (EDHS); Assefa Negera et al. (2013) showed that the level and trend analysis indicated that all the five childhood mortality indicators (neonatal, postnatal, infant, child and under-five mortality) have been steadily declining over the last decade in Ethiopia. They examined that the infant mortality rate has declined from 97 deaths per 1000 live births in 2000 to 77 deaths per 1000 live births in 2005, to 59 deaths per 1000 live births in 2011. This is equivalent to 39 per cent reduction from 2000 to 2011. Further they also find that under-five mortality has shown a continuous reduction over time; from 166 deaths per 1000 in 2000 to 123 deaths per 1000 in 2005, and to 88 deaths per 1000 in 2011.

Gaby BINDER (2013) used the data from the Swiss population from 1912 to 2010 and using regressions and iterative algorithms. Gaby showed that the mortality rates are then extrapolated to higher ages and forecasted to the future. For those models which include a time-dependent process, the forecasting is done using a random walk with drift.

Lenny Stoeldraijer et al. (2013) observed that the separate projection of smoking- and non-smoking-related mortality and the projection of the age profile of mortality. The resulting e^0 in 2050 varies by approximately six years. Using the same historical period (1970-2009) and the observed jump-off rates, the findings generated by different methods result in a range of 2.1 years for women and of 1.8 years for men. For e^{65}, the range is 1.4 and 1.9 years, respectively. Finally they concluded that the choice of the explicit assumptions proved to be more important than the choice of the forecasting method.

Maternal mortality ratios at the Okomfo Anokye Teaching Hospital in Kumasi from the year 2000 to 2010 Smart A. Sarpong (2013) showed that the hospitals Maternal Mortality Ratio (MMR) was relatively stable but had a very alarming average quarterly MMR of 967.7 per 100,000 live births which is about twice the National ratio of 451 per 100,000 live births. With AIC (581.41), we conclude that the ARIMA (1,0,2) model is adequate for forecasting quarterly maternal mortality ratios at the hospital.

Trends and social differentials in child mortality in Rwanda 1990–2010; Aimable Musafili et al. (2014) indicated that mortality rates in Rwanda peaked in 1994 at the time of the genocide (NMR 60/1000 live births,95% CI 51 to 65; U5MR 238/1000 live births, 95% CI 226 to 251). Towards the end of the study period (2005–2010) NMR had been reduced to 26/1000 (95% CI 23 to 29) and U5MR to 65/1000 (95% CI 61 to 70), with little or no difference between urban and rural areas, and household wealth groups, while children of women with no education still had significantly higher U5MR. Recent reductions in child mortality in Rwanda have concurred with improved social equity in child survival. Current challenges include the prevention of newborn deaths.

Adarabiyo M.I. (2014) showed that improvement in socio-economic factors and demographic behaviors have direct impact on child mortality. The estimated model is expected to be used for policy experiments by promoting reduction in child mortality. In Nigeria child mortality has taken a central position and a topical issue to population researcher due to its direct link to lack of good healthcare facilities and poverty among its teeming population.

Carmel Woods and Kim Dunstan (2014) observed that adjustment to the forecast death rates was necessary due to an obvious disjuncture between the death rates in the final year of the fitting period and the first year of the forecast, with males having a sudden decrease and females a sudden increase in life expectancy at birth. They also showed that unrealistic forecasts of death numbers which are particularly obvious for the first few years of the forecast. They therefore applied adjustments to the age-specific death rates in 2012 to give a shift in life expectancy at birth of approximately +0.7 years for males and –0.2 years for females.

E.W. Kimani-Murage (2014) observed that there was a downward trend in IMR, CMR and U5MR in both rural and urban areas. The decline was more rapid and statistically significant in rural areas but not in urban areas, because the gap in urban–rural differentials narrowed overtime. There was also a downward trend in childhood mortality in the slums between 2003 and 2010 from 83 to 57 for IMR, 33 to 24 for CMR, and 113 to 79 for U5MR, although the rates remained higher compared to those for rural and non-slum urban areas in Kenya. Narrowing gap between urban and rural areas may beat tribute to the deplorable living conditions in urban slums.

Data from the period 1920–2012, Ondřej Šimpach and Jitka Langhamrová (2014) showed that two different approaches to modeling age-specific mortality rates, and from the obtained models, they prepared a projection of these rates to 2050. They examined the first type of model is an individual random walk with drift. Male and female population will be analysed for the range of 0–100+ years, and each completed age will be analysed as the individual time series with an annual frequency. The second model will be Lee-Carter, which is currently often used. It is based on Principal components method, which can capture and explain the main factors of mortality. Based on this models there will be constructed the forecasts of age-specific death rates for the period from 2013 to 2050.

Ekezie Dan Dan et al. (2014) revealed that the modeling and forecasting malaria mortality rate using SARIMA Models and they forecast monthly malaria mortality rate for the upcoming year 2014. The forecasted results will help Government and medical professionals to see how to maintain steady decrease of malaria mortality in other to combat the predicted rise in mortality rate envisaged in some months.

Karmaker SC et al. (2014) observed that the under-5 child mortality rate (U5MR) is still high in Bangladesh. They examined life table technique as a bi-variate analysis and Cox proportional hazard model was used to analyze the determinants of U5MR mortality. The risk of dying in the first month of life (37 per 1,000) was nearly two and a half times greater than in the subsequent 11 months (15 per 1,000). Deaths in the neonatal period accounted for 57 percent of all under-five deaths. Cox proportional hazard model analysis factors had significant influence on infant and child mortality. The most significant predictors of neonatal, post-neonatal, infant and child mortality were residence, parent’s education, type of toilet facility, wealth status, watching TV, months of breastfeeding, and birth interval.

John Bound et al. (2014) found that no evidence that survival probabilities declined for the bottom quartile of educational attainment. Nor did distributional analyses find any subgroup experienced absolute declines in survival probabilities. They concluded that recent dramatic and highly publicized estimates of worsening mortality rates among non-Hispanic whites who did not graduate from high school are highly sensitive to alternative approaches to asking the fundamental questions implied. However, it does appear that low SES groups are not sharing equally in improving mortality conditions, which raises concerns about the differential impacts of policies that would raise retirement ages uniformly in response to average increases in life expectancy.

Laurent Callot et al. (2014) observed that empirical evidence that this feature of the Lee-Carter model overly restricts the system dynamics and suggest separating the deterministic and stochastic time series components at the benefit of improved fit and forecasting performance. They showed that the classical Lee-Carter model will otherwise over estimate the reduction of mortality for the younger age groups and will under estimate the reduction of mortality for the older age groups.

Marcus C. Christiansen et al. (2014) discussed that uniqueness and fitting techniques and calibrate them to mortality observations of the German Pension Insurance. They observed the difficulties with coarse tabulation of the empirical data are solved by an age-period-duration Lexis diagram. They revealed that the Forecasting is demonstrated for an exemplary model, showing that duration dependence should not be neglected. While we see a clear longevity trend with respect to age, significant fluctuations but no systematic trend is observed for the duration effects.

Shrikant Kuntla (2014) revealed that sex differential in child mortality is still high in India, it declined during 1992 to 2006 (Gini index from 0.36 to 0.24). This decline was primarily led by a change in within inequality of female child mortality (Gini index from 0.18 to 0.14). Among the selected predictors, breastfeeding (40%), birth order (24%), antenatal care (9%), and mother’s age (7%) emerged as critical contributors for the excess female child mortality in India. They suggested that any efforts to do away with gender differences in child survival should focus more on within female child disparity across different population subgroups alongside male-female disparity. Implications are advanced.

Wasana Aberathna et al. (2014) observed that the life expectancy at birth for males was 70.3 years, and 76.8 for females. The probability of a male aged 55 years surviving another 20 years was 0.71, where as it was 0.85 for the females. Generally there was a downward trend in the mortality index for both sexes during the period 1950-2000 in agreement with similar studies elsewhere; but there was an upward trend from 2000-2008, and as a result the 30-year forecasts showed a slightly upward trend in both cases. However, the lower bounds of 95% confidence intervals for the forecasts showed a downward trend indicating a possibility for the actual forecasts to follow a downward trend.

Brajesh and Dr. Chander (2015) observed that the trend of accidental cases showing a increasing pattern. They showed that the forecast value show that 438811 numbers of deaths may be in the year 2015 with 32.5 rate of increment as compared to 2006, if the rate will be constant and there will be no change in patterns of mortality.

Christina Bohk and Roland Rau (2015) suggest that expected years of life are likely to further increase according to both measures, though cohort life expectancy is forecasted to remain less volatile and, on average, 8.3 years above period life expectancy. Moreover, forecast uncertainty appears to increase faster in the period than in the cohort scenario.

Barry P. Bosworth et al. (2015) observed that indexing the retirement age to increases in average life expectancy to stabilize OASDI finances may have unintended distributional consequences, because most mortality gains have been concentrated among workers in the top half of the earnings distribution. They also revealed that the fact that we cannot identify the sources of the increase in differential mortality contributes to uncertainty about the distributional effects of increases in the retirement age in future years.

Christina Bohk and Roland Rau (2015) Examined that the pros and cons of period and cohort mortality has a long history in demography. While period measures analyze mortality of synthetic cohorts, cohort measures analyze mortality of real cohorts. They suggested that expected years of life are likely to further increase according to both measures, though cohort life expectancy is forecasted to remain less volatile and, on average, 8.3 years above period life expectancy. Moreover, forecast uncertainty appears to increase faster in the period than in the cohort scenario.

Damodar Sahu et al. (2015) observed that infant and child mortality over the time period from 1992-2006 among Scheduled Tribes in rural areas India and after controlling for other factors, birth interval, household wealth, and region were found to be significantly associated with infant and child mortality. Hazard of infant mortality was highest among births to mothers aged 30 years or more (HR=1.3, 95% CI=1.1-1.7) as compared with births to the mother's aged 20-29 years. They examined that hazard of under-five mortality was 42 per cent (95% CI=1.3-1.6) higher among four or more birth order compared with the first birth order. The risk of infant dying was higher among male children (HR = 1.2, 95% CI=1.1-1.4) than among female children while male children were at 30 per cent (HR=0.7, 95% CI=0.6-0.7) less hazard of child mortality than female children.

Mehran Rostami et al. (2015) showed that the time series modeling of the U5MR in Iran, and reveals that improvement of under-five mortality data collection in health facilities and their corresponding systems is a major challenge to fully achieving the MDG-4 in Iran. Studies similar to the present work can enhance the understanding of the invisible patterns in U5MR, monitor progress towards the MDG-4, and predict the impact of future variations on the U5MR.

George Odwe et al. (2015) examined that birth ratios for children born in the 5th calendar year preceding each survey and note the possible effect on under-five mortality estimates in Kenya. They showed that under-five mortality estimates in 2008/09 survey are smaller than that of a similar period in 2003 survey by 17 percent. They also suggested that the remarkable decline in the under five mortality rate recorded in 2008/09 is a function of both overestimation of mortality rate in 2003 survey and underestimation in 2008/09 survey.

Determinants of under-five mortality in Abim district, Karamoja region, Uganda, Lukman Abiodun Nafiu (2016) showed that under-five mortality was significantly high at 95% confidence level among mothers who had first birth below 20 years of age, maternal age at birth of less than 20 years, previous birth interval of less than 2 years, and households that use borehole water. Other factors like maternal education, maternal/paternal occupation and latrine/toilet use were insignificantly related to under-five mortality. They recommended that campaign against early marriage and teenage pregnancy be explicitly done, mothers be encouraged to exclusively breastfeed for at least 2 years, mothers be sensitized about the advantages of family planning, personal hygiene and good sanitation be continuously practiced if under-five mortality in the Abim District is to be controlled.

Underlying cause of death data from death notifications for 1997–2012 obtained from Statistics South Africa, Victoria Pillay-van Wyk et al. (2016) observed that the reversal of HIV/AIDS, non-communicable disease, and injury mortality trends in South Africa during the study period. Mortality differentials showed that the importance of social determinants, raise concerns about the quality of health services, and provide relevant information to policy makers for addressing inequalities. Differences between GBD estimates for South Africa and this study emphasize the need for more careful calibration of global models with local data.

Colin O'Hare and Youwei Li (2016) observed that time series models by considering the fitting quality and in particular, testing the residuals of those models for normality properties. They consider 30 countries and find that almost exclusively the residuals do not demonstrate normality. Further, in Hurst tests of the residuals find evidence that structure remains that is not captured by the models.

The mortality data of Peninsular Malaysia for years 1980 to 2009, Wan Zakiyatussariroh Wan Husin et al. (2016) showed that the most efficient forecasting model was based on lowest values of root mean square error (RMSE) and mean absolute percentage error (MAPE). The results revealed that the proposed LC-DFA model performs the best. They conclude that the LC model in state space framework using EM algorithm is able to provide better estimates compared to the classical LC model. Further work in evaluating the performance of the LC-DFA model in forecasting mortality using life expectancy and other mortality indicators is currently under study.

2.3 Summary

Reduction of mortality usually causes a longer human life span, which is a prime issue in the present world. Endeavour in human life span is still preoccupied within human history (Manton and Singer, 1994) and measurement in human life span is regarded as one of the most important topics in demography (Bongaarts and Feeney, 2002). Generally, human life span is measured by life expectancy at the population level and the maximum life span at the individual level (Manton et al., 1999; Wilmoth, 2000, 2001; Hayflick, 2002) but not satisfactorily. This is because infants and premature deaths are included in life expectancy. The measurement in human life span is still a major concern in the field of biology, demography and even fields like public health and actuarial science. All these discussions have tempted to carry out this study.

Chapter III

Data Sources and Methodology

3.1 Introduction

The first and foremost condition of a good research is to collect reliable data and choose appropriate methodological technique. Without choosing reliable data as well as proper methodology, no researcher can achieve the target level of research outcome. This chapter has discussed about the description of the study area of this research, data sources and analytical techniques, conceptual definition of some important topics, quality of data and limitations of data.

3.2 Description of study area

Bangladesh is the most densely populated country in the world except some islands and city based countries (1015 persons per square kilometer according to census 2011), and is ranked eighth in terms of number of population in the world. The name 'Bangladesh' literally means the land of Bangla, the language of the inhabitants of the country. It is still a poorly urbanized country in South Asia. According to the Census 2011, the urban population is 25.9 percent only. It was a part of British Indian provinces of Bengal and Assam. The borders of present-day Bangladesh were established in course of the partition of the then Bengal and the Indian sub-continent in 1947 as it became the eastern part of the newly-formed state of Pakistan. It was physically separated from the western part by 1,600 km (994 miles) across India. Thereafter, political, cultural and linguistic discrimination as well as economic deprivation led to popular discontent and agitations against the rules in the then West Pakistan. After a long political movement with the victory at the Liberation war from 26 March to December 16, 1971 it became an independent and sovereign state on December 16, 1971 from the colonial rule of Pakistan after a tremendous sacrifice. Bangladesh is a low-lying and riparian country with a total area of 147, 570 square kilometers (56,977 square miles). It is located between 23.8511° north latitude and 89.9250° east longitude. Apart from a short land and water frontier (about 120 miles or 193 kilometers) with Myanmar (formerly named Burma) in the south-eastern region it is mostly surrounded by India and in the southern part it has a highly irregular deltaic coastline of about 580 kilometers, fissured by many rivers and streams flowing into the Bay of Bengal. The territorial waters of Bangladesh extend 12 nautical miles and the exclusive economic zone of the country is 200 nautical miles (370 kilometers).

The main administrative units of Bangladesh are divided into eight divisions. These are Barisal, Chittagong, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur and Sylhet. There are 64 districts (zilas) under these divisions and again the districts have been divided into 488upazials. The country can be characterized by two distinctive features: a broad deltaic alluvial plain subject to frequent flooding and a small hilly region only in the Chittagong district and Chittagong hill tracts in the far south-east and the Sylhet division in the north-east according to physiographical elements (Wikipedia, 2016). Nearly 80 % of the land is made up of fertile alluvial lowland called the Bangladesh Plain. This plain is part of the larger Plain of Bengal and it lies between the Indian foothills of the Himalayan Mountains on the north and the Bay of Bengal on the south, which is sometimes called the Lower Gangetic Plain (Wikipedia, 2016). The characteristics of the plain land from north to south have sometimes been summed up by geographers as “old mud, new mud and marsh”. “*Although altitudes up to 105 meters above sea level occur in the northern part of the plain, most elevations are less than 10 meters above sea level; elevations decrease in the coastal south, where the ground is generally at sea level. With such low elevations and numerous rivers, water – and concomitant flooding – is a predominant physical feature. About 10,000 square kilometers of the total area of Bangladesh is covered with water, and larger areas are routinely flooded during the monsoon season*” (Wikipedia, 2016).

Despite, there are six different seasons in the whole year cycle in Bangladesh such as summer, rainy, autumn, late autumn, winter and spring, practically three seasons are distinguishable as summer, rainy and winter. In spite of trifling regional climatic differences, the wide seasonal variations in rainfall, high temperatures and high humidity in the country is due to Tropical monsoon climate. Around 80 % of Bangladesh's rain falls during the monsoon season. “*The relatively dry region is Rajshahi in the west, where the annual rainfall is about 1600 mm, whereas most parts*

of the country receive at least 2300 mm of rainfall per year. Because of its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest, the region of Sylhet in northeastern Bangladesh receives the greatest average precipitation" (Wikipedia, 2016). "*In general, maximum summer temperatures range between 38 and 41 °C. April is the hottest month in most parts of the country. January is the coolest (but still hot) month, when the average temperature for most of the country is 16-20 °C during the day*
*around 10°C at night" (*Wikipedia, 2016). For these factors the climate of the country is very repulsive with average daily low humidity range 55 to 81% in March and high range 94 to 100% in July (Wikipedia, 2016). Due to high humidity and high temperatures this scratchy hot humid weather continues until October even when the sunny sky returns. The atmosphere is unpleasantly sticky causing heavy rain and flooding for plenty of standing water and excessive moisture. Natural disasters such as floods, tropical cyclones, tornadoes, and tidal bores seriously affect the country, particularly the coastal regions, almost every year (Wikipedia, 2016).

There is amazing ethnic and cultural homogeneity of population in Bangladesh. More than 98% people have Bengali as their mother tongue (BBS, 2012). The people of Bangladesh are very proud for their rich cultural and linguistic heritage as their independent nation is to some extent the consequence of a great movement to uphold and protect their language and culture. In terms of population Bangladesh is the third largest Islamic country in the world. The majority of its population i.e. 89.7% is Muslims and about 9.2% (Census, 2011) are Hindus, constituting a substantial minority. There are also a small number of Buddhists, Christians, and animists. The economy of Bangladesh is mainly Agriculture based. About two-thirds of the gross national product was earned from agriculture in early independence and it absorbed about three-fourths of the total labour force (Chen and Chowdhury, 1975). Afterward, the scenario changes over time and the service including construction has become outstanding at present and only 30% of the labour force is absorbed by agricultural sectors (BBS, 2012).

There are two distinctive features, such as, a broad deltaic plain expose to repeated flooding and a small hilly area crossed by swiftly flowing rivers, the majority of the areas of Bangladesh lie within the broad delta shaped by the Ganges and Brahmaputra rivers according to physiographical division of Bangladesh. Its lands are extremely flat, low-lying, and subject to annual flooding. As a result, alluvial soils in the Bangladesh Plain are usually fertile and are augmented with heavy sediment passed downstream during the rainy season by floodwaters. About 67% of its non-urban land is arable. Permanent crops cover only 2%, meadows cover 4%, and forests and woodland cover about 16%. With this characteristic, every year Bangladesh has to face major difficulty by natural hazards, such as, droughts, cyclones and flooding because of the low lying country. Beside this environmental background, more than 70% people of Bangladesh live in rural areas and their main source of income is agriculture. In contrast, many people are landless and the number is increasing day by day due to high growth rate of the population.

3.3 Data sources and analytical techniques

This research would like to investigate the pattern of mortality trends and differentials. Depending on the trends of mortality, present study again intents to future mortality forecast and future population projection using forecasted mortality to examine the future ageing population situation in Bangladesh. Though projection never gives an exact picture for future but obviously it gives an idea regarding future. Hope this study would be helpful to construct a future policy and giving the recommendation on overall mortality and population features which would be helpful for the future socio-economic development and policy makers of Bangladesh. So it needs data for a long period of time. For this reasoning, Secondary time series data for the period 1981 to 2011 are used to carry out the study which is available in the various census reports of Bangladesh Bureau of Statistics (BBS), Sample Vital Registration System (SVRS), Bangladesh Economic Review and Bangladesh Bank. Three analytical steps have included in this research.

Firstly, the trends and differentials of mortality reduction are investigated using graphical representation and decomposition analysis;

Secondly, sensitivity analysis of life expectancy at birth (e^0) will be carried out to examine the change of age-specific mortality;

Finally, age-specific mortality projection and age-sex population projection will be performed to see the trend of future population age distribution and ageing population situation.

Therefore, we want to use Lee-Carter mortality model (Lee and Carter, 1992) for mortality projection and Cohort Component method (Pollard et al., 1990) for population projection by age and sex.

Lee-Carter mortality model (1992) for mortality projection:

$$Ln[m(x,t)] = a_x + b_x k_t + \epsilon_{x,t} ,$$

$$\text{or, } m(x,t) = Exp(a_x + b_x k_t + \epsilon_{x,t})$$

Where, a_x and b_x are age-specific constants and k_t is time varying index (k is an index of the level of mortality)

[e^{a_x} is the general shape across age of the mortality schedule. The b_x profile tells us which rates decline rapidly and which rates decline slowly in response to changes in k] and

Cohort Component method (Pollard et al., 1990) for population projection by age and sex.

$$P_t = P_{t-1} + B_{t-1,t} - D_{t-1,t} + M_{t-1,t}$$

Where, P_t = population at time t;

P_{t-1} = population at time t-1;

$B_{t-1,t}$ = births, in the interval from time t-1 to time t;

$D_{t-1,t}$ = deaths, in the interval from time t-1 to time t; and

$M_{t-1,t}$ = net migration, in the interval from time t-1 to time t.

Data analysis will be performed by using software EViews 4.1, IBM SPSS Statistics 20 and Microsoft Excel.

3.4 Conceptual definition of used different terms

3.4.1 Age-specific mortality rate

A mortality rate limited to a particular age group, in which the numerator is the number of deaths in that age group, and the denominator is the number of persons in that age group in the population is called age-specific mortality rate. Age-specific mortality rate is typically expressed in units of death per 1000 individuals per year. Most age groupings for age-specific mortality rates (especially when calculating age-specific rates for the entire population) are 5 or 10-year groups (e.g., 0-4, 5-9, 10-14, 15-19, etc.). In order to determine reliability and the chance variation of an age specific mortality rate (especially those based on smaller numbers of events) as well as to determine significant changes over time or significant differences when comparing age-specific rates (e.g. a county rate to the state rate), it is highly recommended that a standard error or confidence intervals (usually at 95%) be calculated and shown for these rates. An age-specific death rate has four components: (i) A specified measurement period, (ii) The numerator, the number of deaths among a specified age group that occurred in a specified geographic area during a given period of time, (iii) The denominator, the total number of people in the population at risk in the same geographic area for the same period of time ("person-years at risk"). The population estimate used is typically the mid-year (July 1) population count estimate for the same year(s) and age(s) included in the numerator and (iv) A constant. The result of the fraction is usually multiplied by some factor of 10 (such as 1,000), so that the rate may be expressed as a whole number.

3.4.2 Birth rate

The birth rate is the total number of live births per 1,000 of a population in a year. The rate of births in a population is calculated in several ways: live births from a universal registration system for births, deaths, and marriages; population counts from a census and estimation through specialized demographic techniques. The birth rate along with mortality and migration rate are used to calculate population growth. Typically, high birth rates are associated with health problems, low life expectancy, low living standards, low social status for women and low educational levels. Demographic transition theory postulates that as a country undergoes economic development and social change its population growth declines, with birth rates serving as an indicator.

3.4.3 Infant and child mortality rate

The number of deaths of children less than 1 year old per 1,000 live births is known as infant mortality rate and the number of deaths of children less than 5 years old per 1000 live births is known as child mortality rate. Infant and child mortality rate affects significantly to the overall mortality. Reduction of infant and child mortality rate is the most important indicator of socio-economic development of a country. Empowering women, removing financial and social barriers to accessing basic services, developing innovations that make the supply of critical services more available to the poor and increasing local accountability of health systems are policy interventions that have allowed health systems to improve equity and reduce infant mortality.

3.4.4 Dependency ratio

Dependency ratio categorizes into three types: total dependency ratio (TDR), young dependency ratio (YDR) and old dependency ratio (ODR). The total dependency ratio (TDR) is the ratio of the total number of dependents, aged 0-14 and over the age of 60 (or 65), to the total population, aged 15-59 (or 15-64). In developing country the retirement age is 60 (60 and over treated as old age) and in developed countries the retirement age is 65 (65 and over treated as old age). Therefore, population of 0-14 age group and 60 and over (or 65 and over) age group are the dependents. Usually it is measured as a percentage. This indicator gives insight into the amount of people of nonworking age compared to the number of those of working age. A high ratio means those of working age, and the overall economy face a greater burden in supporting the aging population.

The young dependency ratio (YDR) is the ratio of population of 0-14 to the population of 15-59 (or 15-64). On the other hand, the elderly dependency ratio or old dependency ratio (ODR) is the ratio of the population of 60 and over (or 65 and over) to the population of 15-59 (or 15-64).

The dependency ratio focuses on separating those of working age, deemed between the ages of 15 and 64 years of age, from those of nonworking age. This also provides an accounting of those who have the potential to earn their own income and who are most likely to not earn their own income. Prior to age 15, various employment regulations make it unlikely these individuals work for any personal income. Once age 64 is reached, the person is generally considered retirement age and is not necessarily expected to be part of the workforce. It is the lack of income potential that generally qualifies those under 15 and over 64 as dependent as it is often necessary for them to receive outside support to meet their needs.

The dependency ratio focuses on separating those of working age, deemed between the ages of 15 and 59 (or 15-64) years of age, from those of nonworking age. This also provides an accounting of those who have the potential to earn their own income and who are most likely to not earn their own income. Prior to age 15, various employment regulations make it unlikely these individuals work for any personal income. Once age 59 (or 64) is reached, the person is generally considered retirement age and is not necessarily expected to be part of the workforce. It is the lack of income potential that generally qualifies those under 15 and over 59 (or 64) as dependent as it is often necessary for them to receive outside support to meet their needs. Dependency ratios are generally reviewed to compare the percentage of the total population, classified as working age that will support the rest of the nonworking age population. This provides an overview for economists to track shifts in the population. As the percentage of nonworking citizens rises, those who are working are likely subject to increased taxes to compensate for the larger dependent population.

3.4.5 Population ageing

Decreasing fertility, increasing longevity, that is, life expectancy at birth and the progression of large-sized cohorts to the older ages are causing elder shares of population to rise. This is referred to as population ageing. The phenomenon of population ageing, which is unprecedented in human history, brings with it sweeping changes in population needs and capacities.

Population ageing has many societal and policy implications. The demographic shift threatens to lower labor force participation and savings rates, increase health expenditures, and strain pension and health schemes. The rising prevalence of non-communicable diseases would create burdens on the elderly. Living arrangements for the elderly and many are concerned that reduced labor force participation and savings and strains on pension and healthcare systems may be the cause of slow economic growth.

3.4.6 Demographic dividend

A demographic dividend is the freeing up of resources for a country's economic development and the future prosperity of its populace as it switches from an agrarian to an industrial economy. In the initial stages of this transition, fertility rates fall, leading to a labor force that is temporarily growing faster than the population dependent on it. All else being equal, per capita income grows more rapidly during this time too. This dividend period generally lasts for a long time - typically five decades or more. Eventually, however, the reduced birth rate reduces the labor force growth. Meanwhile, improvements in medicine and better health practices leads to an ever-expanding elderly population, sapping additional income and putting an end to the demographic dividend.

3.4.7 Socio-economic status

Socioeconomic status is an economic and sociological combined total measure of a person's work experience and of an individual's or family's economic and social position in relation to others, based on income, education and occupation. When analyzing a family's socioeconomic status, the household income, earners' education, and occupation are examined, as well as combined income, versus with an individual, when their own attributes are assessed.

Socioeconomic status is typically broken into three categories (high, middle, and low) to describe the three areas a family or an individual may fall into. When placing a family or individual into one of these categories, any or all of the three variables (income, education, and occupation) can be assessed. Education in higher socio-economic families is typically stressed as much more important, both within the household as well as the local community. In poorer areas, where food and safety are priority, education can take a backseat.

3.4.8 Socio-cultural background

The socio-cultural background seeks to understand why people act as they do based on the influences of their social and cultural group memberships. According to the concept, people are largely influenced by authority figures in their particular societies. The socio-cultural background theory provides researchers with a basis from which they can ask and explain how a person's membership in a certain group affects self-esteem, for example. Other research questions might include how a person's behavior is affected by where the person lives, or why a person of a particular religious group acts in a certain way.

3.5 Quality of data

Data for mortality forecasting come from the population and deaths. The quality of data as well as procedures for data collection, quality control, the formula for population estimates, coding, validation and consistency over time are important concerns. For a significant analysis of mortality trends and differentials and forecasting of mortality, it is needed to ample assessment of reliability of mortality and population data. In a developing country like Bangladesh, the data collected from sample survey, registration and enumeration are affected by various errors which lessen the quality of data. So, to find out the accuracy of demographic data and the degree of error is necessary to get a clear idea about population and mortality.

"A more systematic way of assessing the accuracy of the census information was initiated in 1961 through the post-enumeration checks (PEC) and the internal analysis of age data. The 1961 census of Pakistan marked the first attempt of the government to check the completeness of enumeration and assess the quality of the data collected through the PEC of quality. The check was made within a week after the census count. The differences in rural areas are not as great as in the urban areas. Where the PEC results exceeded the census count, the difference was only 1.2% for the urban areas and 0.2% in the rural areas for males and 1.0% and 0.8% respectively for females. While the census count exceeded the PEC the difference was

2.8% in both urban and rural areas for males, but 2.7% for urban and 0.9% for rural females" (Islam, 1996).

In 1974 the PEC was done after one month of the completion of census aiming to evaluate the coverage error due to omission or duplication of households and to determine the content error with respect to age and marital status as recorded in the individual census trips. In this census the under-enumeration was 6.5%. However, to get a demographically normal population with highly accurate system of age and sex reporting it requires for the purpose of evaluation, 2.6% for males and 2.4% for females, a sex ratio score of 1.5% and a joint score of 9.5%.

The PEC was performed after two weeks of field enumeration to verify the level of under coverage error of 1981 census. It was carried out by independent expert members of BBS. They found under coverage error approximately 3.0% which is much lower than before.

In 1991 census, PEC was conducted after three weeks of the completion of field enumeration. The BBS involved their expert members in PEC who were not involved in the main census. The result of PEC was shown as: net under count coverage error around 4.6%, net under count was endorsed to 6.6% for missed rate and 2.0% for over count rate, the differences in coverage errors in rural areas about 4.0%, net under count in municipal areas about 8.6% and other urban areas about 4.99%.

To check the consistency of the 2001 census data, the PEC was carried out after one month of the completion of enumeration. The PEC found net under coverage rate around 5.0% at national level which was attributed to 4.5% for rural areas, 5.8% for municipal areas, 3.73% for other urban areas and 7.7% for metropolitan areas.

In 2011 census, the PEC was conducted during April 10-14, 2011 which was less than one month after the census. For the first time in census history of Bangladesh, the PEC was conducted by an independent organization, Bangladesh Institute of Development Studies (BIDS). The PEC indicated that net coverage error was 3.97% in Bangladesh. On the other hand, it was 3.8% in rural areas, 5.26% in municipal areas, 4% in other urban areas and 3.86% in metropolitan areas.

3.6 Limitations of the data

Research always has some limitations. In developed countries, the quality of data is much improved than in developing countries. It is difficult to get reliable data in any developing country like Bangladesh, the most densely populated country in the world. Specially to get consistent population and mortality data are more complicated. But to carry out this research on mortality trends, differentials and forecasting of mortality in Bangladesh, reliable population and mortality data is needed. It is noteworthy that this study would like to forecast mortality to know the future course of life expectancy at birth and make a population projection to examine the age distribution of population and ageing situation in Bangladesh. To do so it is necessary to deal with the whole nationwide mortality and population data. Thus, it is very difficult job to use primary data for this research as because to collect nationwide primary data on mortality and population is huge time consuming and also expensive. Hence, it is about to impossible to collect primary data for this study within limited time frame and inadequate fund.

Therefore, this study is performed absolutely by secondary data provided by different census reports, Sample Vital Registration System (SVRS) of Bangladesh Bureau of Statistics (BBS) and also Bangladesh Labour Force Survey Reports, Bangladesh Economic Review etc.

Chapter IV

Socio-economic Development and Demographic Change in Bangladesh

Abstract

In any developing country the main challenge of socio-economic development is hasty population growth. For this hasty population growth a huge capital is to spend in non-productive sectors of the population (such as, children) and suffers from undercapitalization of the economy, underemployment, low wages and pale market demand. Though a least urbanized and agriculture based developing country, the economy of Bangladesh has recently been achieving extensive social, economic and policy transformations and indeed on demographic change its impact is very high. Still natural disasters such as, seasonal inundation, cyclones, draughts and so on frequently distress its lot every year. Using data from various reports available by Bangladesh Bureau of Statistics (BBS) this chapter has intended to examine the demographic change and socio-economic development in Bangladesh for its continuously increasing population. It has been seen by analyzing the trend that the birth rate turned down at a modest pace whereas the death rate turned down to a large extent though infant mortality is still high compared with developed world and also some of the developing countries (e.g. China and SriLanka). A considerable disparity of death and birth rates has also come out between rural and urban areas. Beside this an enormous rural-urban difference in fertility rate appears and the high rural fertility rate is the main hindrance to achieve replacement fertility rate in national level. This study recommends that planned urbanization, improvement of female education, increasing trend of female age at first marriage and reduction in infant mortality rate may be the major factors for further reduction in fertility rate towards the replacement level in Bangladesh by investigating the different fertility affecting factors. At last, this study exhibits that the difference in population size, growth and density according to geographical and administrative divisions specify that it is essential to spread out of all indispensable facilities up to grassroots level in the whole country to attain the replacement level of fertility with controlling the population growth in Bangladesh very soon.

4.1 Introduction

To conduct the present study, it is very important to know the present trend of socio-economic development and demographic situation in Bangladesh. Bangladesh is a South Asian agrarian country which is the most densely populated country in the world except some island and city based countries. It is the eighth most populous country in the world. Its population is about 160 million in 2015 (Wikipedia, 2016). The population growth rate was among the highest in the world in the 1960's and 1970's. Afterwards, it declined remarkably and according to 2011 census it is 1.37% from 2.61% in 1974 (BBS, 2012). Infant mortality is decreased sharply which causes overall mortality decline to a great extent. The country's economy grows rapidly and becomes one of the most growing economies in the world. From agro-based economy, Bangladesh turns to industry based and service oriented economy. Two thirds of the labour forces were engaged in agricultural sectors in 1970's but at present it decreased to 30% in 2015 (Wikipedia, 2016). GDP per capita is increased significantly during the last two decades. The median age as well as mean age at first marriage is also increased, this is obviously a sign of socio-economic development. This chapter attempts to observe the current socio-economic development and demographic change in Bangladesh.

4.2 Socio-economic development

4.2.1 Trends and percentage change of literacy rate

There is a proverb, "education is the backbone of a nation". Among the socio-economic differentials in influencing the demographic parameters of a population, educational attainment of the individuals is the most important one. It influences individual‘s knowledge, attitudes and codes of decent behavior that lead moral choices about our association with others. Education enhances the ability of an individual to achieve desired demographic and health goals. To develop the socio-economic and socio-cultural status of a nation education plays a major role. To remove the social and economic harms education can build up the latent awareness among the people. In contrast, population is a valuable asset of a country. So, as a fundamental element in socio-economic development, it is very important to study the educational level of the people. Since independence there are five censuses taken place in Bangladesh in 1974, 1981, 1991, 2001 and 2011 respectively. The definition of literacy rate changes in different censuses. In the census of 1974, literacy was defined as the ability to read and write in any language. This definition was in compliance with the UNESCO one accepted throughout the world. After that in the 1981 census the definition of literacy covered only persons aged 5 and above and incorporated those who could write a letter in any language. In 1991 census the definition again changed and the ability to write a letter in any language treated as literacy but covered persons aged 7 and above. The cause of the change in definition of the literacy has been reflected in the literacy rates of different census years. Table 4.1a shows that the literacy rate amid people of the 7+ years above age group increased from 26.8% in 1974 to 32.4% in 1991, 45.3% in 2001 and 55.8% in the year 2011. The literacy rate of male was higher than that of female in all census periods. The literacy rate of female however, rose significantly in the 2001 census. Female literacy rate was 16.4% in 1974 and it increased to 25.5% in year 1991, 40.8% in year 2001 and 53.2% in the year 2011.

In contrast, male literacy rate was 36.6% in 1974, 38.9% in 1991, 49.6% in 2001 and 58.4% in the year 2011. The literacy rates of rural and urban areas are shown in table 4.1b and 4.1c respectively. Literacy rates in the urban areas are much higher than in the rural areas in all census periods but variation in literacy rate between males and females still exists in both urban and rural areas. Nevertheless, in recent censuses the variation in literacy rate between males and females is becoming narrower. Table 4.1a also shows the adult literacy rate (15+ year's age group) by sex in all five censuses. The adult literacy rate increased from 25.8% in 1974 to 35.3% in 1991, 47.5% in 2001 and 58.8% in the year 2011 for all peoples. The variation in adult literacy rate for males and females is more or less same as 7+ year's age group literacy rate. It is apparent that urban and rural variation in adult literacy rate is also same as that of 7+ year's age group (Table 4.1b and Table 4.1c).

Table 4.1a: Percentage change for literacy rate of population for 7+ years and 15+ years (Adult) by sex (National) in Bangladesh, 1974-2011

Year	**7+ years**					
	Both Sex		**Male**		**Female**	
	Percent	**Change (%)**	**Percent**	**Change (%)**	**Percent**	**Change (%)**
1974	26.8		36.6		16.4	
1981	26.0	-2.99	33.8	-7.65	17.5	6.71
1991	32.4	24.62	38.9	17.46	25.5	45.71
2001	45.3	39.81	49.6	27.51	40.8	60
2011	55.8	23.18	58.4	17.74	53.2	30.39
15+ years						
1974	25.8		37.2		13.2	
1981	29.2	13.18	39.7	6.72	18.0	36.36
1991	35.3	20.89	44.3	11.59	25.8	43.33
2001	47.5	34.56	53.9	21.67	40.8	58.14
2011	58.8	23.79	62.5	15.96	55.1	35.05

Source: BBS, 1991, 2003, 2012

Table 4.1b: Percentage change for literacy rate of population for 7+ years and 15+ years (Adult) by sex (**Rural**) in Bangladesh, 1974-2011

Year	7+ years					
	Both Sex		Male		Female	
	Percent	Change (%)	Percent	Change (%)	Percent	Change (%)
1974	22.3*		30.8*		13.2*	
1981	20.6*	-7.62	27.3*	-11.36	13.7*	3.79
1991	21.2	2.91	25.8	-5.5	16.3	18.98
2001	40.6	91.51	44.5	72.48	36.7	125.15
2011	49.6	22.17	52.2	17.3	46.9	27.79
15+ years						
1974	23.4		34.6		12.1	
1981	25.4	8.55	35.4	2.31	15.3	26.45
1991	30.1	18.5	38.7	9.32	21.5	40.52
2001	41.9	39.2	47.9	23.77	35.9	66.98
2011	52.0	24.11	55.8	16.49	48.2	34.26

Source: BBS, 1991, 2003, 2012; * literacy rate of population 5+ years

Table 4.1c: Percentage change for literacy rate of population for 7+ years and 15+ years (Adult) by sex (**Urban**) in Bangladesh, 1974-2011

Year	7+ years					
	Both Sex		Male		Female	
	Percent	Change (%)	Percent	Change (%)	Percent	Change (%)
1974	44.0*		52.0*		33.3*	
1981	40.7*	-7.5	48.6*	-6.54	30.3*	-9.01
1991	40.3	-.98	46.2	-4.94	33.3	9.9
2001	60.3	49.63	64.9	40.48	54.8	64.57
2011	66.9	10.95	69.5	7.09	64.3	17.34
15+ years						
1974	48.1		62.5		33.1	
1981	48.1	0	58.0	-7.2	34.1	3.02
1991	54.4	13.1	62.6	7.93	44.0	29.03
2001	64.3	18.2	70.3	12.3	57.1	29.77
2011	70.6	9.8	74.2	5.55	67.0	17.34

Source: BBS, 1991, 2003, 2012; * literacy rate of population 5+ years

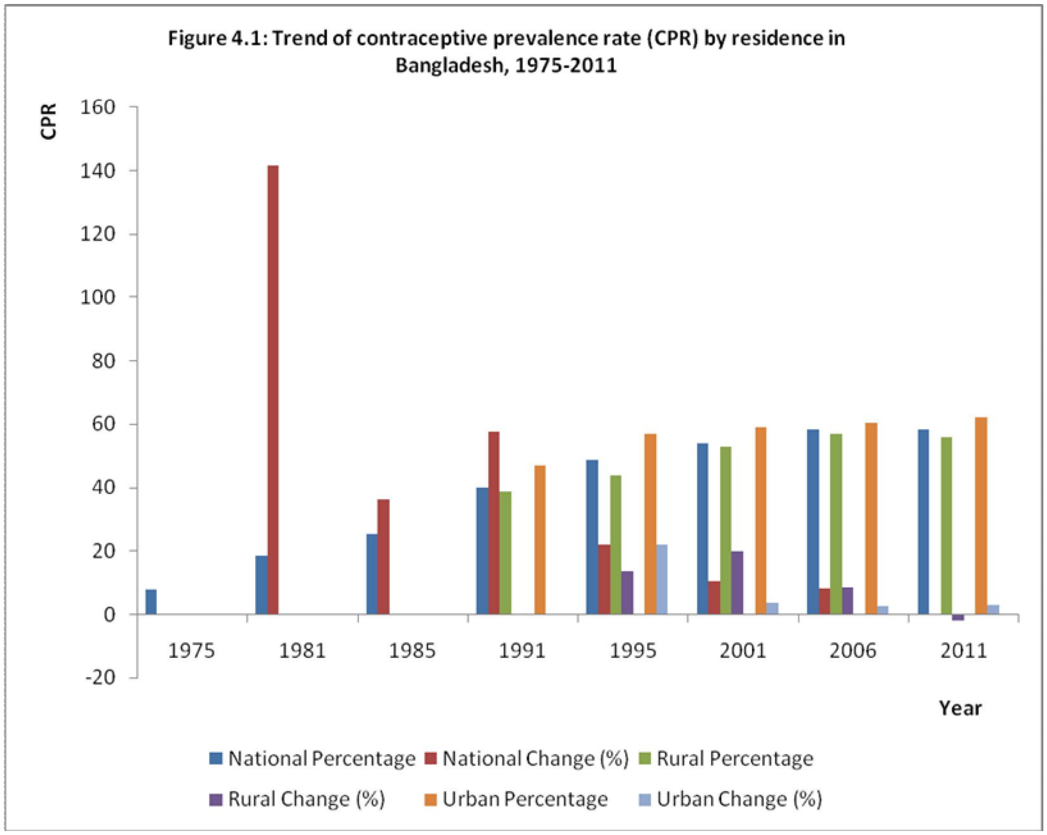
4.2.2 Trends and percentage change of contraceptive prevalence rate (CPR)

There has been a gradual increase in the use of contraceptive methods in Bangladesh over the last 4 decades. Merely successful family planning programme played a significant task on considerable fertility decline in Bangladesh without reasonable socio-economic development (Islam et al., 2003), and then it has been considered as an example of an effective programme in the World (Koenig and others, 1987; Duza, 1990; Islam and others, 1998; Khuda and others, 2000). Contemporary use of contraception is defined as the percent of presently married women who report that they are using a family planning at reproductive age. The ensuing value is called contraceptive prevalence rate (CPR). The trend and rural-urban differentials of use of CPR has been presented in Table 4.2. It is evident that CPR is about 6 percent points more in the urban areas as compared to the rural areas throughout full time trends. Table 4.2 marked that CPR increased more than two folds in 1981, five folds in 1991, more than seven folds in 2006. Percentage of CPR remains alike in 2011 as in 2006. In rural areas highest 20.05% increment occurs during the period 1995-2001 and in urban areas highest 22% increment occurs during the period 1991-1995. In 2011 CPR changes negatively compared to 2006 in rural areas. That means in rural areas CPR decreases in 2011 from 2006. The variation in CPR between rural and urban areas is significant (Table 4.2). Figure 4.1 shows the trends and rural-urban differentials in CPR over the time period 1975-2011.

Table 4.2: Trend of contraceptive prevalence rate (CPR) by residence in Bangladesh, 1975-2011

Year	National		Rural		Urban	
	Percentage	Change (%)	Percentage	Change (%)	Percentage	Change (%)
1975	7.7		NA		NA	
1981	18.6	141.6	NA		NA	
1985	25.3	36.02	NA		NA	
1991	39.9	57.71	38.6		46.8	
1995	48.7	22.06	43.9	13.73	57.1	22
2001	53.9	10.68	52.7	20.05	59.1	3.5
2006	58.3	8.16	57.1	8.35	60.5	2.37
2011	58.3	0	56.0	-1.93	62.2	2.81

Source: BBS, 2003, 2012



4.2.3 Population trends and differentials according to sex and broad age group

According to the population census of 2011, the total population of Bangladesh was 150.6 million and also it was 130.5 million in 2001, 111.5 million in 1991 and 89.9 million in 1981 population censuses respectively (BBS, 2012). The allocation of population and its members according to broad age group is an important aspect for the planners and policy-makers to formulate the efficient socio-economic strategy for the population of different broad age groups for any nation. As a result, it is very important to know the pattern of the allocation of population in different broad age groups by sex categories (male and female). The population is duly separated into three broad age groups, such as, 0-14 age group as young-age, 15-59 age group as working-age and 60 and above age group as old-age. Table 4.3 provides the broad age group population in Bangladesh according to sex and residence (rural and urban). It is clearly seen that the percentage of young-age population decreased from 46.6%

to 31.91% throughout the period 1981-2011. In contrast, the percentage of old-age population increased from 5.68% in 1981 to 6.95% in 2011. However the working-age population has also started to increase. It becomes 61.14% in 2011 from 47.70% in 1981. It is also evident that the proportion of old age population for female is lower than male and the proportion of female in working age is higher than male during the whole period 1981-2011. While the proportion of population in young age is more or less same for both males and females. The same picture is apparent for working age and old age population in rural and urban areas as well. But for the young age population, the proportion of male is higher than female in rural areas whereas the proportion of female is higher than male in urban areas.

Table 4.3: Population trends and differentials of broad age group according to sex and residence in Bangladesh, 1981-2011(in thousands)

Year	Sex	Age Group		
		0-14	15-59	60+
National				
1981	Both	41914 (46.62)	42886 (47.70)	5112 (5.68)
	Male	21523 (46.49)	21962 (47.44)	2810 (6.07)
	Female	20391 (46.75)	20924 (47.97)	2302 (5.28)
1986	Both	47085 (46.49)	48810 (48.2)	5376 (5.31)
	Male	24177 (46.39)	24896 (47.77)	3040 (5.83)
	Female	22908 (46.6)	23914 (48.65)	2336 (4.75)
1991	Both	47997 (45.15)	52615 (49.49)	5703 (5.36)
	Male	24804 (45.32)	26716 (48.82)	3208 (5.86)
	Female	23193 (44.96)	25899 (50.20)	2495 (4.84)
1996	Both	51717 (42.64)	62711 (51.7)	6861 (5.66)
	Male	26866 (43.05)	31695 (50.79)	3843 (6.16)
	Female	24851 (42.2)	31016 (52.67)	3018 (5.13)
2001	Both	48571 (39.06)	68057 (54.73)	7729 (6.21)
	Male	25466(39.73)	34359 (53.61)	4268 (6.66)
	Female	23105 (38.34)	33698 (55.92)	3461 (5.74)
2006	Both	51304 (36.37)	80324 (56.94)	9438 (6.69)
	Male	26826 (36.98)	40536 (55.88)	5184(7.14)
	Female	24478 (35.72)	39788 (58.07)	4254 (6.21)
2011	Both	48051 (31.91)	92058 (61.14)	10469 (6.95)
	Male	25104 (32.56)	46444 (60.23)	5559 (7.21)
	Female	22947 (31.23)	45614 (62.08)	4910 (6.68)

Source: BBS, 1994, 2003, 2012, inside of the parenthesis indicate the **percentage** distribution of population

Table 4.3: (Continued)

Year	Sex	Age Group		
		0-14	**15-59**	**60+**
Rural				
1981	Both	36067 (47.57)	35347 (46.62)	4409 (5.81)
	Male	18522 (48.19)	17499 (45.53)	2412 (6.28)
	Female	17545 (46.92)	17848 (47.74)	1997 (5.34)
1986	Both	39605 (47.50)	39189 (47.00)	4590 (5.50)
	Male	20352 (48.09)	19383 (45.80)	2586 (6.11)
	Female	19253 (46.89)	19806 (48.23)	2004 (4.88)
1991	Both	39594 (46.34)	41051 (48.04)	4798 (5.62)
	Male	20482 (47.17)	20255 (46.64)	2690 (6.19)
	Female	19112 (45.49)	20796 (49.49)	2108 (5.02)
1996	Both	41939 (44.17)	47299 (49.82)	5710 (6.01)
	Male	21794 (45.31)	23131 (48.08)	3181 (6.61)
	Female	20145 (43.01)	24168 (51.59)	2529 (5.40)
2001	Both	38607 (40.60)	50191 (52.78)	6303 (6.62)
	Male	20258 (41.87)	24660 (50.97)	3465 (7.16)
	Female	18349 (39.28)	25531 (54.65)	2838 (6.07)
2006	Both	39905 (37.63)	58624 (55.29)	7506 (7.08)
	Male	20898 (38.60)	29115 (53.79)	4118 (7.61)
	Female	19007 (36.62)	29509 (56.85)	3391 (6.53)
2011	Both	36555 (32.76)	66901 (59.96)	8129 (7.28)
	Male	19111 (33.45)	33732 (59.03)	4299 (7.52)
	Female	17444 (32.04)	33169 (60.92)	3830 (7.04)

Source: BBS, 1994, 2003, 2012, inside of the parenthesis indicate the **percentage** distribution of population

Table 4.3: (Continued)

Year	Sex	Age Group		
		0-14	15-59	60+
Urban				
1981	Both	5847 (41.50)	7539 (53.51)	703 (4.99)
	Male	3001 (38.17)	4463 (56.77)	398 (5.06)
	Female	2846 (45.70)	3076 (49.40)	305 (4.9)
1986	Both	7480 (41.82)	9621 (53.79)	786 (4.39)
	Male	3825 (39.06)	5513 (56.30)	454 (4.64)
	Female	3655 (45.15)	4108 (50.75)	332 (4.10)
1991	Both	8402 (40.26)	11564 (55.41)	905 (4.33)
	Male	4322 (38.24)	6461 (57.17)	518 (4.59)
	Female	4081 (42.64)	5103 (53.32)	387 (4.04)
1996	Both	9778 (37.12)	15412 (58.51)	1151 (4.37)
	Male	5072 (35.47)	8564 (59.9)	662 (4.63)
	Female	4706 (39.08)	6848 (56.86)	489 (4.06)
2001	Both	9964 (3406)	17866 (61.07)	1426 (4.87)
	Male	5208 (33.15)	9699 (61.74)	803 (5.11)
	Female	4756 (35.11)	8167 (60.29)	623 (4.60)
2006	Both	11399 (32.54)	21700 (61.95)	1929 (5.51)
	Male	5928 (32.19)	11421 (62.02)	1066 (5.79)
	Female	5471 (32.93)	10279 (61.87)	863 (5.20)
2011	Both	11590 (29.72)	25028 (64.18)	2378 (6.10)
	Male	5993 (30.02)	12712 (63.67)	1260 (6.31)
	Female	5597 (29.41)	12316 (64.72)	1118 (5.87)

Source: BBS, 1994, 2003, 2012, inside of the parenthesis indicate the **percentage** distribution of population

4.2.4 Trends and differentials of labour force participation

The most essential part of human resources in the economy is manpower. Manpower is composed with the economically active population and the inactive population. The labour force is constituted by the economically active population in any country (Yazidi, 1987). Thus, labour force is one of the major factors moving the economic situation of a country. The dimension of the labour force tends to change over time and will have significant proposition for the economic development of the country. This segment tries to look at the change of the trends and differentials of crude and refined activity of Labour force in Bangladesh during the past four decades (1974-2011).

The crude activity rate is one of the vital procedures of labour force participation rate, It is the percentage of the total population classified in the census as economically active (UN, 1968). Conversely, the refined activity rate is defined as the proportion of economically active persons in the population (BBS, 1991) age 10 and above to the same aged population.

In table 4.4, a little declining is observed in the crude activity rate in 1981 (27.1%) compared to 1974 (28.7%) and it has increased to 28.8% in 1991, 28.9% in 2001 and 30.1% in 2011 at national level. Male crude activity rate was declined in 1981 and 2001 whereas female crude activity was gradually increased from 2.5% in 1974 to 2.8% in 1981, 4.4% in 1991, 7.5% in 2001 and then decreased to 6.1% in 2011 at national level. The pattern of crude activity rate in rural and urban areas is same as national level. The female activity rate is so insignificant that has very negligible effect on overall crude activity rate. Thus it is clear that the crude activity rate shows an irregular pattern over time.

The trend of refined activity rate of male and female also similar as like crude activity rate at national level as well as rural and urban areas. For both sex (total) the refined activity declined from 44.3% in 1974 to 40.5% in 1981 and again it increased to 43.1% in 1991 but yet again decreased to 39.2% in 2001 and remain 39.2% in 2011 at national level. The similar trend is observed for rural and urban areas in Bangladesh as well (Table 4.4). It seems that the declining tendency of refined activity rate was partially due to the decline in child participation in labour force and partly to the increase in school attendance rate (BBS, 2003, 2012).

Table 4.4: Trend of crude and refined rates (%) of labour force by sex and residence in Bangladesh, 1974-2011

Census Year	National			Rural			Urban		
	Male	Female	Both	Male	Female	Both	Male	Female	Both
Crude Activity									
1974	53.0	2.5	28.7	52.9	2.4	28.4	54.1	3.8	32.2
1981	49.9	2.8	27.1	49.6	2.8	26.5	52.2	3.7	30.7
1991	51.9	4.4	28.8	50.9	3.8	27.8	55.3	7.3	33.3
2001	49.6	7.5	28.9	50.3	6.3	28.3	53.5	13.9	33.5
2011	54.2	6.1	30.1	52.2	5.4	29.5	57.6	12.1	35.8
Refined Activity									
1974	80.4	4.0	44.3	81.2	3.8	44.2	73.7	5.8	45.8
1981	73.9	4.3	40.5	75.0	4.2	40.2	69.1	7.5	43.2
1991	77.1	6.7	43.1	77.7	5.8	42.2	75.0	10.3	46.1
2001	66.8	10.1	39.2	64.7	7.9	36.6	63.1	13.7	40.6
2011	70.8	7.8	39.2	66.5	6.1	36.7	68.2	12.4	40.8

Source: Bangladesh population census report2001, 2011, BBS

4.2.5 Trends and differentials of age and sex specific labour force participation

The percentage of the active population in each age group is called age-specific labour force participation rate or activity rate. As the age-specific labour force participation rate takes into consideration the fluctuations in participation due to age, it is an important measure to get a more realistic picture of labour force participation. At national level the noticeable prevalence of males in the labour force, particularly those in the adult ages, 20 and above is observed in Table 4.5a. However, the age-specific labour force participation rate increased among all age groups except first two age groups 15-19 and 20-24 during the period 1981-1991 but it tuned to opposite situation in 2001, there was a general decrease in age-specific labour force participation rates in all age groups of males with ample declines in the first two age groups 15-19 and 20-24, and the age groups 60-64 and 65 and above during the period 1991-2001. Then again, the picture turned opposite direction during the period 2001-2011; it increased in all ages except 10-14 and 65 and over age groups. The significant inter-censal decline in the age-specific labour force participation rates during the periods 1981-2011 for the age groups 10-14, 15-19 and 25-29 are -25.5%, -24.5% and -6.5% respectively, whereas, during the periods 1991-2011, for the same age groups, the inter-censal decline in the age-specific labour force participation rates are -22.6%, - 20.7% and -7.9% respectively. In the period 1991-2011, the age-specific activity rates for the old age groups 60-64 and 65 and above also significantly decreased by -5% and 14.2% respectively. The increasing rate of continuous school enrollment trend and early retirement may be the factor for declining the male labour force participation rate. However, the percentage of active people in age 60 and above is still high compared to developed countries. The key reason of this tendency is the pattern of economic involvement of the old-age in developing countries particularly in agriculture sector where a person can carry on working provided that they are physically able.

In contrast, the age-specific female labour force participation rates increased in all ages during the periods 1981-1991 and then again increased in all ages except age groups 10-14 and 15-19 during the period 1991-2001. It may be due to less school enrollment of girl student and early marriage of female. But with some improvements in school enrollment of girl student and protection of early marriage female labour force participation was decreased during the period 2001-2011. The reality of much lower female activity rate than male is due to alleged male dominant and traditional social culture in Bangladesh.

Figure 4.2a provides the graphical depiction of the age-specific labour force participation rates by sex for census years 1981, 1991, 2001 and 2011. It is seen that there is amazing difference between the labour force participation of two sexes in Bangladesh. So it is noticed that female labour force participation is inadequate and not expectant in Bangladesh. The pattern of male labour force participation rate is also not similar in different census years (Figure 4.2a).

The approximately same pattern of labour force participation rate is observed in rural area for both males and females (Table 4.5b). However table 4.5c shows that in urban area the picture is somewhat different for female. It is observed that female labour force participation rate is increasing gradually in all ages except age groups 10-14 and 15-19. The major cause behind this may be the additional participation of female worker in garments factory in the urban area. Figures 4.2b and 4.2c provide the graphical representation of labour force participation rates by sex for rural and urban areas respectively.

Table 4.5a: Trend of age-specific labour force participation rate (%) by sex (**National**) in Bangladesh, 1981-2011

Year	Sex	Age Group											
		10-14	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**65+**
1981	Male	35.2	65.6	80.1	90.9	92.4	94.1	92.5	93.5	90.5	90.7	84.7	70.9
	Female	3.38	4.12	4.45	4.65	4.66	4.62	4.86	4.57	4.80	4.44	4.57	4.63
1991	Male	32.3	61.8	81.5	93.3	96.4	97.2	97.0	97.0	95.9	94.9	91.3	81.5
	Female	6.6	7.7	6.5	6.0	6.3	6.2	6.3	6.1	7.0	6.8	7.9	7.5
2001	Male	16.0	40.2	64.1	78.0	87.6	89.6	90.1	90.5	89.0	88.1	83.8	70.9
	Female	4.3	7.1	11.3	9.9	10.6	10.4	10.3	9.7	10.2	9.9	10.2	9.8
2011	Male	9.7	41.1	73.6	91.1	95.8	96.7	96.8	96.5	95.1	92.3	86.3	67.3
	Female	2.7	9.5	10.5	10.2	9.9	8.9	8.3	7.3	6.8	5.7	5.2	3.5
Change 81-11	Male	-25.5	-24.5	-6.5	0.2	3.4	2.6	4.3	3	4.6	1.6	1.6	-3.6
	Female	-0.68	5.38	6.05	5.55	5.24	4.28	3.44	2.73	2	1.26	0.63	-1.13
Change 91-11	Male	-22.6	-20.7	-7.9	-2.2	-0.6	-0.5	-0.2	-0.5	-0.8	-2.6	-5	-14.2
	Female	-3.9	1.8	4	4.2	3.6	2.7	2	1.2	-0.2	-1.1	-2.7	-4
Change 01-11	Male	-6.3	0.9	9.5	13.1	8.2	7.1	6.7	6	6.1	4.2	2.5	-3.6
	Female	-1.6	2.4	-0.8	0.3	-0.7	-1.5	-2	-2.4	-3.4	-4.2	-5	-6.3

Source: Bangladesh population census 1991, 2001 and 2011, Analytical report Vol. 1 and National Report (provisional), BBS

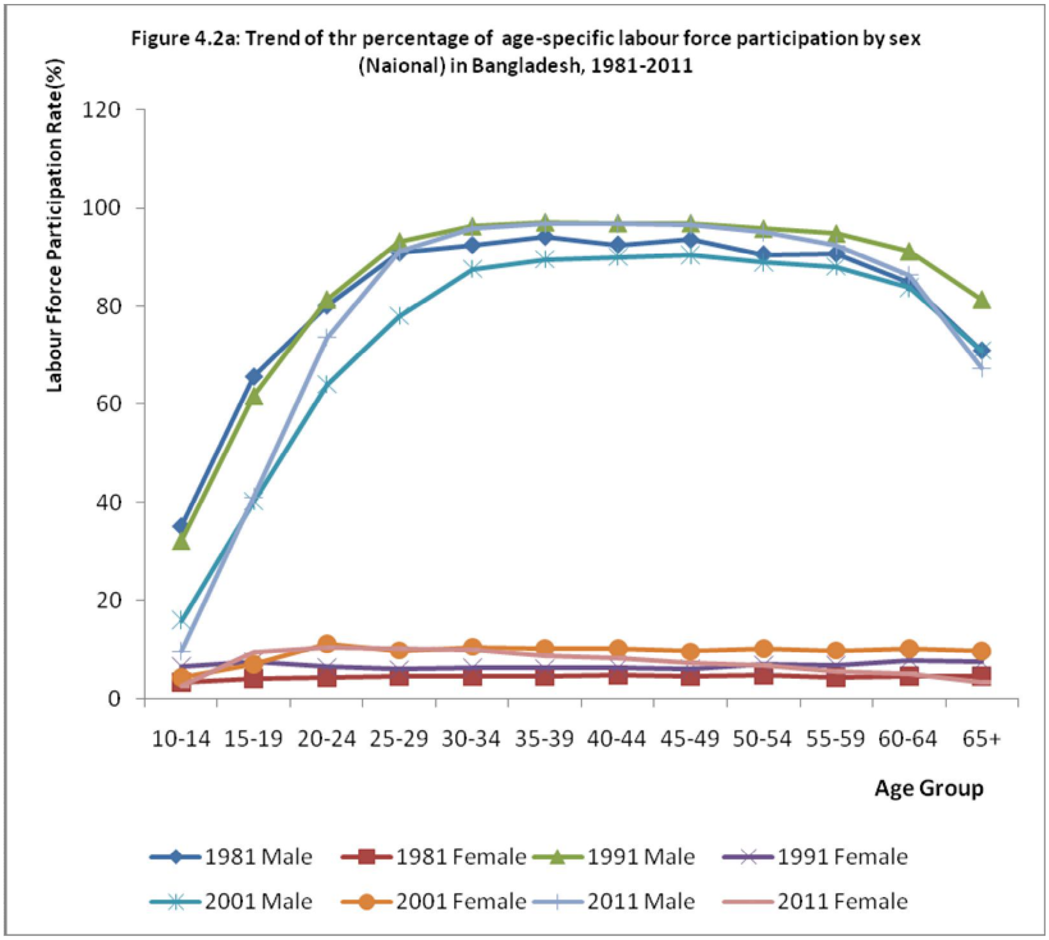


Figure 4.2a: Trend of thr percentage of age-specific labour force participation by sex (Naional) in Bangladesh, 1981-2011
Labour Fforce Participation Rate(%)
120
100
80
60
40
20
0
10-14 15-19 20-24 25-29 30-34 35-39 40-44 45-49 50-54 55-59 60-64 65+
Age Group
1981 Male
1981 Female
1991 Male
1991 Female
2001 Male
2001 Female
2011 Male
2011 Female

Table 4.5b: Trend of age-specific labour force participation rate (%) by sex (**Rural**) in Bangladesh, 1981-2011

Year	Sex	Age Group											
		10-14	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**65+**
1981	Male	37.6	68.1	83.4	91.3	92.5	93.8	92.7	93.4	91.2	91.1	86.1	70.6
	Female	3.2	4.0	4.2	4.3	4.3	4.3	4.6	4.4	4.7	4.4	4.5	3.7
1991	Male	33.9	64.3	83.9	94.0	96.4	97.1	97.0	97.0	96.1	95.2	92.0	82.5
	Female	6.1	6.8	5.4	4.9	5.0	5.0	5.3	5.3	6.3	6.3	7.4	7.2
2001	Male	16.5	40.9	66.5	79.2	87.7	89.8	90.2	90.7	89.4	88.7	84.8	72.4
	Female	3.8	4.9	9.7	8.3	9.1	9.1	8.9	8.4	9.5	9.4	10.0	9.8
2011	Male	8.9	33.6	59.1	88.9	93.8	95.2	91.9	86.1	83.8	82.5	85.2	68.8
	Female	2.1	3.7	8.5	9.6	9.8	9.9	9.1	7.9	8.9	8.1	10.1	8.2
Change 81-11	Male	-28.7	-34.5	-24.3	-2.4	1.3	1.4	-0.8	-7.3	-7.4	-8.6	-0.9	-1.8
	Female	-1.1	-0.3	4.3	5.3	5.5	5.6	4.5	3.5	4.2	3.7	5.6	4.5
Change 91-11	Male	-25	-30.7	-24.8	-5.1	-2.6	-1.9	-5.1	-10.9	-12.3	-12.7	-6.8	-13.7
	Female	-4	-3.1	3.1	4.7	4.8	4.9	3.8	2.6	2.6	1.8	2.7	1
Change 01-11	Male	-7.6	-7.3	-7.4	9.7	6.1	5.4	1.7	-4.6	-5.6	-6.2	0.4	-3.6
	Female	-1.7	-1.2	-1.2	1.3	0.7	0.8	0.2	-0.5	-0.6	-1.3	0.1	-1.6

Source: Bangladesh population census 1991, 2001 and 2011, Analytical report Vol. 1 and National Report (provisional), BBS

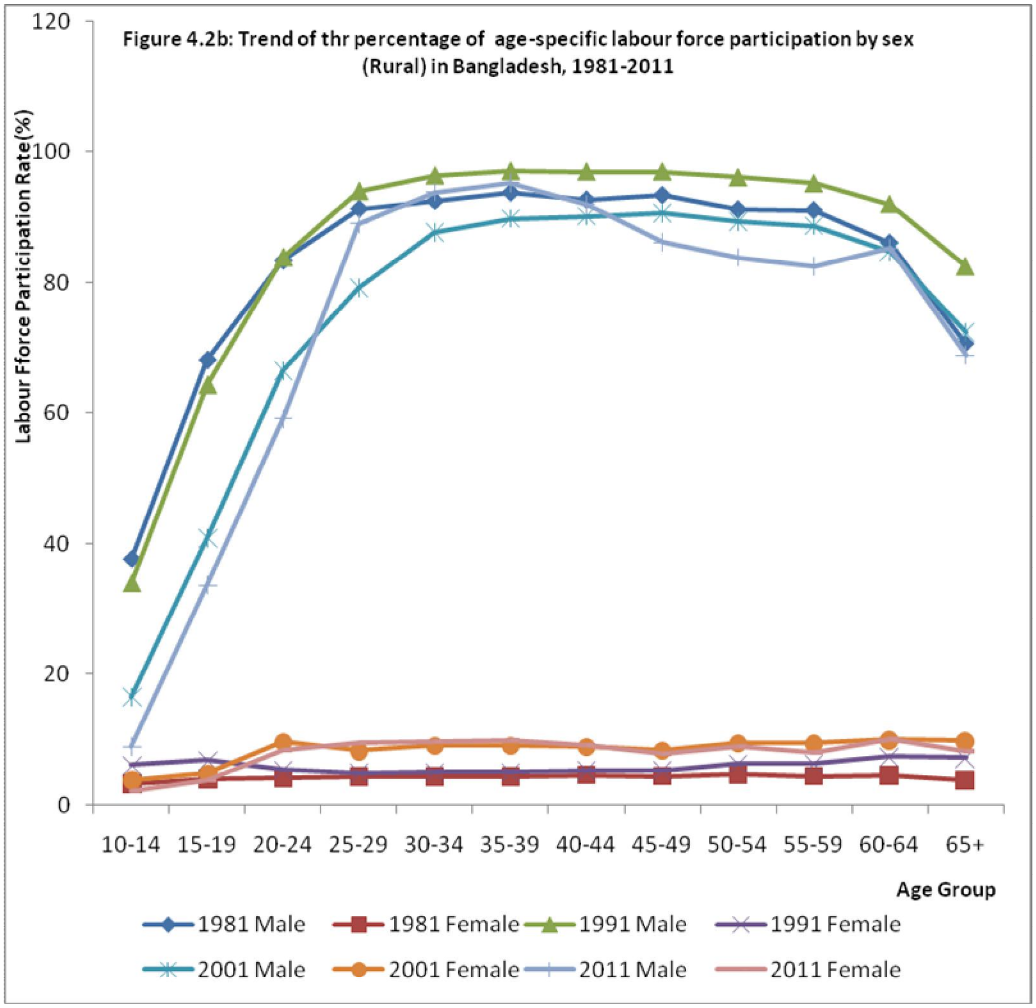


Figure 4.2b: Trend of thr percentage of age-specific labour force participation by sex (Rural) in Bangladesh, 1981-2011
Labour Fforce Participation Rate(%)
120
100
80
60
40
20
0
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65+
Age Group
1981 Male
1981 Female
1991 Male
1991 Female
2001 Male
2001 Female
2011 Male
2011 Female

Table 4.5c: Trend of age-specific labour force participation rate (%) by sex (**Urban**) in Bangladesh, 1981-2011

Year	Sex	Age Group											
		10-14	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**65+**
1981	Male	21.8	54.3	73.4	89.8	92.2	95.2	91.4	94.1	86.9	88.4	89.8	56.7
	Female	4.3	4.6	5.8	6.8	6.7	6.6	6.8	6.1	5.4	5.0	5.0	3.5
1991	Male	25.6	53.1	75.4	91.4	96.3	97.3	97.2	97.1	95.3	93.4	88.0	76.3
	Female	8.6	10.9	10.5	10.5	11.6	11.5	11.3	10.0	10.6	9.4	10.5	9.2
2001	Male	13.9	38.2	59.2	75.2	87.5	89.3	89.7	89.8	88.0	85.9	79.4	64.1
	Female	6.1	12.9	15.9	14.9	15.6	14.9	15.6	14.5	13.6	12.0	11.0	9.7
2011	Male	7.4	25.1	48.5	65.5	84.6	87.3	91.8	92.1	89.2	86.3	82.5	63.6
	Female	4.9	12.1	16.2	17.3	20.1	18.2	19.5	19.8	19.2	15.4	13.2	11.1
Change	Male	-14.4	-29.2	-24.9	-24.3	-7.6	-7.9	0.4	-2	2.3	-2.1	-7.3	6.9
81-11	Female	0.6	7.5	10.4	10.5	13.4	11.6	12.7	13.7	13.8	10.4	8.2	7.6
Change	Male	-18.2	-28	-26.9	-25.9	-11.7	-10	-5.4	-5	-6.1	-7.1	-5.5	-12.7
91-11	Female	-3.7	1.2	5.7	6.8	8.5	6.7	8.2	9.8	8.6	6	2.7	1.9
Change	Male	-6.5	-13.1	-10.7	-9.7	-2.9	-2	2.1	2.3	1.2	0.4	3.1	-0.5
01-11	Female	-1.2	-0.8	0.3	2.4	4.5	3.3	3.9	5.3	5.6	3.4	2.2	1.4

Source: Bangladesh population census 1991, 2001 and 2011, Analytical report Vol. 1 and National Report (provisional), BBS

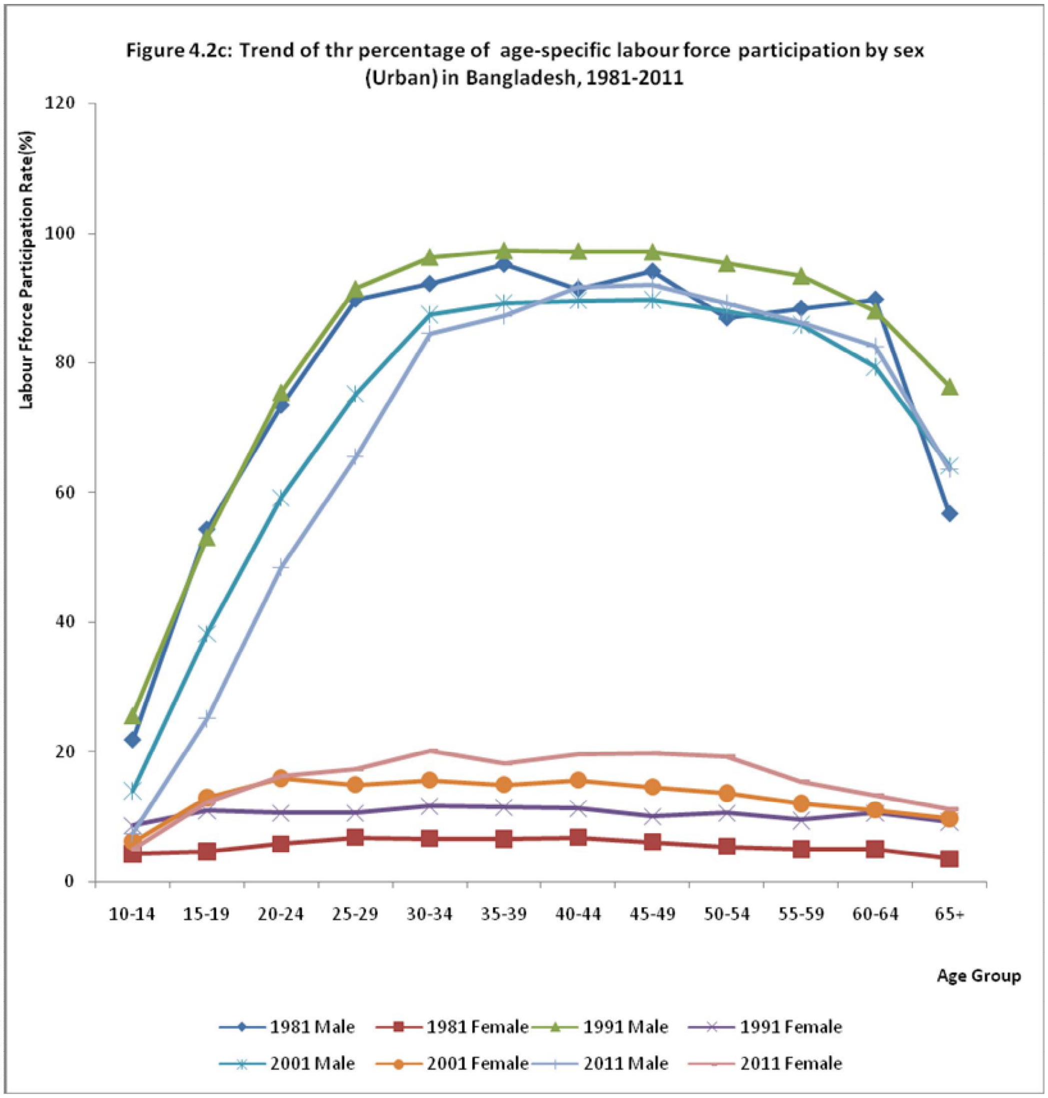


Figure 4.2c: Trend of thr percentage of age-specific labour force participation by sex (Urban) in Bangladesh, 1981-2011
Labour Fforce Participation Rate(%)
120
100
80
60
40
20
0
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65+
Age Group
1981 Male
1981 Female
1991 Male
1991 Female
2001 Male
2001 Female
2011 Male
2011 Female

4.2.6 Growth trend of GDP

Gross Domestic Product (GDP) is the main economic indicator of a country. GDP started to get better in Bangladesh from 1990's. Before that time it was poorer for its slow growth rate. Until now, the growth trend and structural change of GDP are not satisfactory for Bangladesh. The economic development is measured by the growth trend of GDP per capita in any country. Table 4.6 shows the trend of real GDP per capita, growth rate of GDP per capita and changing pattern of sectoral shares in GDP from 1974-2011 in Bangladesh. In 1974 the real GDP per capita was US$ 225.0, which increased slowly until 1991 in Bangladesh. The amount of real GDP per capita increased from US$ 225.0 in 1974 to US$ 748.0 in 2011. That means the growth is more than three folds during the period. The average growth rate of GDP per capita is only around 14 US$ per year by these 37 years. The growth rate of real GDP per capita was in the boundary of 1.23% to 6.71% during the period 1974-2011. The highest and lowest growth rate of real GDP was observed as 6.71% in 2011 and 1.23% in 1981. It is noticeable that the growth rate of real GDP was getting better after 1991.

A great deal of change happened in the composition of sectoral share in GDP through the period 1974-2001, but according to the Table 4.6 the pattern of change was not similar. The major components of GDP in Bangladesh are agriculture, industry and service. In 1974, agriculture was the dominating sectoral contributor in GDP; afterwards, the scenario has changed over time and the service has become foremost contributor from 1981 to 2011. The contribution of agricultural in GDP was 59.26% in 1974 and subsequently, the share of agricultural in GDP started to fall gradually and continued until 2011. Whereas, the contribution of industries started to grow significantly and became 30.38% in 2011 from 7.19% in 1974. It has been seen that just after independence of Bangladesh, the share of industry in GDP was very low because of poor attention in the establishment of necessary industries before independence. Thereafter, it started to grow gradually until 2011 due to relatively stable political environment and appreciation of foreign investment by the government. Even then, it still remains behind compared to the other two sectors. The share of the service sector in GDP started to grow after independence of

Bangladesh and it continued until 1991, after that it fell in 1996 (from 49.73% in 1991 to 49.45% in 1996). Then again started to rise from 2006 and it reached 49.60% in 2011. At present, the share of service sector in GDP is the largest among all contributor sectors in GDP in Bangladesh. This is a good symptom for country's future economic growth. Beside we should also careful for improvement in agricultural sectors with modern technology because still agriculture absorbs two-thirds labour force of country's total labour force and maximum part of rural people depends on agriculture base economy. Real GDP per capita, growth rate of GDP per capita and individual sectoral (agriculture, Industry and service) share in GDP are shown in Figure 4.3a, 4.3b and 4.3c respectively.

Table 4.6: Trend of real GDP per capita (US$), growth rate of GDP per capita and Structural transformation of broad sectoral shares of GDP in Bangladesh, 1974-2011

Year	Real GDP per capita	Growth rate of GDP per capita (%)	Sectoral shares in GDP (percent)		
			Agriculture	Industry	Services
1974	225.0	5.66	59.26	7.19	33.55
1981	226.0	1.23	33.07	17.31	49.62
1986	243.0	4.16	31.15	19.13	49.73
1991	263.0	4.23	29.23	21.04	49.73
1996	305.0	5.90	25.68	24.87	49.45
2001	362.0	5.30	25.03	26.20	48.77
2006	447	6.43	21.84	29.03	49.14
2011	748.0	6.71	20.01	30.38	49.60

Source: BBS, 1991, 2003, 2012, Bangladesh Economic Review-2013

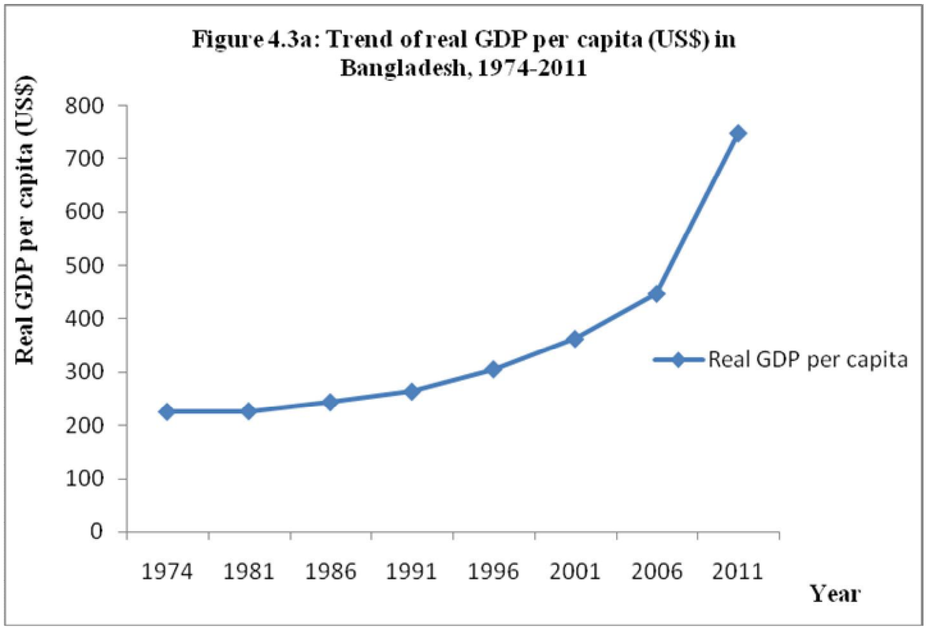


Figure 4.3a: Trend of real GDP per capita (US$) in Bangladesh, 1974-2011
Real GDP per capita (US$)
800
700
600
500
400
300
200
100
0
1974
1981
1986
1991
1996
2001
2006
2011
Year
Real GDP per capita

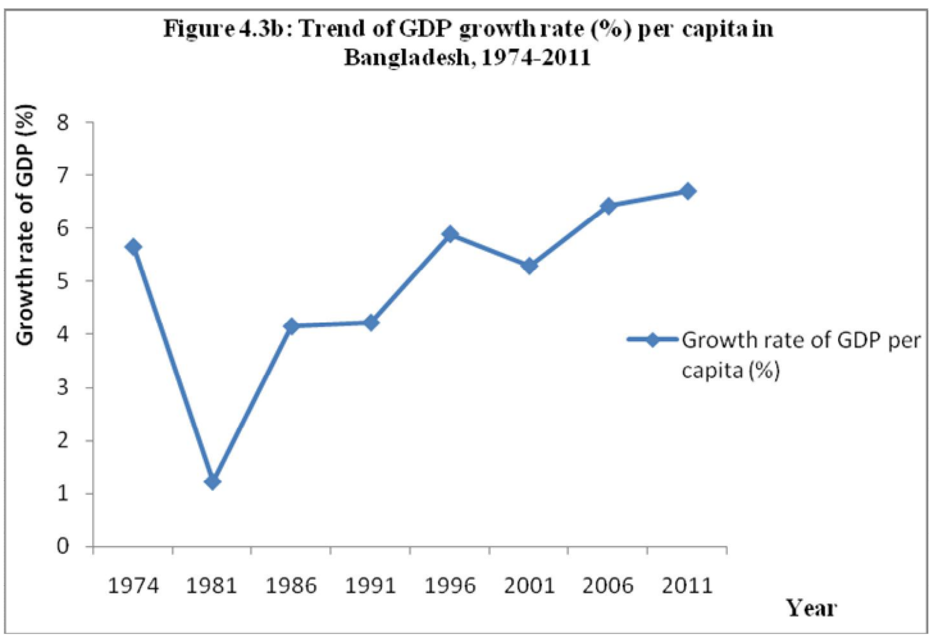
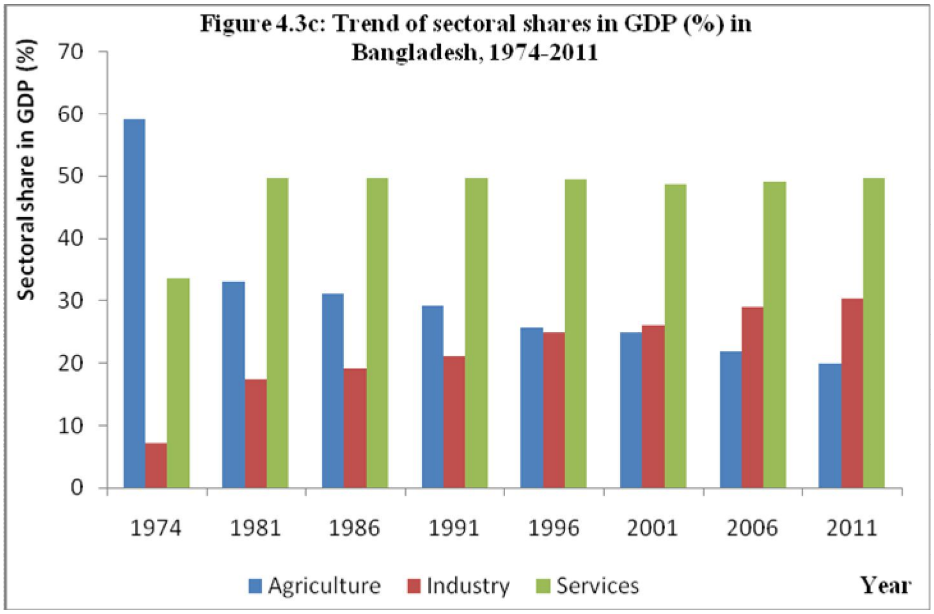


Figure 4.3b: Trend of GDP growth rate (%) per capita in Bangladesh, 1974-2011
Growth rate of GDP (%)
8
7
6
5
4
3
2
1
0
1974
1981
1986
1991
1996
2001
2006
2011
Year
Growth rate of GDP per capita (%)



4.3 Demographic change

4.3.1 Total population trend

In Bangladesh the total population was 150.6 million according to the population census held in 2011 compared to 130.4 million in 2001, 111.5 million in 1991 and 89.9 million in 1981 population censuses respectively (BBS, 2003, 2011). The population growth rate of the country in the four census years were 1.37%, 1.47%, 2.17% and 2.35% per year and the population density were 1015, 890, 755 and 590 persons per sq. km. respectively (BBS, 2004,2012). The percentage of urban population has increased to 25.90% in 2011, from 23.40% in 2001, 19.63% in 1991 and 15.18% in 1981. Although the birth rate was very high, the population of Bangladesh remained more or less unchanged until the end of the eighteenth century because of the equally high mortality rate. This implies population growth rate was insignificant. While the beginning of the nineteenth century, the population started to increase slowly. In 1801 the estimated population of Bangladesh became about 14.5 million with the modest growth rate 0.67% per year (Islam, 1995). The total population was twice by the year 1901 because of the modest growth rate of less than 0.70% per year. About 14.4 million people increased in 100 years. On the other hand, the same amount of increase was happened in the next 50 years. Afterwards, population increased very rapidly. From 1951 to 1974, the population growth rate was extremely high and the total population increased about 29 million within those 23 years. The population growth rate became as high as 2.61% per year in the country in 1974. Yet, it was quicker during the next 37 years, with about 80 million population increase during 1974-2011, regardless of the firm decline of the population growth rate since 1974. It is remarkable that the maximum population growth rate was recorded in 1974, and it was about 2.61% per year. Since then, it decreased and went down to 1.37% per year in 2011.

At the beginning of the twentieth century the estimated density of population was 196 persons per square kilometer and until the middle of this century the rate of increase was modest. Afterwards, density of population increased quickly and it stood at 1015 persons per square kilometer in 2011. The urban population percentage in the country was changed something like similar magnitude. Urban population was only 2.43% in the early twentieth century and it reached 4.33% in the middle of this century. Since then, urban population was increased rapidly and it became 25.90% in 2011. The pace of population growth, population density and urban population percentage has shown in the table 4.7. It has been seen that the population growth rate is very high despite the decrease (1.37% per year) from the previously recorded higher rate of above 2% (2.61% to 2.17% per year) during the 1974-91 period. Figures 4.4a, 4.4b, 4.4c and 4.4d show the total population trend from 1801 to 2011, trend of population growth rate from 1801 to 2011, trend of population density per square kilometer from 1901 to 2011, and trend of urban population percentage from 1901 to 2011 respectively in Bangladesh. It is observed that there is significant relationship between the increase in urban population and the population density. To control the additional population burden in urban areas and to keep urban environment safe and healthy, expansion of urban areas with proper plan or urban facilities in rural areas is also needed.

Table 4.7: Trend of total population, density, percentage of urban population and growth rates of population in Bangladesh, 1801, 1901-2011

Year	Population (in millions)	Annual growth rate	Population density (per Sq. km.)	Urban pop. (%)
1801	14.5	0.67	NA	NA
1901	28.9	0.72	196	2.43
1911	31.6	0.89	214	2.55
1921	33.3	0.52	225	2.64
1931	35.6	0.67	241	3.02
1941	42.0	1.65	285	3.66
1951	41.9	-0.02	299	4.33
1961	50.8	1.93	374	5.19
1974	71.3	2.61	518	8.78
1981	89.9	2.35	609	15.18
1991	111.5	2.17	755	19.63
2001	130.4	1.47	881	23.40
2011	150.6	1.37	1015	25.90

Source: Bangladesh population census 1991, 2001 & 2011. Analytical Report respectively, BBS

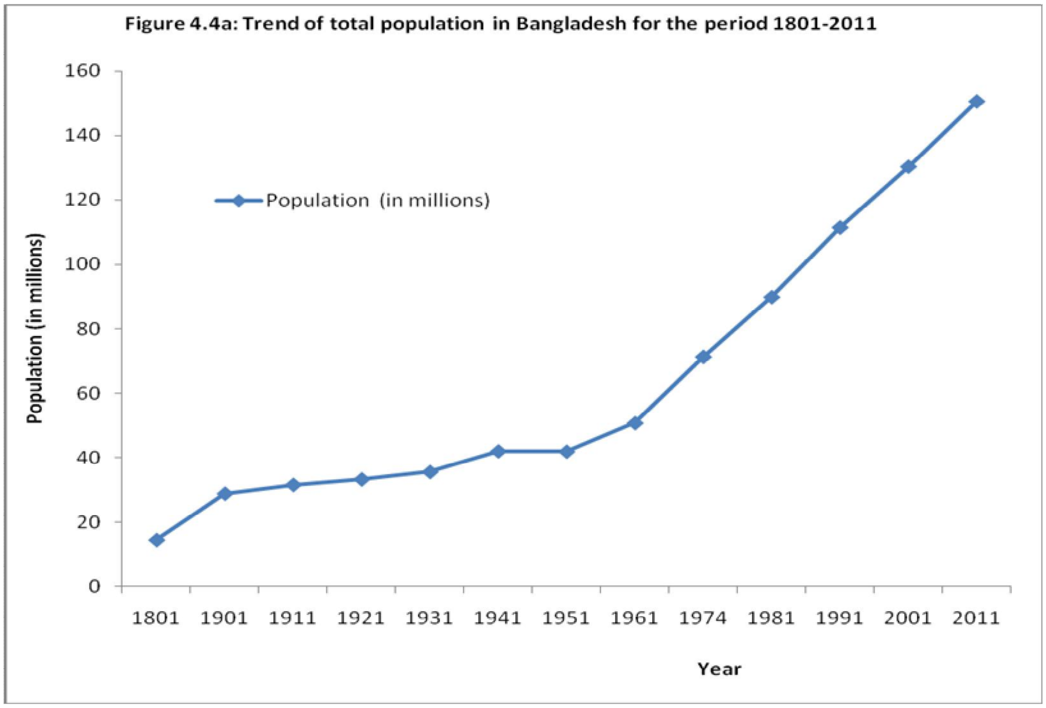


Figure 4.4a: Trend of total population in Bangladesh for the period 1801-2011
Population (in millions)
Population (in millions)
160
140
120
100
80
60
40
20
0
1801 1901 1911 1921 1931 1941 1951 1961 1974 1981 1991 2001 2011
Year

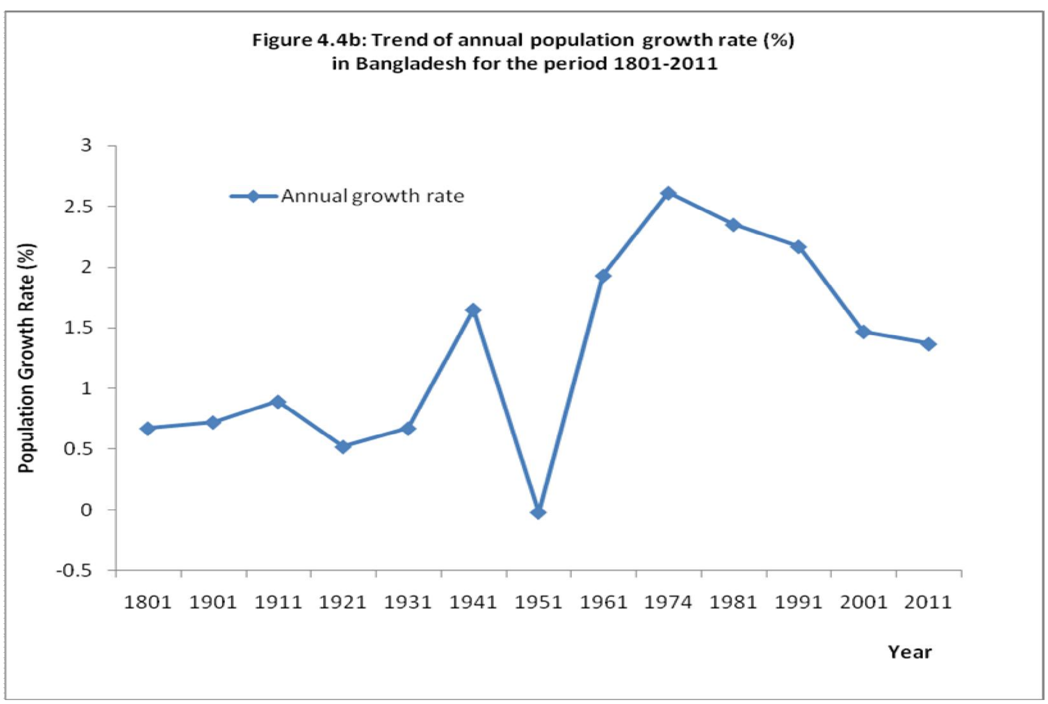


Figure 4.4b: Trend of annual population growth rate (%)
in Bangladesh for the period 1801-2011
Annual growth rate
Population Growth Rate (%)
3
2.5
2
1.5
1
0.5
0
-0.5
1801 1901 1911 1921 1931 1941 1951 1961 1974 1981 1991 2001 2011
Year

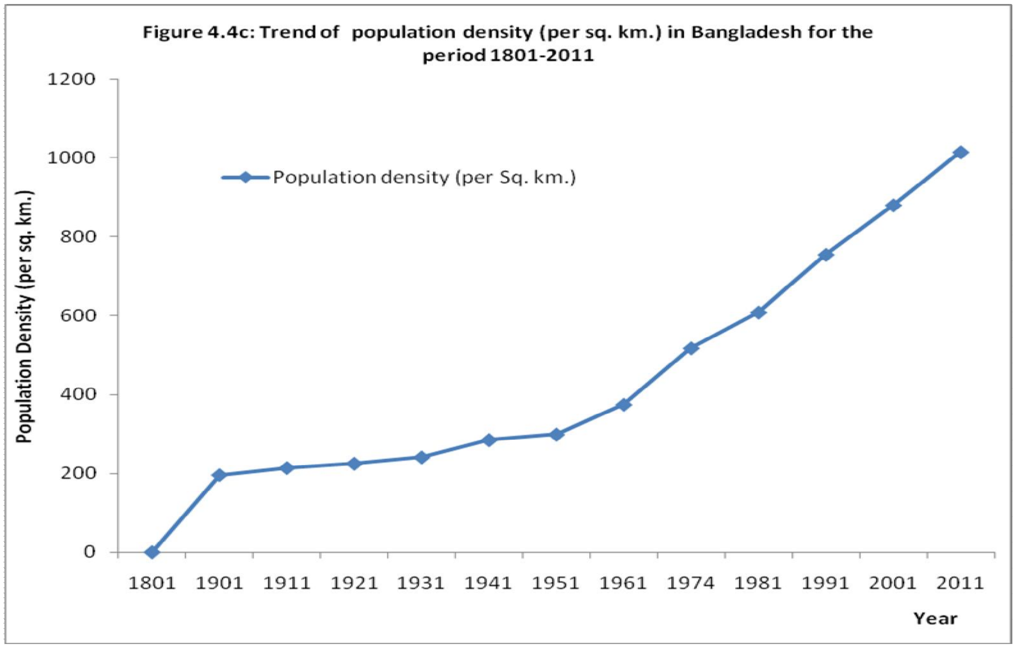


Figure 4.4c: Trend of population density (per sq. km.) in Bangladesh for the period 1801-2011
Population density (per Sq. km.)
Population Density (per sq. km.)
0
200
400
600
800
1000
1200
1801 1901 1911 1921 1931 1941 1951 1961 1974 1981 1991 2001 2011
Year

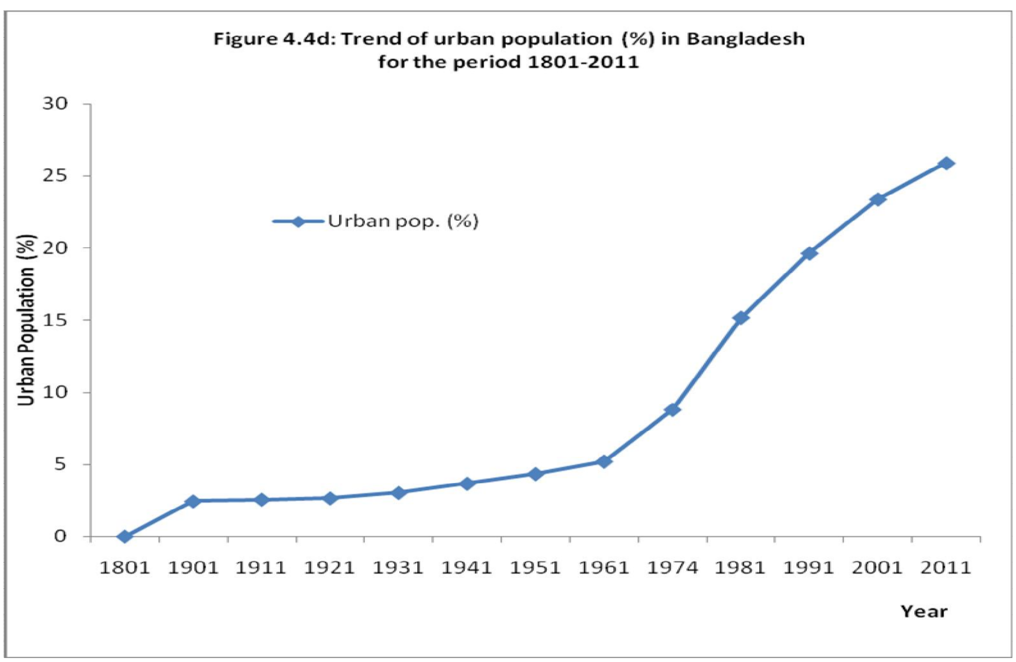


Figure 4.4d: Trend of urban population (%) in Bangladesh for the period 1801-2011
Urban pop. (%)
Urban Population (%)
0
5
10
15
20
25
30
1801 1901 1911 1921 1931 1941 1951 1961 1974 1981 1991 2001 2011
Year

4.3.2 Median age of population

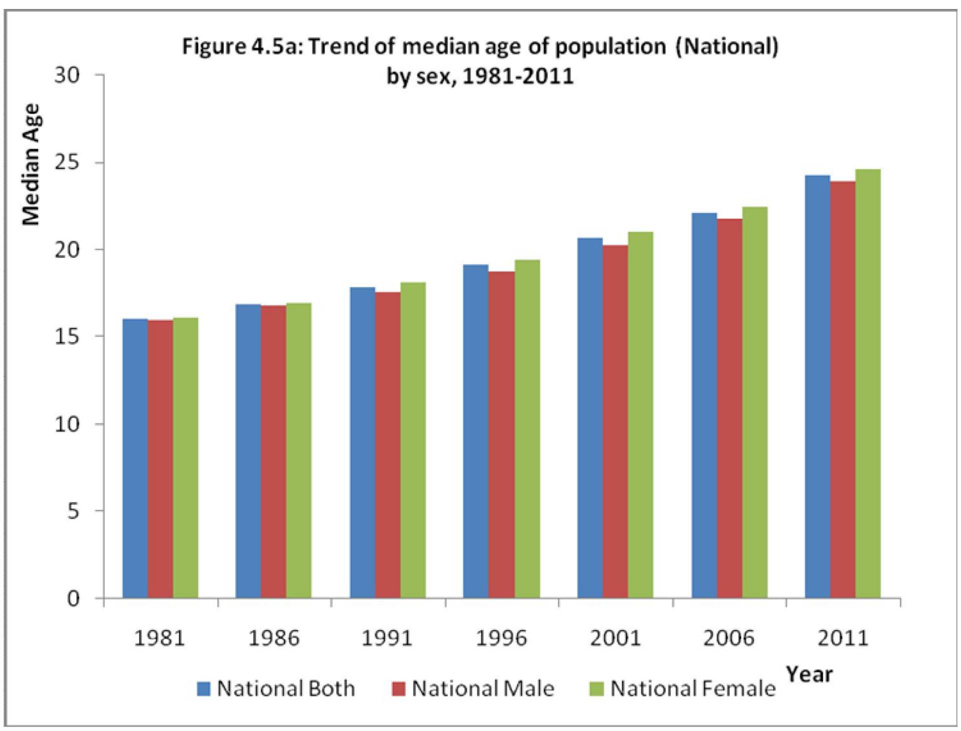
The age which divides the entire population into two numerically equal groups is called median age. That is, half of the people are younger than the median age and half of the people are older. It is a solitary indicator that summarizes the age distribution of a population. The trend of the median age of population for Bangladesh by sex and residence during the period 1981-2011 is shown in the table 4.8. It is down-to-earth that the median age of the people of Bangladesh among all census periods is very youngish, while it increased to 24.28 years in 2011 from 20.69 years in 2001, 17.86 years in 1991 and 16.09 years in 1981. Female median age is a little higher than male median age in all census periods from 1981-2001. In 1981 the male median age was 16.03 years and female median age was 16.14 years, whereas in 2011 it increased to 23.93 years for the males and 24.60 for the females. The rural and urban variation of median age of population is not so high, somewhat only 2 years (Table 4.8). It can be noticed that the median age of population is higher in the urban areas than in the rural areas in all the census periods. The variation of fertility rate and mortality rate between rural and urban areas may be the cause for this. Because, the fertility rate and mortality rate of urban areas are much lower than those in the rural areas due to better healthcare facility in the former. The median age of population in rural area was 15.36 years in 1981 and it increased to 23.83 years in 2011. In contrast, in 1981, the median age of population was 19.02 years in urban areas and it increased to 25.44 years in 2011. The variation in the median age of population between males and females is approximately same in Bangladesh.

Figure 4.5a, 4.5b and 4.5c depicts the pattern of median age of population for national, rural and urban population of Bangladesh respectively.

Table 4.8: The pattern of the trend of median age of population by the differential of sex and residence in Bangladesh, 1981 to 2011

Year	National			Rural			Urban		
	Both	Male	Female	Both	Male	Female	Both	Male	Female
1981	16.09	16.03	16.14	15.36	14.54	16.05	19.02	20.79	16.63
1986	16.92	16.84	17.00	16.24	15.48	16.88	19.36	20.89	17.53
1991	17.86	17.57	18.11	17.15	16.18	17.94	20.07	21.30	18.73
1996	19.15	18.74	19.48	18.39	17.15	19.31	21.08	22.10	19.99
2001	20.69	20.25	21.03	20.08	18.96	20.89	22.16	22.92	21.42
2006	22.15	21.76	22.48	21.65	20.85	22.31	23.41	23.90	22.94
2011	24.28	23.93	24.60	23.83	23.26	24.34	25.44	25.88	25.08

Source: Author self calculated using BBS population data (5 year age group)



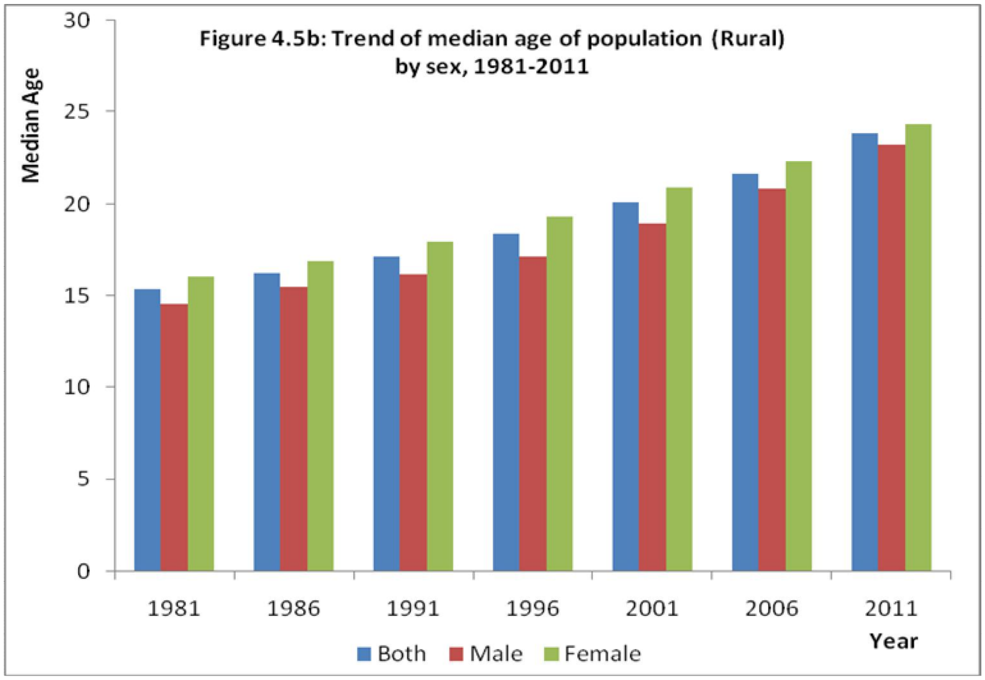


Figure 4.5b: Trend of median age of population (Rural)
by sex, 1981-2011
Median Age
30
25
20
15
10
5
0
1981
1986
1991
1996
2001
2006
2011
Year
Both
Male
Female

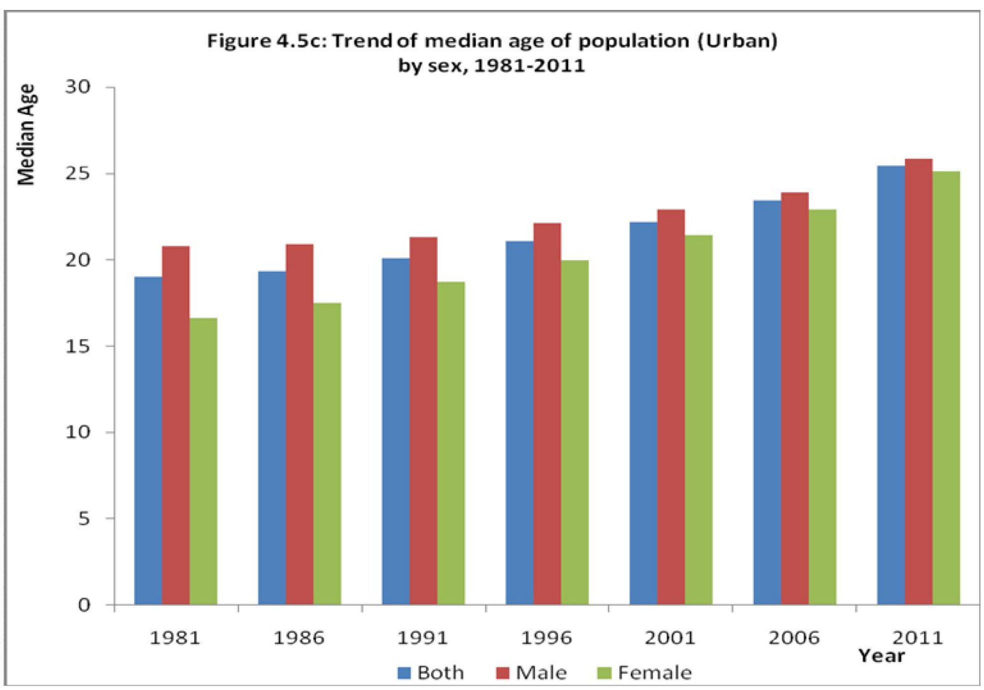


Figure 4.5c: Trend of median age of population (Urban)
by sex, 1981-2011
Median Age
30
25
20
15
10
5
0
1981
1986
1991
1996
2001
2006
2011
Year
Both
Male
Female

4.3.3 Overall mortality trend

To reflect the health situation of a country the mortality rates and ratios are essential indicators. Factors like age, sex, race, occupation, cause, and social classes are associated with the death rate. As a result, to formulate the policy and execution of programs for more progress in future deaths the assessment of the patterns and fortitude of the levels and trends in mortality are required. At the early twentieth century the crude death rate (CDR) was very high. In 1911 CDR was about 45.6 per thousand people (Table 4.9a). Then it increased a little about 47.3 per thousand in 1921 and after that it continuously decreased except in 1951. During the period 1941-1951 CDR became about 40.7 per thousand. Afterwards, the level of mortality declined dramatically between the period 1951-1981. It became 11.5 per thousand in 1981 from 40.7 per thousand in 1951. It continued declining until 2001 and became 4.8 per thousand in 2001. The CDR then slightly increased to 5.5 per thousand in 2011 (BBS, 2003, 2012). Even though, later BBS explained that their preceding estimate was rather underestimated but the declining trend in the level of mortality can be evidently specified from the estimates. This declining trend of mortality was possibly due to the initiative of the government, mainly after 1990. After 1990 till to-day government has been trying continuously to get better country's health care services for all people using government's own ability and international Aids. For this reason, the government has started to expand the health facilities up to remote rural areas through establishing the community health complex.

The variation in CDR by residence is shown in Table 4.9b and table 4.9c. It is observed that CDR in rural areas is always higher than that of urban areas. The declining trend of CDR among various census periods of Bangladesh from 1911 to 2011 is shown in figure 4.6a. It is seen that the trend of the mortality rate had been continuously declining from 1911 to 2011 except 1951 (Figure 4.6a). As a very crude indicator of mortality which is highly affected by the population size and age distribution, the CDR cannot be a good measure of mortality data. Consequently, the study of the age-specific mortality rate and its standardized rate is very important to know the mortality situation in a nation. Thus, the age-specific mortality trend will be discussed in chapter V in details.

Table 4.9a: Trend of Crude birth rate (CBR), crude death rate (CDR) and infant mortality rate (IMR) for **National** in Bangladesh, 1911-2011

Year	Crude birth rate (CBR)	Crude death rate (CDR)	Infant mortality rate(IMR)
1911	53.8	45.6	205
1921	52.9	47.3	198
1931	50.4	41.7	179
1941	52.7	37.8	168
1951	49.4	40.7	144
1961	47.0	29.7	125
1974	48.3	19.4	128
1981	34.6	11.5	111
1986	34.4	12.1	116
1991	31.6	11.2	92
1996	25.6	8.2	67
2001	18.9	4.8	56
2006	20.6	5.6	45
2011	19.2	5.5	35

Source: BBS, 1994, 2004, 2012

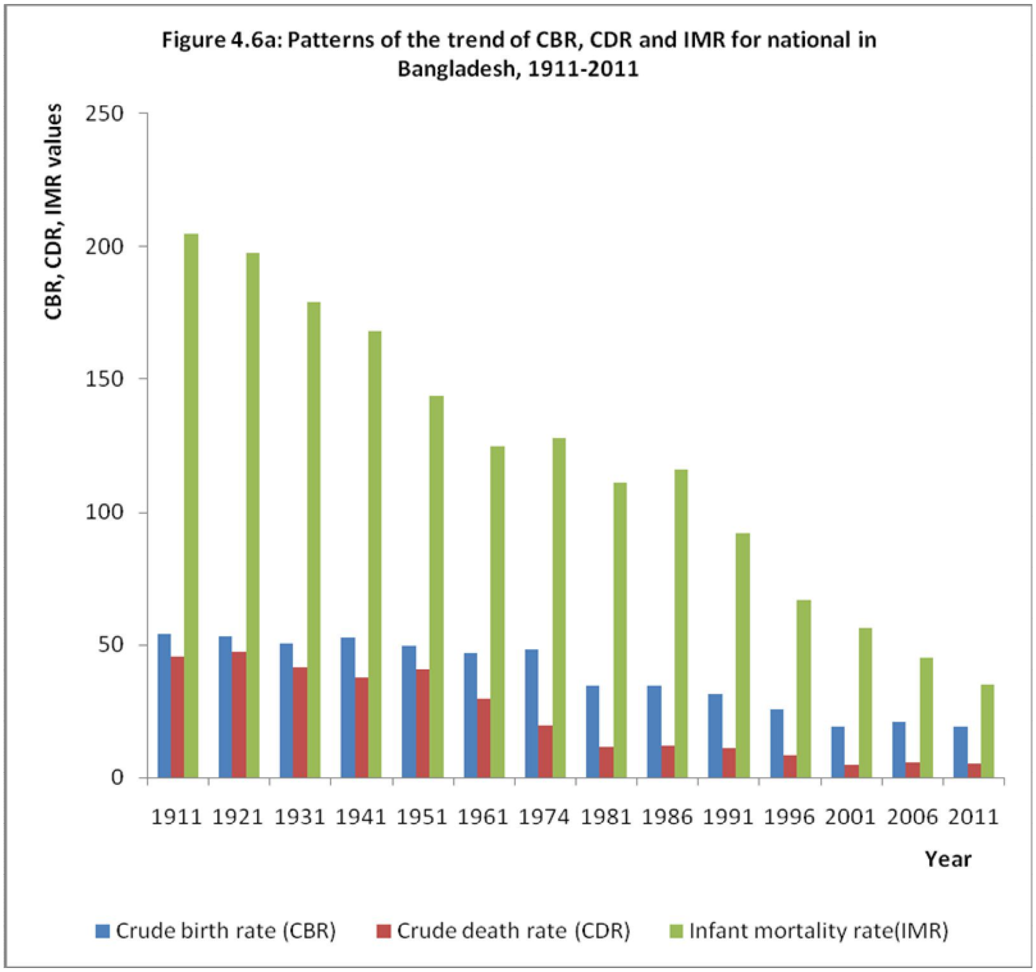


Table 4.9b: Trend of Crude birth rate (CBR), crude death rate (CDR) and infant mortality rate (IMR) for **Rural** in Bangladesh, 1981-2011

Year	Crude birth rate (CBR)	Crude death rate (CDR)	Infant mortality rate(IMR)
1981	35.7	12.2	112
1986	35.4	12.3	118
1991	32.9	11.5	94
1996	27.8	8.8	76
2001	20.7	5.2	60
2006	21.7	6.0	47
2011	20.2	5.8	36

Source: BBS, 2012

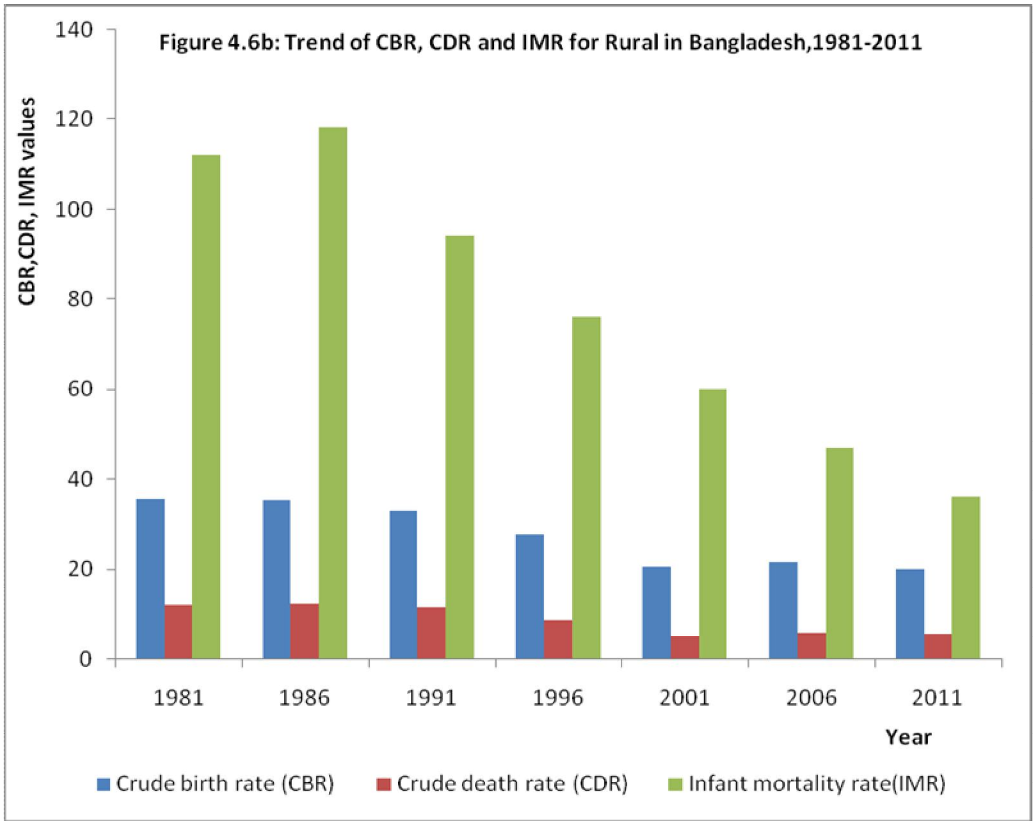
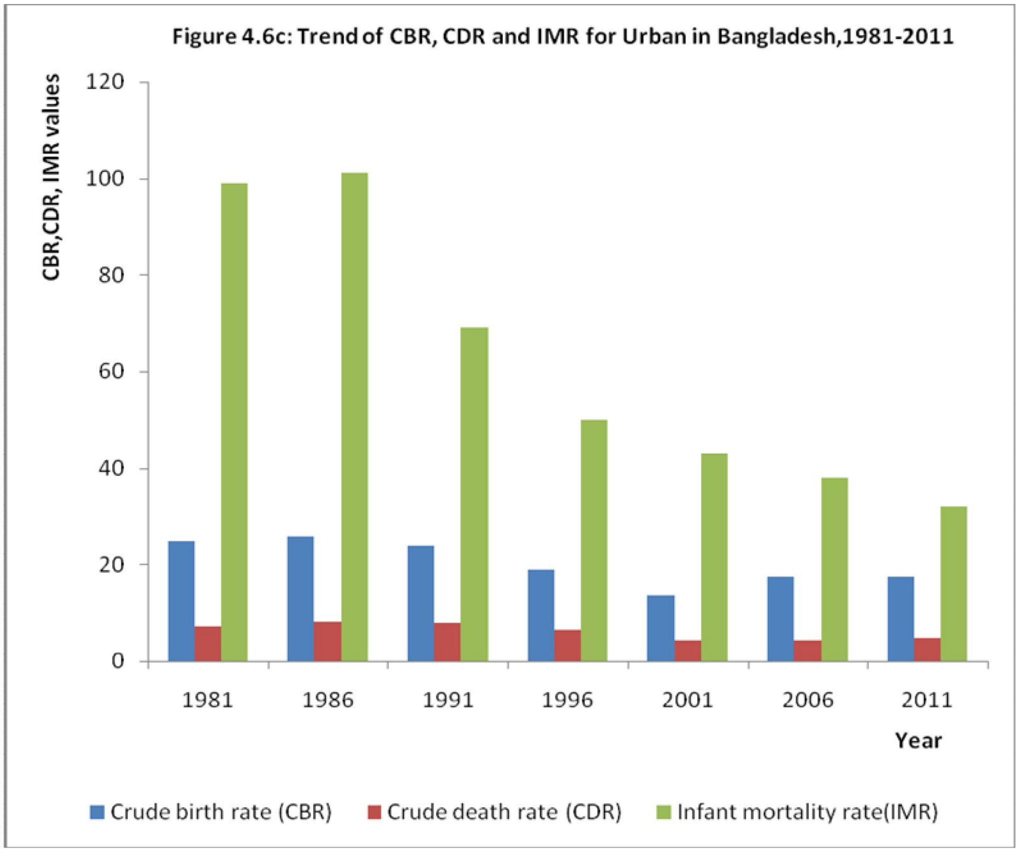


Table 4.9c: Trend of Crude birth rate (CBR), crude death rate (CDR) and infant mortality rate (IMR) for **Urban** in Bangladesh, 1981-2011

Year	Crude birth rate (CBR)	Crude death rate (CDR)	Infant mortality rate(IMR)
1981	24.8	7.2	99
1986	25.9	8.1	101
1991	23.9	7.8	69
1996	19.0	6.5	50
2001	13.6	4.3	43
2006	17.5	4.4	38
2011	17.4	4.8	32

Source: BBS, 2012



4.3.4 Infant and child mortality trend

The overall mortality has declined to a possible minimum level over the last few decades. Right now, the important task of the further reduction in mortality rate can be happened through reducing the level of infant and child mortality as well as the maternal mortality. The rate of infant and child mortality is still very high in comparison with other countries which have completed the stage II demographic transition (CPD-UNFPA, 2003). This is because Bangladesh is a rural based country (still about 70% people are living in rural areas in 2011). Inadequate health awareness and poor public health care facility are common in rural areas with its early marriage propensity. This is why, though Bangladesh has been improving public health care facility for more than last two decades, public health facility and health awareness is still not satisfactory for its huge population.

Until the middle of the last century the infant mortality rate (IMR) was extremely high. In 1911 IMR was as high as 205 per thousand live births and it was consistently above 140 per thousand live births until 1951 (Table 4.9a). In 1961, IMR declined to 125 and again increased to 128 in 1974 and then during the period 1974-2011, the IMR decreased to 35 per thousand live births. The variation in rural and urban areas is an important matter in national IMR, as Bangladesh is still a rural based country. It is considerably noticeable that the socio economic and all types of health care facilities are relatively poor in rural areas than in urban areas. Thus, rural and urban differentials are one of the most important dominant factors of overall high IMR. With the rural-urban differential in IMR, it is required to point out that the early marriage and lack of adequate public health facility even in urban areas are also another cause of high IMR, though both trends have started to improve at a very slow pace. The rural and urban differentials in infant mortality rate are shown in the tables 4.9b and 4.9c. From both the tables 4.9b and 4.9c it is apparent that rural infant mortality rate during all census periods from 1981-2011 is always higher than that of urban areas. The picture of the level of overall IMR of Bangladesh during census periods from 1911-2011 is observed in figure 4.6a. Although the huge reduction of the level of infant mortality rate in Bangladesh during the census periods 1911-2011, still the infant mortality rate is very high compared to the achievements made in the overall mortality as well as in the level of fertility. The decreasing pace in infant mortality rate appeared to be speedier after the independence of Bangladesh than that of the pre independence period. This achievement has become possible since the government has taken proper steps to improve public health care facilities and the increasing health awareness among the people after the independence of the country.

4.3.5 Trend of total fertility rate (TFR)

Total fertility rate (TFR) is a summary measure of fertility obtained by summing the age specific fertility rates for each single year or each age group (usually of five year age groups) of women in the child-bearing age. It states the number of children a woman would bear during her lifetime at the rates specified by the schedule of age specific fertility rates for a particular year. In the middle of seventies of the last century the fertility rate started to decline (Islam, 1995; 2003) because of the government birth control initiative through family planning workers sent even to the remote villages. Though the crude birth rate (CBR) was 47 per thousand population in 1961, it increased to 48.3 per thousand in 1974 (Table 4.9a). Again the CBR declined to 34.6 per thousand people in 1981 and it came down to 31.6 per thousand in 1991, to 18.9 in 2001 and 19.2 in 2011. Like CDR, CBR estimates is also provided by BBS and it seems to be something underestimated to some extent; even then, it can be easily traced that the rapid decline of the CBR was from 48 per thousand population in the mid seventies. Figure 4.6a shows the trend of the level of CBR in Bangladesh during census periods 1911 to 2011. The rural-urban variation into CBR during the census period 1981-2011 is demonstrated in the table 4.9b and 4.9c. The important message has been traced out from the rural-urban variation in CBR. Like CDR the rural CBR was always higher than urban CBR during all census periods from 1981-2011, since in rural areas all types of facilities, e.g., socio-economic condition, public health care facilities, health awareness, education facility and so on, are much poorer compared with those in urban areas.

Table 4.10 illustrates the declining trend of total fertility rate (TFR) from above 6 children per woman in 1974 to 5.04 in 1981. Again the TFR declined from 5.04 children per woman to 3.41 during the period 1981-1996, it became 2.56 children per woman in 2001 and 2.11 children per woman in 2011 (SVRS, 2012). Nevertheless, the decline in TFR during the 5-year period 1996-2001 was the highest during the whole period from 1981-2011. The TFR declined more or less one child per woman in this period. The significant differential of TFR exists between rural and urban areas. It is evident that the TFR of rural areas is always higher than that of urban areas in all census periods. The TFR of rural areas was 5.28 children per woman in 1981 and it decreased to 4.51 children per woman in 1991, 2.84 children per woman in 2001 and 2.25 children per woman in 2011. On the other hand, the TFR of urban areas was 3.20 children per woman in 1981 and it decreased to 2.89 in 1991, 1.73 children per woman in 2001 and 1.71 children per woman in 2011. It is observed a very appreciable matter that the urban TFR has already came down below the replacement rate (2.1 children per woman) since 2001 while the rural TFR is still far from replacement level of fertility rate. In spite of the tremendous improvement in urban TFR, the national TFR is still a little higher than target replacement level by the influence of rural TFR due to Bangladesh being a rural dominating country although the government initiative through family planning awareness among all the people. Figure 4.7 demonstrates the trend of TFR according to residence of Bangladesh for the period 1974-2011.

Table 4.10: Trend of total fertility rate (TFR) according to residence in Bangladesh, 1974-2011

Year	National	Rural	Urban
1974	6.30	NA	NA
1981	5.04	5.28	3.20
1986	4.70	4.89	3.26
1991	4.24	4.51	2.89
1996	3.41	3.76	2.48
2001	2.56	2.84	1.73
2006	2.41	2.63	1.81
2011	2.11	2.25	1.71

Source: BBS, 2003, 2012; NA: Not available

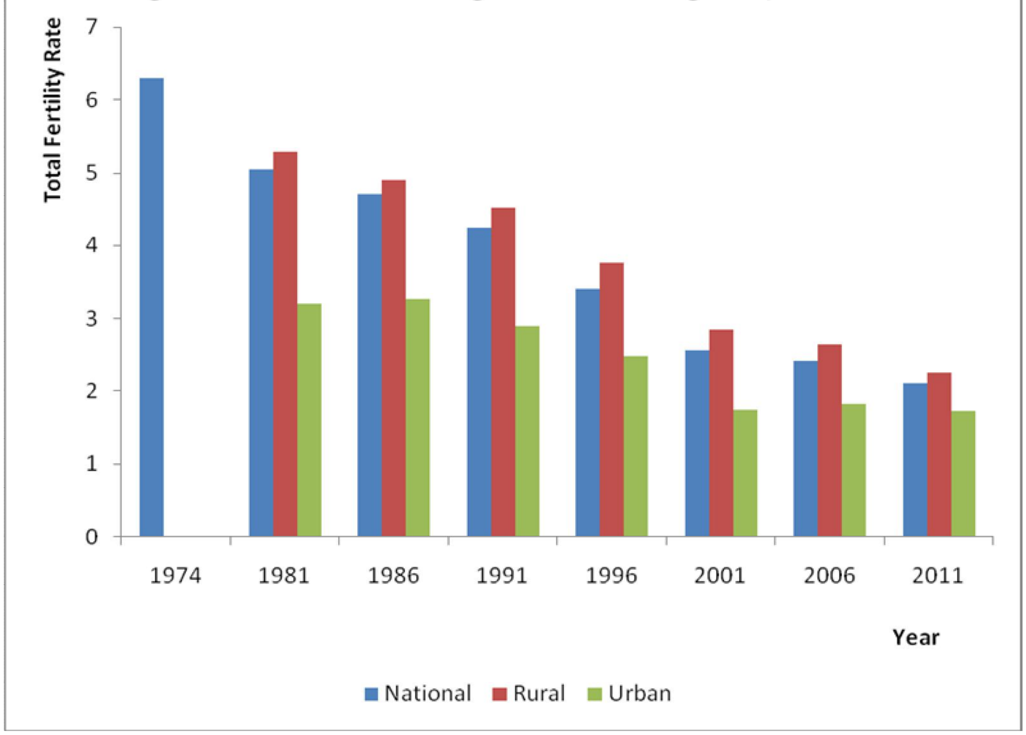


Figure 4.7: Trend of TFR according to residence in Bangladesh, 1974-2011

4.3.6 Trend of mean age at first marriage

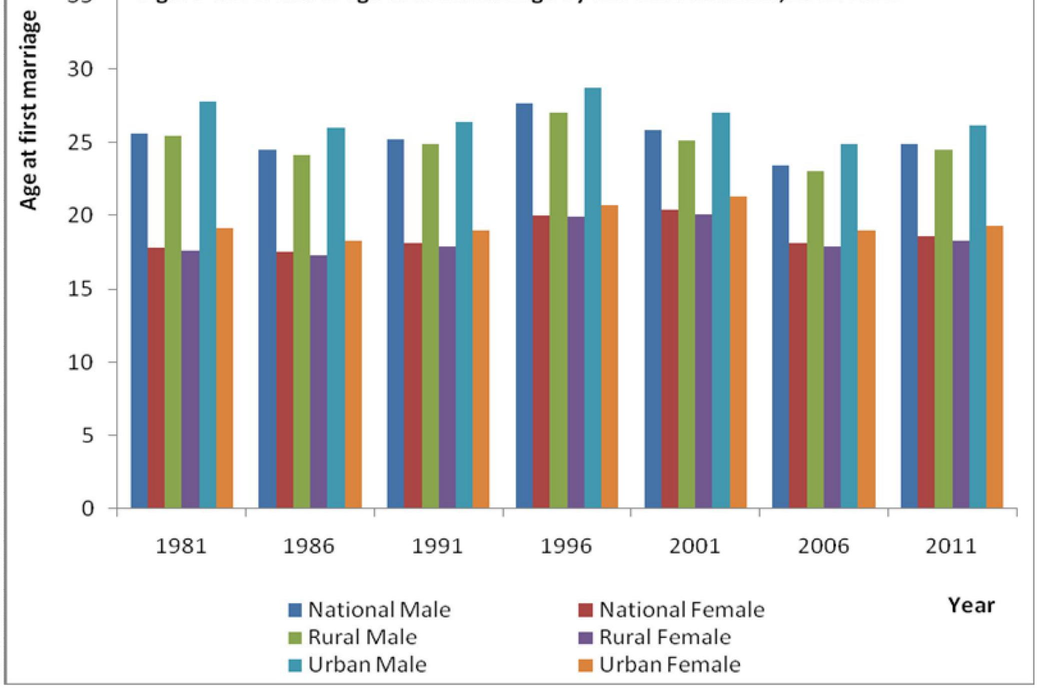
Mean age at first marriage (MAFM) is one of the most important indicators of socio economic development. It has direct impact on fertility and duration of marriage. Women may have to give more children, wanted or unwanted due to long effective time span. It is expected that if marriage takes place at an early age then the first pregnancy also begin at an early age. And, still, marriage is almost universal in Bangladesh. Table 4.11 demonstrates the MAFM for male and female in Bangladesh for the period 1981-2011. The MAFM for females was very low in 1941, only 13.4 years (Islam and Ahmed, 1998). During the period 1941-1981, the MAFM increased by 4.4 years for females, i.e. 17.8 years for females and 25.6 years for males. In 2011, it became to 18.6 years for females and 24.9 years for males. Regardless of this increasing tendency of female MAFM in Bangladesh, still a large section of women get married as well as become pregnant at below 20 years of age posing high risks for both mother and child and results high infant mortality (CPD-UNFPA, 2003), in addition to high maternal mortality rates due to further lacking in different other related factors, such as, public health care policy, provision of child and maternal care, availability of health care, education etc. Consequently, the low MAFM is the cause of long reproductive lifespan as well as the high risk for both mother and children due to high incidence of pregnancy related complications (CPD-UNFPA, 2003). It is also perceptible that the difference of the MAFM between males and females was 7.8 years in 1981 and it becomes 6.3 in 2011. The differential of the MAFM for both male and female between rural and urban is also shown in the same table (Table 4.11). It is seen that urban MAFM is higher than the rural MAFM for both male and female in all censuses but this variation is not enough to make a shorter reproductive lifespan. This indicates that a large section of females in the urban areas also get married at less than 20 years of age (CPD-UNFPA, 2003). Figure 4.8 illustrates the trend of MAFM for both male and female by national, rural and urban for the period 1981-2011.

Table 4.11: Mean age at first marriage (AFM) by sex and residence in Bangladesh, 1981-2011

Year	National		Rural		Urban	
	Male	Female	Male	Female	Male	Female
1981	25.6	17.8	25.4	17.6	27.8	19.1
1986	24.5	17.5	24.1	17.3	26.0	18.3
1991	25.2	18.1	24.9	17.9	26.4	19.0
1996	27.6	20.0	27.0	19.9	28.7	20.7
2001	25.8	20.4	25.1	20.1	27.0	21.3
2006	23.4	18.1	23.0	17.9	24.9	19.0
2011	24.9	18.6	24.5	18.3	26.1	19.3

Source: BBS, 2004, 2012

Figure 4.8: Trend of age at first marriage by sex and residence, 1981-2011



4.4 Summary

The current conditions of the socio-economic development and demographic change in Bangladesh have focused in this chapter. The total population of Bangladesh increased to 150.6 million in 2011 compared to 130.03 million in 2001, 111.5 million in 1991 and 89.9 million in 1981 as recorded in the population censuses 2011, 2001, 1991 and 1981 respectively. The most important characteristic of the population of Bangladesh is natural increase. The population growth rate is still high (1.37%) and fertility rate is still a little higher than the replacement level although the population growth rate decreased to 1.37% in 2011 from 2.61% in 1974. The population size, growth and density also vary according to geographical and administrative divisions. As Bangladesh is a rural agriculture based country, still more than 70% people live in rural areas and they are reasonably deprived from all facilities than urban peoples. To achieve target level fertility rate as well as controlling the population growth rate to reach a goal of stable population, it is more essential to spread out of all necessary facilities up to rural areas to provide a standard living status as soon as possible. In this circumstance, economic emancipation has a significant role. This chapter has outlined the economic development of Bangladesh. And it is a fact that Bangladesh has achieved more economic development than its early independence period despite political instability, over population burden and natural disasters; but the development is not satisfactory enough as the country needs to improve the living standard of her citizens.

As the current status of demographic change in Bangladesh, the death rate has declined to a large extent while the birth rate declined at a reasonable pace from 53.8 per 1000 people in 1911 to 48.3 per 1000 people in 1974 and then 19.2 per 1000 in 2011. It appears that the birth rate declined faster during the period 1974-2011 than 1911-1974. It is also remarkable that the infant mortality rate (IMR) declined more than 70% during the period 1974-2011 though it is still high compared to the developed and some of developing countries. The variation of death and birth rates between rural and urban areas is significant. The level of fertility declined at a moderate pace from 6.30 children per woman in 1974 to 2.11 in 2011 which is very close to replacement level and the use of family planning methods increased gradually. A large rural-urban difference of fertility rate is indicating that the rural agrarian based Bangladesh can be able to reach her target replacement level fertility (2.1 children per woman) with the proper and planned urbanization or urban facilities providing in rural areas. It has also been focused in this chapter that it might be really more difficult to decrease the level of fertility further to reach the replacement level of fertility due to high infant and child mortality. Thus, the fertility level can start to increase again while approaching replacement level fertility, i.e. without further decrease of infant and child mortality and increase of female education it might not be easy to reach the replacement level fertility rate.

Again from this chapter, it has been realized that universal education especially for girls can reduce infant and child mortality, thereby reducing the fertility to replacement level. As there is common marriage tendency in Bangladesh, mean age at first marriage (MAFM) for female is an important aspect for fertility decline. It is a fact that the female MAFM in Bangladesh has increased from 17.8 years in 1981 to 18.6 years in 2011, but it is not at all a good signal, because still a larger portion of females marry at below 20 years of age (SVRS, 2012) which is somewhat very low MAFM compared to those countries who have already reached replacement level or lower rate of fertility. In contrast, low MAFM is not only making longer reproductive lifespan but it is also pretense high risk for the mother and the child (CPD-UNFPA, 2003). In this situation, growing rate of female education or universal female education can be particular and successful step for reducing fertility rate up to the replacement level through increasing MAFM thereby reducing the IMR in Bangladesh.

Chapter V

Trends and Differentials of Mortality in Bangladesh

Abstract

In the last few decades the whole world have experienced with wonderful improvements in health and survival. The life expectancy at birth (e^0) for the world's population rose significantly during the last 50 years. Though, longevity has advanced in almost all of the world's populations, development in all regions was not same. As a developing country Bangladesh, the life expectancy at birth (e^0) has not increased yet with the expectation compared with the developed world as well as some of the developing countries, although the gradual progress has occurred in last two decades. As a result, the aim of this study is to assess the degree of the change in mortality level. With the view of this aim, this chapter would like to observe the trends and differentials of mortality as well as the life expectancy in Bangladesh using Bangladesh Bureau of Statistics (BBS) published data from different reports. The age specific mortality trends indicate that the high infant and child mortality is a foremost hurdle of mortality rates decline and e^0 increase. Sensitivity analysis of e^0 exposes a significant aspect that infant and child mortality is still major hindrance of e^0 increase, although generally individual living span has been increasing for both males and females. It indicates another important message that the female e^0 increasing pace is slight faster than male.

5.1 Introduction

In the last few decades the whole world have experienced with wonderful improvements in health and survival. According to the United Nations' *2010 Revision* of *World Population Prospects*, life expectancy at birth (e^0) for the world's population as a whole rose from 48 years in 1950-1955 to 68 years in 2005-2010. However, as longevity has advanced in almost all of the world's populations, development in some regions has exceeded than in others. For example, a 26-year increase in life expectancy at birth (e^0) happened in Asia, from 43 years in 1950-1955 to 69 years in 2005-2010, at the same time in Africa it increased by 17 years over the last half century, from 38 years in 1950-1955 to 55 years in 2005-2010.

The aim of this chapter is to observe the patterns of mortality trends and differentials to get a clear idea regarding present condition of mortality as well as life expectancy at birth (e^0) in Bangladesh. The population of Bangladesh has increased from 42 million in 1941 to 150.6 million in 2011 (BBS, 2011) and approximately 160 million in 2015 (Wikipedia, 2016). It is remarkable that Bangladesh is the most densely populated country (1015 per sq. kilometer according to BBS, 2011) in the world except some of the island and city based countries. In its 150.6 million people, 77.1 million are males and 73.5 million are females. However, the crude birth rate of Bangladesh declines from 48 per thousand in 1970 to 19.2 in 2011 and crude death rate from 21 per thousand in 1970 to 5.5 in 2011. In the same period, the total fertility rate (TFR) declined from 7.0 children per woman in 1970 to 4.24 in 1991 and 2.11 in 2011 (BBS, 2012) and infant mortality declined from 125 in 1971 to 92 in 1991 and 35 in 2011 (Mitra et al., 1997 and BBS, 2012).

On the basis of the above information, this chapter attempts to deal with mortality trends and differentials in Bangladesh. Considerable research has been done on the trends and determinants of mortality rate in developed countries (Feldman et al., 1989; Mackenbach et al., 1997; Cutler et al., 2006; Torrey and Haub, 2004) although only a few in Bangladesh and other South Asian countries (Alam et al., 2005; Hurt et al., 2004; Rahman, 2000; Rahman, 1999; Mostafa and Ginneken, 2000; Souza and Bhuiya, 1982; Mcintosh et al., 1986; Rahman, 1997; Soares; 2007) which demonstrates further studies on the issues. In particular, the chapter has following objectives:

(i) to examine the magnitude of the change of mortality trends and differentials by age- and sex-specific,

(ii) to investigate the sensitivity of life expectancy at birth (e^0) by age-specific mortality change and

(iii) to decompose the differences of crude death rate between different census populations into age composition of population and age specific mortality rate schedule.

5.2 Trends of mortality in Bangladesh

5.2.1 Percentage change in life expectancy at birth (e^0) trend

There are many approaches to determine the level of mortality change. The change of age-structure is usually inclined by the crude death rate based on general mortality level in a population. Though it is hard to urge determining the rate of mortality change, the crude death rates are easy to understand. To some extent this problem may be solved by using standardized crude death rate however the selection of the standard age-structure can have some effects on the result. Moreover, there are several drawbacks to interpret the mortality change using standardized crude death rate. It is well known to use life expectancy at birth (e^0) to analyze the change of mortality, as it is a good summery measure of the mortality change of all ages in a population. While the measurement and interpretation of life expectancy changes are affected by a problem of relative magnitude (Arriaga, 1984, pp. 83). Table 5.1 illustrates the percentage change of e^0 for both males and females for the period of 1981-2011 with 5-year intervals and sex-difference of the percentage change (male and female percentage difference). The highest increasing of e^0 took place in the period 1991-1996 for males (8.14%) and for females it was in the period 1996-01 (8.84%), while the lowest increasing period was 1986-91 (males 1.18% and females 0.68%), on the other hand, the period 1981-86 was the decreasing period for both sex (males -1.59% and females -1.61%). In the sex difference column it is observed that the increasing rate of female e^0 is higher than that of male during the periods 1996-01 and 2001-06, whereas in the other period it is in the opposite direction (Table 5.1). For the case of rural and urban areas the scenario is more or less alike. The only difference is observed for the period 1981-1986 in the urban areas in sex difference where the changing rate of female life expectancy is higher than that of male.

The percentage change of life expectancy at age 60 (e^{60}) for males and females as well as sex difference of the percentage change is shown in Table 5.2. It is observed that the highest increase happened in 1991-1996 period for both males and females whereas it declined in the period 1996-2001 and 2001-2006 for males and in the period 1986-91 for females. In the rural areas the highest increase also happened in the period 1991-1996 for both males and females but it declined in the period 2001-2006 for males and 1986-91 for females. In urban areas significant increase occurred in the periods 1986-91 and 1996-2001 for males and in the periods 1996-2001 and 2006-11 for females, however it declined in the period 1981-86 for both males and females. It is remarkable that in the urban areas increasing percentage of e^{60} for females is higher than males in all the periods except 1986-91 which is shown in the Sex difference column of Table 5.2 as well.

Table 5.3 represented the percentage change of life expectancy at age 65 (e^{65}) for both males and females and sex-difference of the percentage change. It is notable that the e^{65} has increased through all periods for females but for males it decreased in the periods 1996-2001 and 2001-2006.The foremost increasing period among all 5-year periods is 1991-96 for both males and females. On the other hand the smallest increasing period is 1981-86 for males and 1996-2001 for females. It is also notable that in the last three periods the increasing rate (%) of e^{65} for female is significantly higher than that of male (Table 5.3). In rural areas the scenario is not so different but in urban areas female e^{65} changes faster than male e^{65} in all the periods except 1986-91. It is observable that the life expectancy of both males and females are increasing gradually but the increasing pace of female life expectancies (e^{0}, e^{60} and e^{65}) is faster than male life expectancies (e^{0}, e^{60} and e^{65}). Though at the initial periods male life expectancy is higher than female life expectancy but later on female life expectancies become higher than those of males. Therefore, we can conclude that maternal mortality and reproductive health facility have improved remarkably because it is the main cause of increasing female life expectancies (e^{0}, e^{60} and e^{65}).

Table 5.1: Percentage change in life expectancy at birth (e^0) by sex and sex-difference in Bangladesh, 1981-2011

Year	Male (e^0)	Female (e^0)	Percentage change of e^0		
			Male (%)	Female (%)	Sex-diff. (%)
National					
1981	56.63	56.56	_	_	_
1986	55.73	55.65	-1.59	-1.61	0.02
1991	56.39	56.03	1.18	0.68	0.50
1996	60.98	59.83	8.14	6.78	1.36
2001	63.81	65.12	4.64	8.84	-4.20
2006	66.21	68.12	3.76	4.61	-0.85
2011	68.63	69.81	3.66	2.48	1.18
Rural					
1981	56.18	56.12	_	_	_
1986	55.43	55.21	-1.33	-1.62	0.29
1991	55.96	55.62	0.96	0.74	0.22
1996	60.25	59.29	7.67	6.60	1.07
2001	63.26	64.58	5.00	8.92	-3.92
2006	65.54	67.53	3.60	4.57	-0.97
2011	67.99	69.19	3.74	2.46	1.28
Urban					
1981	61.58	60.55	_	_	_
1986	58.46	59.36	-5.07	-1.97	-3.10
1991	59.65	59.68	2.04	0.54	1.50
1996	64.82	63.26	8.67	6.00	2.67
2001	67.79	68.35	4.58	8.05	-3.47
2006	69.76	71.21	2.91	4.18	-1.27
2011	71.74	72.93	2.84	2.42	0.42

Note: Negative sign indicates the decreasing tendency of life expectancy at birth (e^0) change individually for both male and female, whereas negative sign indicate male life expectancy increase slower than female life expectancy in sex-difference.

*Rate of life expectancy at birth changes are calculated as $\frac{e_m^o(t+5)-e_m^0(t)}{e_m^0(t)}$ for male and $\frac{e_f^o(t+5)-e_f^0(t)}{e_f^0(t)}$ for female, where e_m^0 and e_f^0 indicate male and female life expectancy at birth and t indicates time.

Table 5.2: Percentage change in life expectancy at age 60 (e^{60}) by sex and sex-difference in Bangladesh, 1981-2011

Year	Male (e^{60})	Female (e^{60})	Percentage change of e^{60}		
			Male (%)	Female (%)	Sex-diff. (%)
National					
1981	13.25	13.72	_	_	_
1986	14.06	14.75	6.11	7.51	-1.40
1991	15.08	14.72	7.26	-0.20	7.46
1996	19.37	18.07	28.45	22.76	5.69
2001	19.27	18.60	-0.52	2.93	-3.45
2006	17.47	19.07	-9.34	2.53	-11.87
2011	18.95	21.84	8.47	14.53	-6.06
Rural					
1981	13.21	13.66	_	_	_
1986	14.10	14.68	6.74	7.47	-0.73
1991	14.75	14.49	4.61	-1.29	5.90
1996	16.92	16.33	14.71	12.70	2.01
2001	18.56	17.90	9.69	9.61	0.08
2006	17.31	19.05	-6.74	6.43	-13.17
2011	18.94	21.94	9.42	15.17	-5.75
Urban					
1981	16.22	16.49	_	_	_
1986	13.62	16.06	-16.03	-2.61	-13.42
1991	16.51	15.33	21.22	-4.55	25.77
1996	17.80	17.00	7.81	10.89	-3.08
2001	21.42	20.81	20.34	22.41	-2.07
2006	17.99	17.74	-16.01	-14.75	-1.26
2011	18.92	21.65	5.17	22.04	-16.87

Note: Negative sign indicates the decreasing tendency of life expectancy at 60 (e^{60}) changes individually for both male and female, whereas negative sign indicate male life expectancy increase slower than female life expectancy in sex-difference.

*Rate of life expectancy at 60 changes are calculated as $\frac{e_m^{60}(t+5)-e_m^{60}(t)}{e_m^{60}(t)}$ for male and $\frac{e_f^{6o}(t+5)-e_f^{60}(t)}{e_f^{60}(t)}$ for female, where e_m^{60} and e_f^{60} indicate male and female life expectancy at 60 and t indicates time.

Table 5.3: Percentage change in life expectancy at 65 (e^{65}) by sex and sex-difference in Bangladesh, 1981-2011

Year	Male (e^{65})	Female (e^{65})	Percentage change of e^{65}		
			Male (%)	Female (%)	Sex-diff. (%)
National					
1981	10.16	10.54	_	_	_
1986	11.01	11.21	8.37	6.36	2.01
1991	12.49	11.82	13.44	5.44	8.00
1996	15.86	14.62	26.98	23.69	3.29
2001	15.55	14.75	-1.96	0.89	-2.84
2006	14.34	15.90	-7.78	7.80	-15.58
2011	15.72	18.47	9.62	16.16	-6.54
Rural					
1981	10.14	10.47	_	_	_
1986	11.01	11.16	8.58	6.59	1.99
1991	12.18	11.73	10.63	5.11	5.52
1996	13.66	12.93	12.15	10.23	1.92
2001	14.85	14.11	8.71	9.13	-0.42
2006	14.30	15.87	-3.70	12.47	-16.17
2011	15.84	18.67	10.77	17.64	-6.87
Urban					
1981	13.17	13.89	_	_	_
1986	10.93	12.30	-17.01	-11.45	-5.56
1991	13.63	12.42	24.70	0.98	23.73
1996	14.52	13.57	6.53	9.26	-2.73
2001	17.62	16.72	21.35	23.21	-1.86
2006	14.50	14.43	-17.71	-13.70	-4.01
2011	15.46	18.10	6.62	25.43	-18.81

Note: Negative sign indicates the decreasing tendency of life expectancy at 65 (e^{65}) changes individually for both male and female, whereas negative sign indicate male life expectancy increase slower than female life expectancy in sex-difference.

*Rate of life expectancy at 65 changes are calculated as $\frac{e_m^{65}(t+5)-e_m^{65}(t)}{e_m^{65}(t)}$ for male and $\frac{e_f^{65}(t+5)-e_f^{65}(t)}{e_f^{65}(t)}$ for female, where e_m^{65} and e_f^{65} indicate male and female life expectancy at 65 and t indicates time.

5.2.2 Patterns of change in age-specific mortality trend

The change of the tempo of age-specific mortality plays a vital role to construct a life table. So it is essential to look at the change of the pace of age-specific mortality for constructing life table. Accordingly, the change in mortality among different age groups resulting the change of e^0. We have utilized the age-specific mortality rate by sex in this study to construct two different life tables for males and females separately to check the velocity of age-specific mortality change. The age-specific mortality trend for national level in Bangladesh over the period 1981-2011 is demonstrated in Table 5.4a. It is a noticeable that before 1991 the age-specific mortality changes were scattered. Afterwards, the country developed some facilities in the health care sector and as a result the age specific mortality started to decline increasingly in all age groups. But it is also evident that in comparison with developed and some of the developing countries the infant & child mortality is still high, and for this reason e^0 is not increased satisfactorily in Bangladesh. Nevertheless, the declining trend of old-age mortality cheers up the panorama although infant and child mortality improvement is not that satisfactory in Bangladesh. It is apparent that infant and child and old-age mortality declines play an important role in e^0 increase.

Although there was lack of socio-economic development in Bangladesh during the last two decades, e^0 has increased gradually and this is a good sign. It is obvious that credible increase of e^0 is not possible without improvement of infant and child mortality. Therefore, augmentation of health care facilities as well as socio-economic condition is necessary to improve mortality situation.

Table 5.4b and 5.4c displays the age-specific death rates of rural and urban areas respectively. It is observed that mortality rate of urban areas is much lower than that of rural areas in all age groups for both males and females. Improved socio-economic conditions and health facilities might be the cause for this disparity of mortality rates. It is a striking signal that the infant and child mortality and old-age mortality declines have key role for increasing the e^0 than adult-age mortality change. This growing trend will gradually be slower in future. It is remarkable that female mortality of the developed and most of the developing countries is lower than the male mortality rate. But it appears somewhat different in Bangladesh. It is observed that in the reproductive age groups (15-49) female mortality is greater than male mortality. However, in the other age group female mortality is lower than that of male. It might be a cause that the female mortality (both overall and age-specific mortality) declines at a bit higher rate than male mortality. It seems that the high female mortality rate in 15-49 age groups is the cause of high maternal and reproductive mortality. Therefore, it may be concluded that more attention should be given to both health and socio-economic development in Bangladesh to improve the life expectancy at birth (e^0).

Table 5.4a: Trend of the observed age-specific death rates (ASDRs), 1981-2011(National)

Mortality rates (per 1000 population)								
Age group	Male				Female			
	1981	1991	2001	2011	1981	1991	2001	2011
0	103.20	95.12	62.52	36.99	97.74	90	60.06	35.17
1-4	13.72	14.02	4.13	2.54	13.72	13.29	4.15	2.5
5-9	1.89	3.83	0.78	0.85	2.01	3.33	0.91	0.75
10-14	0.99	1.70	0.70	1.01	0.94	1.52	0.7	0.74
15-19	0.92	1.95	0.93	0.73	1.5	2.58	0.93	0.94
20-14	1.08	2.32	1.72	0.96	1.62	3.18	1.61	0.84
25-29	1.27	2.89	1.61	1.21	1.81	4.08	1.67	1.14
30-34	1.67	3.61	1.58	1.48	2.52	4.66	1.72	0.96
35-39	3.15	4.60	1.69	1.92	3.6	5.98	1.9	2.04
40-44	5.29	5.52	2.84	3.44	6.28	6.23	2.82	2.21
45-49	8.80	9.37	3.62	5.62	8.55	10.11	3.69	2.75
50-54	15.07	14.10	5.06	9.50	14.47	12.76	4.91	5.95
55-59	23.02	21.41	8.57	14.36	25.25	19.49	7.83	8.68
60-64	32.65	35.06	14.67	20.43	30.03	31.65	13.74	16.19
65-69	52.63	42.37	17.38	31.90	46.36	40.55	16.85	26.15
70-74	58.86	70.00	35.55	47.78	54.74	74.56	38.42	40.78
75+	238.14	125.25	117.18	92.07	233.63	145.5	131.71	72.97

Source: Sample Vital registration System (SVRS) 2002, 2010, 2012. Bangladesh Bureau of Statistics (BBS).

Table 5.4b: Trend of the observed age-specific death rates (ASDRs), 1981-2011(Rural)

Mortality rates (per 1000 population)								
Age group	Male				Female			
	1981	1991	2001	2011	1981	1991	2001	2011
0	106.37	94.65	70.81	42.37	100.88	95.41	67.3	37.66
1-4	14.2	15.95	4.38	3.01	12.29	12.98	4.89	2.9
5-9	2	4	0.75	0.97	2.12	3.45	0.93	0.92
10-14	1.01	1.79	0.72	1.04	0.93	1.6	0.73	0.89
15-19	1.03	2.23	0.98	0.93	1.43	2.77	0.95	0.94
20-14	1.28	2.48	1.98	1.08	1.6	3.41	1.86	1
25-29	1.26	3.04	1.82	1.23	1.8	4.37	1.8	1.27
30-34	1.62	3.9	1.66	1.61	2.61	4.95	1.84	0.92
35-39	3.32	4.91	1.75	2.14	3.5	6.22	1.96	2.05
40-44	5.18	5.84	3.16	3.36	6.12	6.43	3.09	2.54
45-49	8.87	10.06	3.96	6.1	8.42	10.48	4.15	2.98
50-54	15.66	14.72	5.39	8.89	14.37	13.02	5.17	6.2
55-59	23.11	22.05	8.42	13.36	25.31	20	7.77	8.65
60-64	33.12	36.15	15.51	21.78	29.98	34.23	15.09	16.97
65-69	52.97	43.55	19.22	32.1	46.59	40.55	18.36	24.36
70-74	58.89	69.92	37.57	47.02	54.96	75.57	40.41	39.74
75+	238.57	132.7	126.82	90.88	238.58	147.9	143.72	73.04

Source: Sample Vital registration System (SVRS) 2002, 2010, 2012. Bangladesh Bureau of Statistics (BBS).

Table 5.4c: Trend of the observed age-specific death rates (ASDRs), 1981-2011(Urban)

Mortality rates (per 1000 population)								
Age group	Male				Female			
	1981	1991	2001	2011	1981	1991	2001	2011
0	83.9	72.37	43.08	27.11	76.69	65.25	41.95	30.55
1-4	8.45	8.99	3.39	1.6	8.7	8.49	3.77	1.68
5-9	1.09	2.58	0.88	0.6	1.04	2.4	0.84	0.41
10-14	0.88	1.11	0.63	0.95	1.06	1.04	0.61	0.44
15-19	1.07	1.02	0.8	0.32	1.41	1.58	0.88	0.93
20-14	1.33	1.41	1.13	0.73	1.75	1.94	1.07	0.58
25-29	1.45	1.89	1.11	1.18	2.01	2.51	1.35	0.93
30-34	1.73	2.04	1.36	1.29	2.34	3.1	1.42	1.03
35-39	2.04	2.62	1.54	1.58	4.22	4.46	1.75	2.04
40-44	6.09	3.89	2.08	3.56	7.75	5.03	2.14	1.67
45-49	8.1	4.71	2.79	4.85	9.38	7.67	2.62	2.33
50-54	9.89	10.15	4.19	10.51	14.54	10.86	4.18	5.48
55-59	21.5	15.93	8.99	16.16	24.74	15.45	8.02	8.74
60-64	26.62	28.16	12.32	17.9	31.61	30.15	9.65	14.58
65-69	45.93	37.52	12.87	31.46	44.38	40.53	13.4	30.01
70-74	58.61	49.97	29.45	49.47	56.14	58.72	31.72	43.1
75+	113.14	119.8	96.18	94.8	102.56	140.57	105.7	72.49

Source: Sample Vital registration System (SVRS) 2002, 2010, 2012. Bangladesh Bureau of Statistics (BBS).

5.2.3 Patterns of change for sex-specific mortality trend

Studies on sex differences in health in a large number of countries has brought to light an important paradox: women use more health services and report worse self-rated health than men, but women are less likely to die than same-aged men throughout the life, indicating that they may, in fact, be healthier. This paradox has been the subject of earlier studies, starting with that by Nathanson (1975) and followed by numerous others (see e.g., Idler 2003; Maclntyre, Ford, and Hunt 1999; Molarius and Janson 2002; Verbrugge 1989). There are several possible explanations for the worse self-rated health but lower mortality of women. First, there may be sex differences in the distributions of chronic conditions, driven by biological, behavioral, or psychological factors (Lawlor, Ebrahim, and Davey Smith 2001; Molarius and Janson 2002; Verbrugge 1989). Women may be more likely than men to suffer from health conditions such as cardiovascular disease (CVD) or respiratory conditions that not only contribute to worse self-rated health but also have relatively large effects on the probability of death. Although this explanation does not address why women and men have different distributions of health conditions, it may account for the sex differences in self-rated health and mortality that have been observed. Second, women may be healthier than men (as evidenced by their lower mortality), but simply report worse health on surveys. A commonly held view is that since women are less stoical than men, they are more likely to factor less-serious ailments into their reports of poor health (Spiers et al. 2003). A twist on the same idea is that women are more accurate reporters of health than are men: they know more about their own health, perhaps because of their greater use of health care, and are more willing to discuss their health and admit health problems to interviewers (Idler 2003; Verbrugge 1989). Although these ideas have been expressed in many studies, they are not uncontroversial.

However, there is no clear idea about the cause of these differences. According to some of the researchers, the difference in mortality between male and female may be caused by the biological and behavioral factors (Waldron, 1993, 1995). Waldron shows that higher rate of cigarette smoking habit in men contribute roughly half of the adult sex-difference in mortality. For judging the sex-difference in mortality she relies on univariate rather than multivariate decomposition (Waldron, 1992). In contrast, Wingard (1982) found a much smaller effect of smoking on sex-differences in mortality by a multivariate decomposition. Waldron also showed some other causes of sex-difference in mortality, such as occupational hazard, accident and violence, and biological lower vulnerability are also other causes of higher male mortality than female. It has been shown that multiple causes are at work (for example, personal behavior of smoking and diet, accident risk etc.) to make disparity in mortality between male and female Lopez (1981). Again the socio-economic status is also another most important cause of sex-difference in mortality, which is to be measured by occupation and social life status Vallin (1995). From the above literature, it is perceptible that sex-difference in mortality study is one of the most important matters of mortality analysis and forecasting. We would like to commence by demonstrating the rate of mortality changes for male and female separately to focus on this reason.

In Table 5.5a the proportionate rates of the change of male and female mortality rate are depicted during the five-year intervals at national level in Bangladesh. It is observed the same prototype of declining rate for both males and females. The negative values are shaded in the Table 5.5a which indicates the declining of mortality rate during the period. The period 1996-2001 is the most impressive period than all the others, while the period 1981-1986 is frustrating than the others. However, it is remarkable that the infant and child mortality and old-age mortality declines during all periods. It has been also seen approximately same picture for rural and urban areas from the Table 5.5b and Table 5.5c respectively.

Table 5.6a demonstrates the difference of mortality rate changes between male and female at national level. There has been appeared a major diverse pattern from comparative study on change in mortality rate between male and female. Negative values are shaded here in the Table 5.6a and it means that the male mortality decline rate is larger than that of female, while the positive values means that the female mortality rate is quickly declined than that of male. It is commonly observed that the female mortality has declined less than the male among infant and child ages (0-14) in most of the periods. Tremendous improvement appears in the female mortality at the reproductive age groups (15-49) over the periods 1991-96 and 1996-2001 where the female mortality decline rate is greater than male. In the last period (2006-11) female mortality declining rate is higher than male among all the reproductive age, early old age and old age groups except 15-19, 35-39 and 70-74 age groups. Whereas in the period 2001-2006, female mortality decline rate is faster than male from the age group 35-39 and onwards. In the first two age groups 1981-86 and 1986-91, it is seen that old age (65-69 to 75 and over) mortality of female declines quickly than male. Table 5.6b and Table 5.6c illustrate the Sex difference of mortality for rural and urban areas. The scenario is more or less alike as national level. The sex difference in mortality indicates that the infant and child mortality and old-age mortality are dominating the age-specific mortality among all age groups. As these two types of mortality have considerable effect on increase of life expectancy than any other age group, it is indispensable to highlight on the infant and child mortality and old-age mortality improvements.

Table 5.5a: Trend of sex specific mortality change by age in Bangladesh, 1981-2011(National)

Mortality change												
Age Group	Male						Female					
	1981-86	1986-91	1991-96	1996-01	2001-06	2006-11	1981-86	1986-91	1991-96	1996-01	2001-06	2006-11
0	-0.009	-0.07	-0.139	-0.237	-0.139	-0.313	-0.011	-0.069	-0.135	-0.228	-0.168	-0.296
1-4	0.092	-0.064	-0.228	-0.5	0.034	-0.405	0.095	-0.115	-0.164	-0.627	-0.017	-0.387
5-9	0.847	0.097 0.9	-0.235	-0.734	0.821	-0.401	0.562	0.061	-0.222	-0.649	0.703	-0.516
10-14	0.576	0.09 0.25	-0.165	-0.507	0.500	-0.038	0.500	0.078	-0.151	-0.457	0.057	0.000
15-19	0.837	0.15 -0.21	-0.128	-0.453	0.108	-0.291	0.587	0.084	-0.186	-0.557	0.312	-0.230
20-14	0.787	0.20 -0.45	-0.03	-0.236	-0.035	-0.422	0.722	0.140	-0.123	-0.423	0.019	-0.488
25-29	0.921	0.18 -0.01	-0.097	-0.383	-0.199	-0.062	0.950	0.156	-0.152	-0.517	0.108	-0.384
30-34	0.880	0.15 -0.4	-0.144	-0.489	0.095	-0.145	0.698	0.089	-0.178	-0.551	0.291	-0.568
35-39	0.403	0.04 -0.6	-0.198	-0.542	0.473	-0.229	0.556	0.068	-0.206	-0.600	0.200	-0.105
40-44	0.091	-0.043	-0.176	-0.376	0.278	-0.052	0.072	-0.074	-0.181	-0.447	-0.046	-0.178
45-49	0.123	-0.052	-0.222	-0.503	0.541	0.007	0.208	-0.021	-0.219	-0.533	0.114	-0.331
50-54	0.035	-0.096	-0.249	-0.522	0.913	-0.019	-0.006	-0.113	-0.248	-0.489	0.283	-0.056
55-59	0.026	-0.094	-0.234	-0.477	0.791	-0.065	-0.085	-0.157	-0.261	-0.456	0.327	-0.165
60-64	0.124	-0.045	-0.209	-0.471	0.609	-0.134	0.108	-0.049	-0.206	-0.454	0.522	-0.226
65-69	-0.061	-0.143	-0.251	-0.452	0.795	0.022	-0.015	-0.113	-0.237	-0.455	0.627	-0.046
70-74	0.192	-0.002	-0.165	-0.392	0.772	-0.241	0.309	0.041	-0.149	-0.395	0.192	-0.109
75+	-0.292	-0.257	-0.032	-0.033	-0.116	-0.111	-0.222	-0.199	-0.141	-0.038	-0.281	-0.230

Note: Negative sign indicates the decreasing tendency of mortality rates change for both male and female. *Rates of mortality changes are calculated as $\frac{M(x,t+5)-M(x,t)}{M(x,t)}$ for male and $\frac{F(x,t+5)-F(x,t)}{F(x,t)}$ for female. Where $M(x,t)$ and $F(x,t)$ are indicating the male and female mortality rate in age interval and t indicates time.

Table 5.5b: Trend of sex specific mortality change by age in Bangladesh, 1981-2011(Rural)

Age Group	Mortality change: Male 1981-86	1986-91	1991-96	1996-01	2001-06	2006-11	Female 1981-86	1986-91	1991-96	1996-01	2001-06	2006-11
0	0.162	-0.234	-0.085	-0.183	-0.170	-0.279	0.111	-0.148	-0.140	-0.179	-0.234	-0.270
1-4	-0.057	0.191	-0.409	-0.536	0.053	-0.347	0.208	-0.126	-0.148	-0.558	-0.135	-0.314
5-9	0.520	0.316	-0.445	-0.662	0.827	-0.292	0.259	0.292	-0.342	-0.590	0.817	-0.456
10-14	0.792	-0.011	-0.156	-0.523	0.528	-0.055	0.237	0.391	-0.119	-0.482	0.247	-0.022
15-19	1.049	0.057	-0.063	-0.531	0.061	-0.106	0.741	0.112	0.072	-0.680	0.537	-0.356
20-14	0.734	0.117	0.109	-0.280	-0.111	-0.386	1.019	0.056	-0.152	-0.356	-0.070	-0.422
25-29	0.921	0.256	-0.125	-0.316	-0.258	-0.089	0.872	0.297	-0.249	-0.451	0.267	-0.443
30-34	0.877	0.283	-0.279	-0.409	0.223	-0.207	0.421	0.334	-0.319	-0.454	0.413	-0.646
35-39	-0.202	0.853	-0.330	-0.468	0.554	-0.213	0.520	0.169	-0.357	-0.510	0.296	-0.193
40-44	-0.025	0.156	-0.241	-0.287	0.168	-0.089	0.114	-0.057	-0.115	-0.457	-0.042	-0.142
45-49	-0.289	0.594	-0.238	-0.484	0.460	0.055	-0.122	0.418	-0.162	-0.527	0.051	-0.317
50-54	-0.162	0.122	-0.390	-0.400	0.790	-0.079	-0.383	0.470	-0.333	-0.405	0.261	-0.049
55-59	-0.198	0.190	-0.402	-0.362	0.804	-0.120	-0.172	-0.045	-0.335	-0.416	0.342	-0.171
60-64	-0.080	0.186	-0.372	-0.316	0.619	-0.133	-0.240	0.502	-0.360	-0.311	0.383	-0.187
65-69	0.099	-0.252	-0.215	-0.438	0.597	0.046	-0.045	-0.089	-0.237	-0.406	0.526	-0.130
70-74	0.025	0.158	-0.173	-0.351	0.676	-0.253	0.214	0.132	-0.155	-0.367	0.103	-0.109
75+	-0.323	-0.178	-0.116	0.082	-0.173	-0.134	-0.259	-0.164	-0.087	0.065	-0.337	-0.234

Note: Negative sign indicates the decreasing tendency of mortality rates change for both male and female.

*Rates of mortality changes are calculated as $\frac{M(x,t+5)-M(x,t)}{M(x,t)}$ for male and $\frac{F(x,t+5)-F(x,t)}{F(x,t)}$ for female. Where $M(x,t)$ and $F(x,t)$ are indicating the male and female mortality rate in age interval and t indicates time.

Table 5.5c: Trend of sex specific mortality change by age in Bangladesh, 1981-2011(Urban)

Age Group	Mortality change											
	Male						Female					
	1981-86	1986-91	1991-96	1996-01	2001-06	2006-11	1981-86	1986-91	1991-96	1996-01	2001-06	2006-11
0	0.234	-0.301	-0.204	-0.253	-0.155	-0.255	0.270	-0.330	-0.161	-0.233	0.056	-0.310
1-4	0.174	-0.094	-0.367	-0.404	-0.091	-0.481	0.222	-0.201	-0.326	-0.341	-0.058	-0.527
5-9	0.963	0.206	-0.132	-0.607	0.795	-0.620	2.029	-0.238	-0.167	-0.580	0.238	-0.606
10-14	0.250	0.009	0.090	-0.479	0.413	0.067	-0.255	0.316	0.125	-0.479	-0.328	0.073
15-19	0.215	-0.215	0.255	-0.375	0.238	-0.677	-0.099	0.244	0.044	-0.467	-0.114	0.192
20-14	0.459	-0.273	0.227	-0.347	0.212	-0.467	0.417	-0.218	0.093	-0.495	0.299	-0.583
25-29	0.014	0.286	-0.085	-0.358	0.018	0.044	0.642	-0.239	-0.068	-0.423	-0.415	0.177
30-34	-0.468	1.217	0.039	-0.358	-0.324	0.402	-0.188	0.632	-0.100	-0.491	-0.148	-0.149
35-39	-0.662	2.797	0.019	-0.423	0.234	-0.168	-0.441	0.890	-0.177	-0.523	-0.103	0.299
40-44	-0.401	0.066	-0.008	-0.461	0.659	0.032	-0.388	0.061	-0.093	-0.531	-0.093	-0.139
45-49	-0.364	-0.085	0.229	-0.518	0.548	0.123	-0.355	0.268	-0.117	-0.613	0.309	-0.321
50-54	0.251	-0.179	-0.162	-0.508	1.332	0.076	0.428	-0.477	-0.238	-0.495	0.330	-0.014
55-59	0.039	-0.287	-0.095	-0.376	0.781	0.009	0.018	-0.387	-0.208	-0.345	0.277	-0.146
60-64	0.417	-0.253	-0.242	-0.423	0.501	-0.032	-0.447	0.725	-0.318	-0.530	1.179	-0.307
65-69	0.055	-0.226	-0.150	-0.596	1.577	-0.052	0.162	-0.214	-0.260	-0.553	0.866	0.200
70-74	0.417	-0.398	-0.089	-0.353	1.143	-0.216	0.534	-0.318	-0.164	-0.354	0.912	-0.289
75+	0.408	-0.248	-0.067	-0.140	0.029	-0.043	0.035	0.324	-0.059	-0.201	0.044	-0.343

Note: Negative sign indicates the decreasing tendency of mortality rates change for both male and female.

*Rates of mortality changes are calculated as $\frac{M(x,t+5)-M(x,t)}{M(x,t)}$ for male and $\frac{F(x,t+5)-F(x,t)}{F(x,t)}$ for female. Where $M(x,t)$ and $F(x,t)$ are indicating the male and female mortality rate in age interval and t indicates time.

Table 5.6a: Sex differences in rates of mortality changes by age in Bangladesh, for the period, 1981-2011[a] (National)

Age Group	Period					
	1981-86	1986-91	1991-96	1996-01	2001-06	2006-11
0	0.002	-0.001	-0.004	-0.009	0.029	-0.017
1-4	-0.003	0.051	-0.064	0.127	0.051	-0.018
5-9	0.285	0.036	-0.013	-0.085	0.118	0.115
10-14	0.076	0.012	-0.014	-0.05	0.443	-0.038
15-19	0.25	0.07	0.058	0.104	-0.204	-0.061
20-14	0.065	0.062	0.093	0.187	-0.054	0.066
25-29	-0.029	0.028	0.055	0.134	-0.307	0.322
30-34	0.182	0.061	0.034	0.062	-0.196	0.423
35-39	-0.153	-0.027	0.008	0.058	0.273	-0.124
40-44	0.019	0.031	0.005	0.071	0.324	0.126
45-49	-0.085	-0.031	-0.003	0.03	0.427	0.338
50-54	0.041	0.017	-0.001	-0.033	0.63	0.037
55-59	0.111	0.063	0.027	-0.021	0.464	0.1
60-64	0.016	0.004	-0.003	-0.017	0.087	0.092
65-69	-0.046	-0.03	-0.014	0.003	0.168	0.068
70-74	-0.117	-0.043	-0.016	0.003	0.58	-0.132
75+	-0.07	-0.058	0.109	0.005	0.165	0.119

Note: The value of positive sign indicates that male mortality rate is relatively high to female mortality rate and negative sign indicates totally opposite direction.

[*]sex-differences in mortality change are calculated as $\frac{M(x,t+5)-M(x,t)}{M(x,t)}-\frac{F(x,t+5)-F(x,t)}{F(x,t)}$

where, $M(x,t)$ and $F(x,t)$ are indicating the male and female mortality rate in age interval and t indicates time.

Table 5.6b: Sex differences in rates of mortality changes by age in Bangladesh, for the period, 1981-2011[a] (Rural)

Age Group	Period					
	1981-86	1986-91	1991-96	1996-01	2001-06	2006-11
0	0.051	-0.086	0.055	-0.004	0.064	-0.009
1-4	-0.265	0.317	-0.261	0.022	0.188	-0.033
5-9	0.261	0.024	-0.103	-0.072	0.01	0.164
10-14	0.555	-0.402	-0.037	-0.041	0.281	-0.033
15-19	0.308	-0.055	-0.135	0.149	-0.476	0.25
20-14	-0.285	0.061	0.261	0.076	-0.041	0.036
25-29	0.049	-0.041	0.124	0.135	-0.525	0.354
30-34	0.456	-0.051	0.04	0.045	-0.19	0.439
35-39	-0.722	0.684	0.027	0.042	0.258	-0.02
40-44	-0.139	0.213	-0.126	0.17	0.21	0.053
45-49	-0.167	0.176	-0.076	0.043	0.409	0.372
50-54	0.221	-0.348	-0.057	0.005	0.529	-0.03
55-59	-0.026	0.235	-0.067	0.054	0.462	0.051
60-64	0.16	-0.316	-0.012	-0.005	0.236	0.054
65-69	0.144	-0.163	0.022	-0.032	0.071	0.176
70-74	-0.189	0.026	-0.018	0.016	0.573	-0.144
75+	-0.064	-0.014	-0.029	0.017	0.164	0.1

Note: The value of positive sign indicates that male mortality rate rose relatively to female mortality rate and negative sign indicates just opposite direction.

[*] sex-differences in mortality change are calculated as $\frac{M(x,t+5)-M(x,t)}{M(x,t)} - \frac{F(x,t+5)-F(x,t)}{F(x,t)}$

Where, $M(x,t)$ and $F(x,t)$ are indicating the male and female mortality rate in age interval and t indicates time.

Table 5.6c: Sex differences in rates of mortality changes by age in Bangladesh, for the period, 1981-2011[a] (Urban)

Age Group	Period					
	1981-86	1986-91	1991-96	1996-01	2001-06	2006-11
0	-0.036	0.029	-0.043	-0.02	-0.211	0.055
1-4	-0.048	0.107	-0.041	-0.063	-0.033	0.046
5-9	-1.066	0.444	0.035	-0.027	0.557	-0.014
10-14	0.505	-0.307	-0.035	0	0.741	-0.006
15-19	0.314	-0.459	0.211	0.092	0.352	-0.869
20-14	0.042	-0.055	0.134	0.148	-0.087	0.116
25-29	-0.628	0.525	-0.017	0.065	0.433	-0.133
30-34	-0.28	0.585	0.139	0.133	-0.176	0.551
35-39	-0.221	1.907	0.196	0.1	0.337	-0.467
40-44	-0.013	0.005	0.085	0.07	0.752	0.171
45-49	-0.009	-0.353	0.346	0.095	0.239	0.444
50-54	-0.177	0.298	0.076	-0.013	1.002	0.09
55-59	0.021	0.1	0.113	-0.031	0.504	0.155
60-64	0.864	-0.978	0.076	0.107	-0.678	0.275
65-69	-0.107	-0.012	0.11	-0.043	0.711	-0.252
70-74	-0.117	-0.08	0.075	0.001	0.231	0.073
75+	0.373	-0.572	-0.008	0.061	-0.015	0.3

Note: The value of positive sign indicates that male mortality rate rose relatively to female mortality rate and negative sign indicates just opposite direction.

[*]sex-differences in mortality change are calculated as $\frac{M(x,t+5)-M(x,t)}{M(x,t)} - \frac{F(x,t+5)-F(x,t)}{F(x,t)}$

where, $M(x, t)$ and $F(x, t)$ are indicating the male and female mortality rate in age interval and t indicates time.

5.3 Sensitivity analysis of life expectancy at birth due to mortality change

Sensitivity analysis (also called perturbation analysis) of e^0 asks how the results of the life expectancy at birth would change in response to changes in the mortality. Sensitivity analysis is useful because it can project the consequences of changes in the mortality rates. Such changes could result from human actions, either intentional (e.g., policies to encourage reproduction, public health interventions, or conservation strategies applied to endangered species) or unintentional (e.g., consequences of pollution or environmental degradation), or natural changes. It can be used to compare potential policy interventions and identify interventions that would have particularly large effects. If an outcome is particularly sensitive to a particular parameter, that parameter may be an attractive target for intervention. It can be used retrospectively to decompose observed changes in life expectancy at birth into contribution from changes in mortality.

The effect of changes in mortality on e^0 can be found by sensitivity analysis. Sensitivity analysis of e^0 can present the impact of a proportional decline in mortality in different age group (Demetrius, 1974; Keyfitz, 1977; Vaupel, 1986 and Pollard, 1988). This method has also used to investigate the sensitivity of e^0 by the change in mortality (Tuljapurkar and Boe, 1998). Let $\mu(x, t)$ be the force of mortality, $p\ (x, t)$ be the probability of survivorship at age x and time t and $e(x, t)$ represent the period life expectancy at age x. To find the effect of function $\mu(x, t)$ on $e(x, t)$, Demetrius and Keyfitz have defined a variant measure 'H' which is known as entropy or information in other perspective. The heterogeneity of a population with respect to mortality rate at different ages can be measured by the variant measure 'H'. Here H=0 implies that everyone dies at the same age and H=1 implies that the force of mortality is equal at all ages. The formula they defined to investigate the percentage change of e_0 is as follows:

$$H(t) = \frac{\int_0^w p(x,t)\int_0^x \mu(a,t)\,da\,dx}{\int_0^w p(x,t)\,dx}$$

Another alternative expression of 'H' has been given by them and using its decomposition technique, it can be categorized the percentage change of e^0 by age group separately and collectively. The alternative expression is as follows

$$H(t) = \frac{\int_0^w \int_0^x p(x,t)\mu(a,t)\,da\,dx}{e(0,t)} = \frac{\int_0^w \int_x^w p(x,t)\mu(a,t)\,da\,dx}{e(0,t)} = \frac{\int_0^w \int_0^w \mu(x,t)p(x,t)e(x,t)\,dx}{e(0,t)}$$

And its decomposition formula is; $\eta(x) = \frac{\mu(x,t)\,p(x,t)e(x,t)}{e(0,t)}; where, H(t) = \int_0^w \eta(x,t)dx$

Here, w represents an individual's highest living age of, $\eta(x, t)$ is a possible measure of increasing life expectancy (or equal to saving life in years) by reducing mortality at age x and $H(t)$ is a measure of percentage change of increasing life expectancy by total mortality reduce at time t. The values of $\eta(x, t)$ will be comparatively higher for those age groups which have major effect on e^0 by mortality rate improvement.

Table 5.7 illustrates the change of e^0 for the change of mortality during the period 1981-2011 at national level as well as rural and urban areas. At national level the highest increasing rate of e^0 is 19.03% for male and 18.73% for female in 1991, whereas the lowest increasing rate is in 2001, which is 11.20% for males and 10.82% for females. In rural areas highest increasing is found in 1991 (19.45% for males and 19.11 for females) and lowest increasing is found in 2001 (11.74% for males and 11.43% for females). That means changing pattern of rural areas follows national level. Again in urban areas highest increasing period is different from national level and it is in 1986 (16.00% for males and 18.07% for females). But the highest decreasing period in urban areas is same as national level and that is in 2001 (9.72% for males and 9.42% for females). It has been seen an increasing tendency till 1991 and after that it is decreasing both at national level and in rural areas. However, in urban areas increasing tendency is seen till 1986 and then it is decreasing. Figure 5.1a exhibits the trend of the logarithmic values of $\eta(x, t)$ for males and Figure 5.1b for females at national level during the period 1981-2011. More or less similar trends are seen in these two figures. The infant and child mortality has major effect on e^0 for both males and females in these two figures. The old-age mortality decline has also an amazing effect on e^0 throughout the period (1981-2011). Figures 5.2a and 5.2b display the logarithmic sensitivity of rural areas for males and females respectively, whereas, the figures 5.3a and 5.3b display the same for urban areas. The pictures of rural and urban areas are somewhat alike as national level. Hence from all the figures (5.1a, 5.1b, 5.2a, 5.2b, 5.3a and 5.3b), we can see an important aspect that increase of e^0 depends on infant and child mortality decline and also to some extent adult and old age mortality decline. As a result, those mortality declines have increased the individual life span. That means people become older than before. The old-age mortality (50-54, to 70-74) in Bangladesh is still high compared to the countries with high e^0 (nearly 80 years or above), that's why it has also some importance in increase the e_0. Thus, it can be concluded that the sensitivity analysis of e^0 implies that the decreasing tendency in mortality mostly, the infant and child as well as old-age mortality and to some extent adult-age mortality will have considerable effects on the increasing trend of the e^0 in Bangladesh.

Table 5.7: Values of $H(t) = \int_0^w \eta(x,t)dx$ for males and females in Bangladesh, for the period 1981-2011.

Year	National		Rural		Urban	
	Male	Female	Male	Female	Male	Female
1981	0.1636	0.1665	0.1664	0.1648	0.1598	0.1739
1986	0.1805	0.1820	0.1827	0.1828	0.1600	0.1807
1991	0.1903	0.1873	0.1945	0.1911	0.1522	0.1548
1996	0.1590	0.1569	0.1653	0.1675	0.1388	0.1367
2001	0.1120	0.1082	0.1174	0.1143	0.0972	0.0942
2006	0.1348	0.1266	0.1387	0.1312	0.1209	0.1087
2011	0.1207	0.1111	0.1260	0.1151	0.1102	0.1038

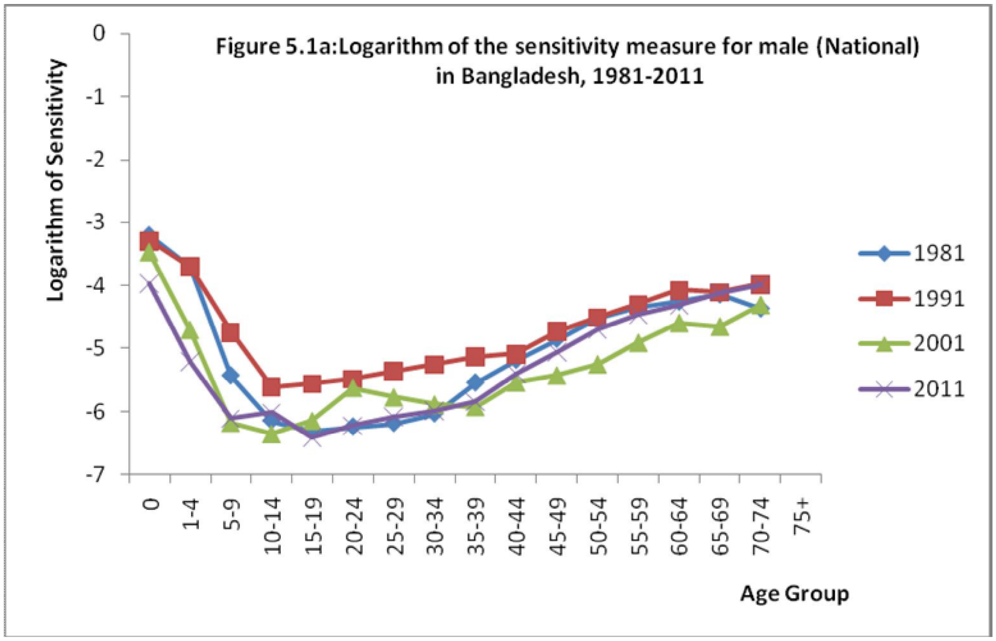


Figure 5.1a:Logarithm of the sensitivity measure for male (National) in Bangladesh, 1981-2011
Logarithm of Sensitivity
0
-1
-2
-3
-4
-5
-6
-7
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group
1981
1991
2001
2011

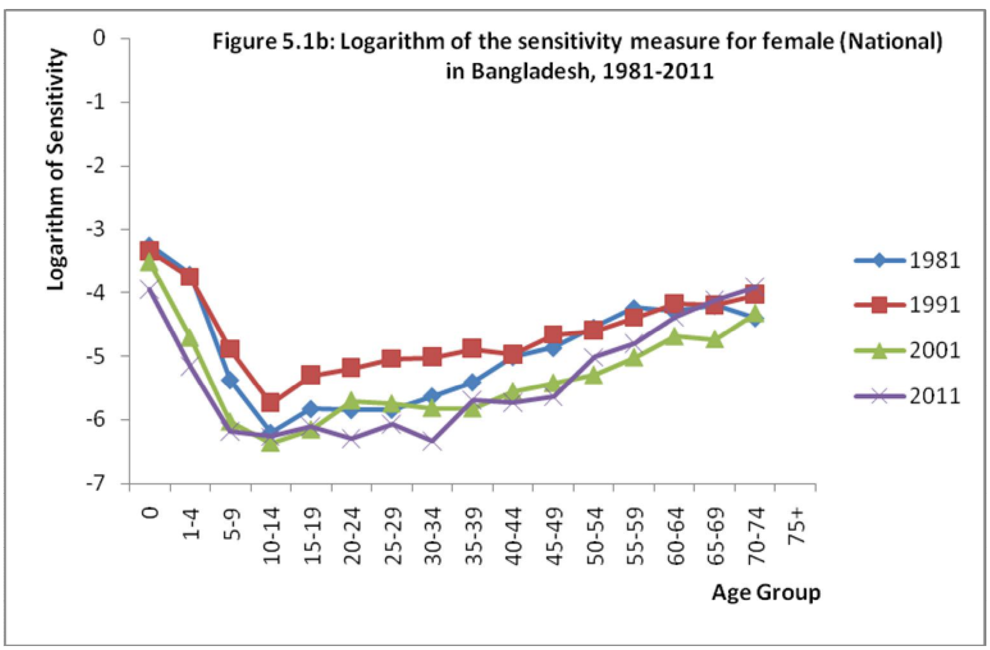


Figure 5.1b: Logarithm of the sensitivity measure for female (National) in Bangladesh, 1981-2011
Logarithm of Sensitivity
0
-1
-2
-3
-4
-5
-6
-7
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group
1981
1991
2001
2011

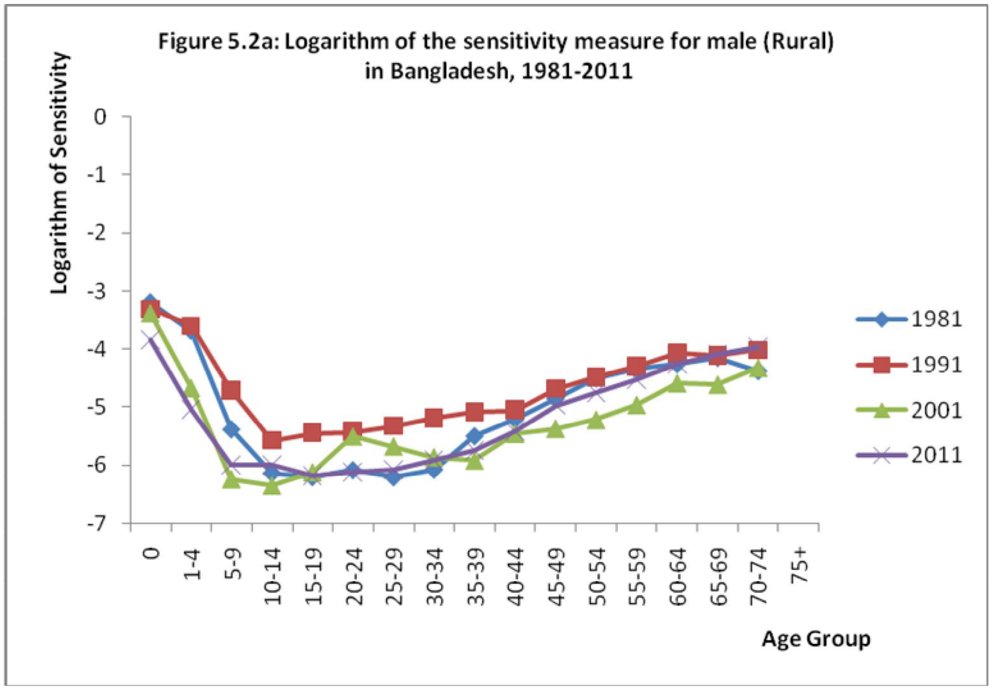


Figure 5.2a: Logarithm of the sensitivity measure for male (Rural) in Bangladesh, 1981-2011
Logarithm of Sensitivity
0
-1
-2
-3
-4
-5
-6
-7
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group
1981
1991
2001
2011

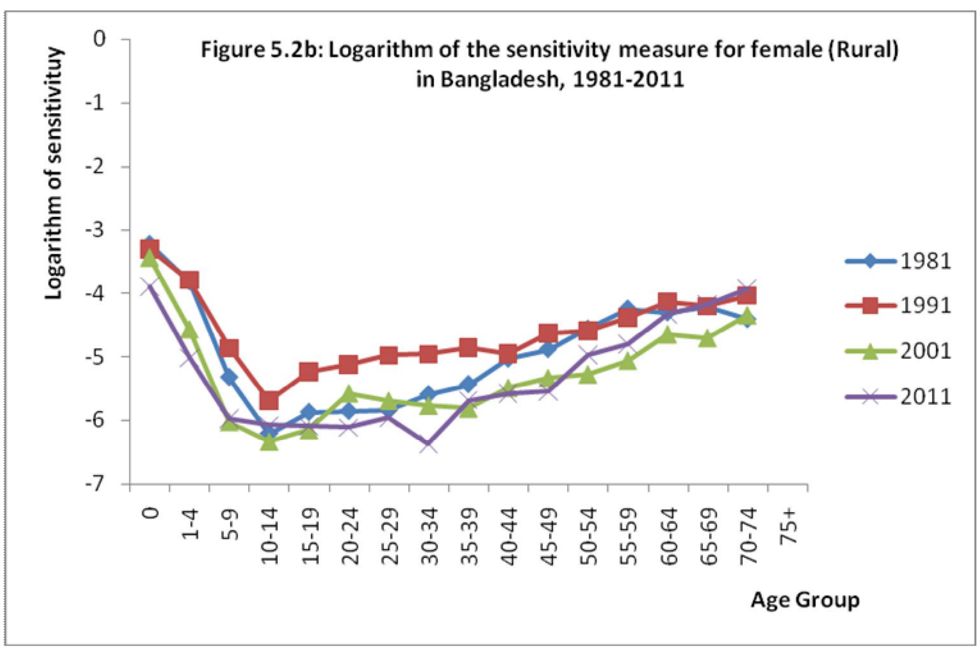


Figure 5.2b: Logarithm of the sensitivity measure for female (Rural) in Bangladesh, 1981-2011
Logarithm of sensitivituy
0
-1
-2
-3
-4
-5
-6
-7
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group
1981
1991
2001
2011

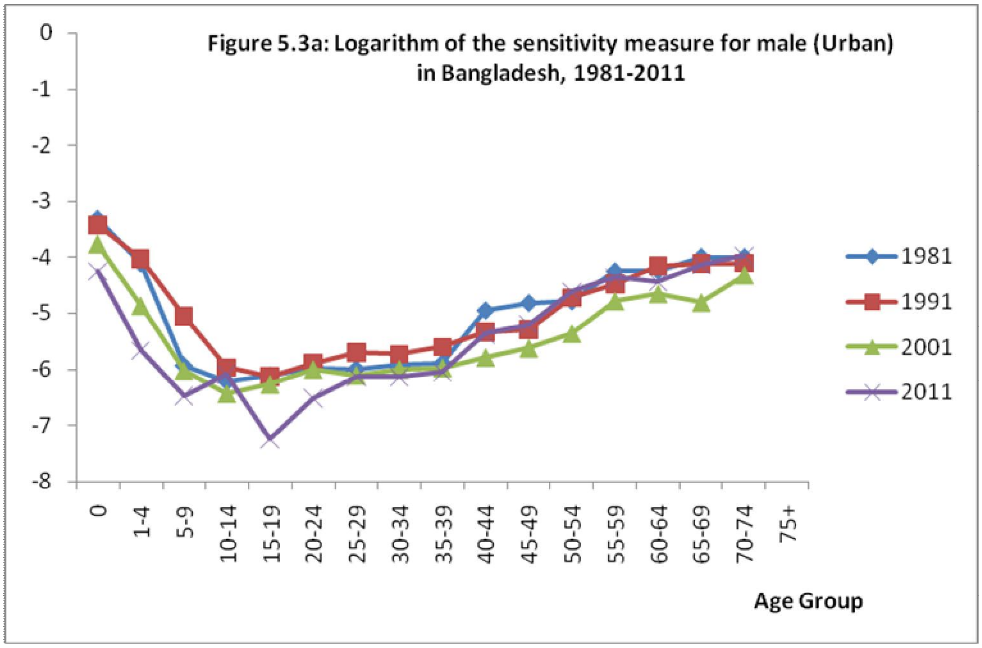


Figure 5.3a: Logarithm of the sensitivity measure for male (Urban) in Bangladesh, 1981-2011
0
-1
-2
-3
-4
-5
-6
-7
-8
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group
1981
1991
2001
2011

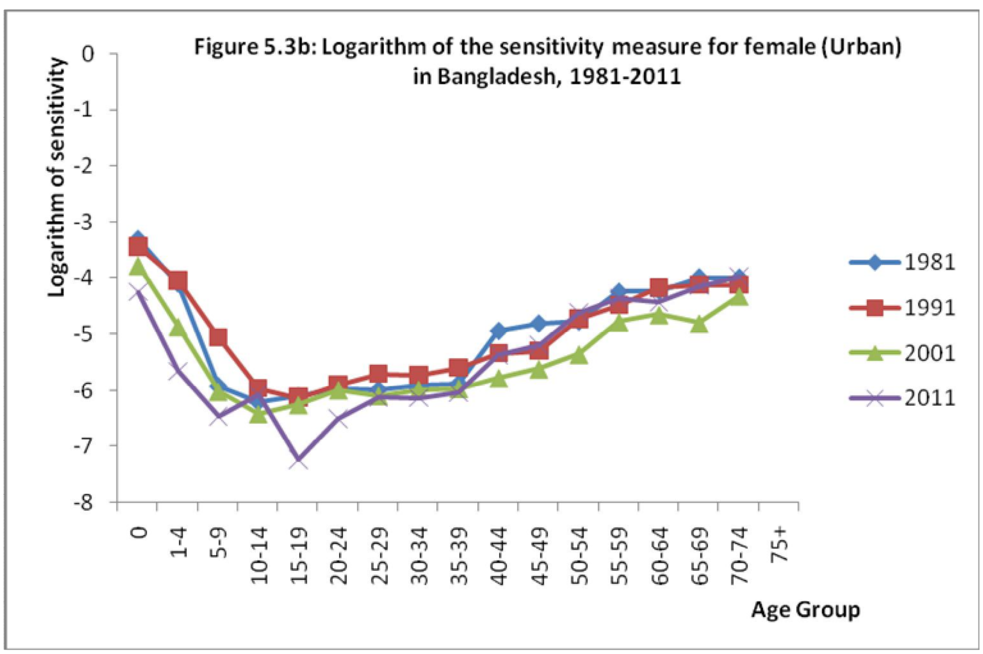


Figure 5.3b: Logarithm of the sensitivity measure for female (Urban) in Bangladesh, 1981-2011
Logarithm of sensitivity
0
-1
-2
-3
-4
-5
-6
-7
-8
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group
1981
1991
2001
2011

5.4 Decomposition of changes in mortality trends

Decomposition is a technique which identifies the amount of the difference between the death rates in census populations A and B (A and B indicate two census periods, such as 1981 and 1991, 1991 and 2001, 2001 and 2011, 1981 and 2011) attributable to differences in their age distributions (Kitagawa, 1955). In this study it is used to distribute the change of CDR between two components which is also used by Ogawa in 1978. Let us suppose that we are interested in decomposing the difference between the crude death rates in populations A and B. The original difference can be defined as Δ.

Here, $\Delta = CDR^B - CDR^A = \sum_i C_i^B.M_i^B - \sum_i C_i^A.M_i^A$, Where, C_i = Age composition proportion of population, M_i = Age specific mortality distribution, A and B stand for the two census periods.

$$\text{Or,}\quad \Delta = \frac{\sum_i C_i^B.M_i^B}{2} + \frac{\sum_i C_i^B.M_i^B}{2} - \frac{\sum_i C_i^A.M_i^A}{2} - \frac{\sum_i C_i^A.M_i^A}{2} + \frac{\sum_i C_i^B.M_i^A}{2} - \frac{\sum_i C_i^B.M_i^A}{2} + \frac{\sum_i C_i^A.M_i^B}{2} - \frac{\sum_i C_i^A.M_i^B}{2}$$

$$= \sum_i C_i^B.\left[\frac{M_i^B + M_i^A}{2}\right] - \sum_i C_i^A.\left[\frac{M_i^B + M_i^A}{2}\right] + \sum_i M_i^B.\left[\frac{C_i^A + C_i^B}{2}\right] - \sum_i M_i^A.\left[\frac{C_i^A + C_i^B}{2}\right]$$

$$= \sum_i \left(C_i^B - C_i^A\right).\left[\frac{M_i^B + M_i^A}{2}\right] - \sum_i \left(M_i^B - M_i^A\right).\left[\frac{C_i^A + C_i^B}{2}\right] \quad \ldots\ldots\ldots\ldots (5.1)$$

= difference in age composition. [weighted by average age specific mortality]

+ difference in rate schedules . [weighted by average age composition]

= contribution of age compositional differences to Δ + contribution of rate schedule differences in Δ

Using the above CDR decomposition formula CDR can be split into two components, one is compositional change in age specific proportion of population and another is age specific mortality rate schedule between two census periods.

Table 5.8a depicts the application of the above procedure (5.1) to the decomposition of differences between the crude death rates in different census populations for males at national level. It has been observed that difference in age composition of population account for 43% of the difference between crude death rates of 1981 and 1991 census populations of Bangladesh and difference in rate schedules account for the remaining 57%. In this case, both factors contribute in the same direction to the difference. Between 1991 and 2001 populations the contribution of age composition is 4% and rate schedule is 96% and also the direction of both factors is same. But between 2001 and 2011 the difference of both the factors contribute in opposite direction. The same thing happens between 1981 and 2011 populations as well. Similarly Table 5.8b shows the decomposition of differences between crude death rates of different census populations for female. Here in this Table it is seen that both the factors contribute in the same direction between 1981 and 1991 and also between 1991 and 2001; whereas, both the factors contribute in opposite direction between 2001 and 2011 as well as 1981 and 2011.

Table 5.9a and 5.9b demonstrate the contribution of both the factors of rural areas for males and females respectively and Table 5.10a and 5.10b demonstrate the same for urban areas. In most of the cases age specific mortality rate schedule contribute greatly to the differences than age composition of population.

Table 5.8a: Decomposition of differences of CDR in different census periods for male (national)

Decomposition Period	Decomposition result
1981 to 1991	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}=0.012847$; $CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}=0.011608$ Original differences= $CDR^{1991}- CDR^{1981}$=0.011608-0.012847=-0.001239 Contribution of age compositional differences=-0.000534 Contribution of age specific rate differences=-0.000704 Total contribution=-0.001239 Proportion of difference attributable to differences in age composition =-0.000534/-0.001239=0.43=43% Proportion of difference attributable to differences in rate schedule =-0.000704/-0.001239=0.57=57%
1991 to 2001	$CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}=0.011608$; $CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}=0.005976$ Original differences= $CDR^{2001}- CDR^{1991}$=0.005976-0.011608=-0.005632 Contribution of age compositional differences=-0.000245 Contribution of age specific rate differences=-0.005387 Total contribution=-0.005632 Proportion of difference attributable to differences in age composition =-0.000245/-0.005632=0.043=4% Proportion of difference attributable to differences in rate schedule =-0.005387/-0.005632=0.96=96%
2001 to 2011	$CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}=0.005976$; $CDR^{2011}=\Sigma C_i^{2011}.M_i^{2011}=0.006223$ Original differences= $CDR^{2011}- CDR^{2001}$=0.006223-0.005976=0.000247 Contribution of age compositional differences=0.000347 Contribution of age specific rate differences=-0.000100 Total contribution=0.000247 Proportion of difference attributable to differences in age composition =0.000347/0.000247=1.4=140% Proportion of difference attributable to differences in rate schedule =-0.000100/0.000247=-0.40=-40%
1981 to 2011	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}=0.012847$; $CDR^{2011}=\Sigma C_i^{2011}.M_i^{2011}=0.006223$ Original differences= $CDR^{2011}- CDR^{1981}$=0.006223-0.012847=-0.006624 Contribution of age compositional differences=0.000081 Contribution of age specific rate differences=-0.006705 Total contribution=-0.006624 Proportion of difference attributable to differences in age composition =0.000081/-0.006624=-0.01=-1% Proportion of difference attributable to differences in rate schedule =-0.006705/-0.006624=1.01=101%

Table 5.8b: Decomposition of differences of CDR in different census periods for female (national)

Decomposition Period	Decomposition result
1981 to 1991	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}$=0.012100; $CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}$=0.011110 Original differences= CDR^{1991}- CDR^{1981}=0.011110-0.012100=-0.00099 Contribution of age compositional differences=-0.000810 Contribution of age specific rate differences=-0.000180 Total contribution=-0.00099 Proportion of difference attributable to differences in age composition =-0.000810/-0.00099=0.818=82% Proportion of difference attributable to differences in rate schedule =-0.000180/-0.00099=0.1818=18%
1991 to 2001	$CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}$=0.01111; $CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}$=0.005690 Original differences= CDR^{2001}- CDR^{1991}=0.005690-0.01111=-0.00542 Contribution of age compositional differences=-0.000197 Contribution of age specific rate differences=-0.005223 Total contribution=-0.00542 Proportion of difference attributable to differences in age composition =-0.000197/-0.00542=0.036=4% Proportion of difference attributable to differences in rate schedule =-0.005223/-0.00542=0.96=96%
2001 to 2011	$CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}$=0.005659; $CDR^{2011}=\Sigma C_i^{2011}.M_i^{2011}$=0.004734 Original differences= CDR^{2011}- CDR^{2001}=0.004734-0.005659=-0.000956 Contribution of age compositional differences=0.000514 Contribution of age specific rate differences=-0.001470 Total contribution=-0.000956 Proportion of difference attributable to differences in age composition =0.000514/-0.000956=-0.54=-54% Proportion of difference attributable to differences in rate schedule =-0.001470/-0.000956=1.54=154%
1981 to 2011	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}$=0.0121; $CDR^{2011}=\Sigma C_i^{2011}.M_i^{2011}$=0.004734 Original differences= CDR^{2011}- CDR^{1981}=0.004734-0.0121=-0.007366 Contribution of age compositional differences=0.000091 Contribution of age specific rate differences=-0.007458 Total contribution=-0.007366 Proportion of difference attributable to differences in age composition =0.000091/-0.007366=-0.01=-1% Proportion of difference attributable to differences in rate schedule =-0.007458/-0.007366=1.01=101%

Table 5.9a: Decomposition of differences of CDR in different census periods for male (rural)

Decomposition Period	Decomposition result
1981 to 1991	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}=0.013576$; $CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}=0.012651$ Original differences= $CDR^{1991}-CDR^{1981}$=0.012651-0.013576=-0.000925 Contribution of age compositional differences=-0.000433 Contribution of age specific rate differences=-0.000493 Total contribution=-0.000925 Proportion of difference attributable to differences in age composition =-0.000433/-0.000925=0.468=47% Proportion of difference attributable to differences in rate schedule =-0.000493/-0.000925=0.533=53%
1991 to 2001	$CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}=0.012651$; $CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}=0.006813$ Original differences= $CDR^{2001}-CDR^{1991}$=0.006813-0.012651=-0.00584 Contribution of age compositional differences=-0.000202 Contribution of age specific rate differences=-0.005635 Total contribution=-0.00584 Proportion of difference attributable to differences in age composition =-0.000202/-0.00584=0.035=4% Proportion of difference attributable to differences in rate schedule =-0.005635/-0.00584=0.96=96%
2001 to 2011	$CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}=0.006813$; $CDR^{2011}=\Sigma C_i^{2011}.M_i^{2011}=0.006562$ Original differences= $CDR^{2011}-CDR^{2001}$=0.006562-0.006813=-0.000252 Contribution of age compositional differences=0.000202 Contribution of age specific rate differences=-0.000454 Total contribution=-0.000252 Proportion of difference attributable to differences in age composition =0.000202/-0.000252=-0.80=-80% Proportion of difference attributable to differences in rate schedule =-0.000454/-0.00052=1.80=180%
1981 to 2011	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}=0.013576$; $CDR^{2011}=\Sigma C_i^{2011}.M_i^{2011}=0.006562$ Original differences= $CDR^{2011}-CDR^{1981}$=0.006562-0.013576=-0.007014 Contribution of age compositional differences=-0.000047 Contribution of age specific rate differences=-0.006967 Total contribution=-0.007014 Proportion of difference attributable to differences in age composition =-0.000047/-0.007014=0.01=1% Proportion of difference attributable to differences in rate schedule =-0.006967/-0.007014=0.99=99%

Table 5.9b: Decomposition of differences of CDR in different census periods for female (rural)

Decomposition Period	Decomposition result
1981 to 1991	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}$=0.012147; $CDR^{1991}= \Sigma C_i^{1991}.M_i^{1991}$=0.011744 Original differences= CDR^{1991}- CDR^{1981}=0.011744-0.012147=-0.000403 Contribution of age compositional differences=-0.000629 Contribution of age specific rate differences=0.000226 Total contribution=-0.000403 Proportion of difference attributable to differences in age composition =-0.000629/-0.000403=1.56=156% Proportion of difference attributable to differences in rate schedule =0.000226/-0.000925=-0.56=-56%
1991 to 2001	$CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}$=0.011744; $CDR^{2001}= \Sigma C_i^{2001}.M_i^{2001}$=0.006454 Original differences= CDR^{2001}- CDR^{1991}=0.006454-0.011744=-0.00529 Contribution of age compositional differences=-0.000158 Contribution of age specific rate differences=-0.005132 Total contribution=-0.00529 Proportion of difference attributable to differences in age composition =-0.000158/-0.00529=0.03=3% Proportion of difference attributable to differences in rate schedule =-0.005132/-0.00529=0.97=97%
2001 to 2011	$CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}$=0.006454; $CDR^{2011}= \Sigma C_i^{2011}.M_i^{2011}$=0.005046 Original differences= CDR^{2011}- CDR^{2001}=0.005046-0.006454=-0.001408 Contribution of age compositional differences=0.000517 Contribution of age specific rate differences=-0.001925 Total contribution=-0.001408 Proportion of difference attributable to differences in age composition =0.000517/-0.001408=-0.37=-37% Proportion of difference attributable to differences in rate schedule =-0.001925/-0.001408=1.37=137%
1981 to 2011	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}$=0.012147; $CDR^{2011}= \Sigma C_i^{2011}.M_i^{2011}$=0.005046 Original differences= CDR^{2011}- CDR^{1981}=0.005046-0.012147=-0.007101 Contribution of age compositional differences=0.000315 Contribution of age specific rate differences=-0.007416 Total contribution=-0.007101 Proportion of difference attributable to differences in age composition =0.000315/-0.007101=-0.04=-4% Proportion of difference attributable to differences in rate schedule =-0.007416/-0.007101=1.04=104%

Table 5.10a: Decomposition of differences of CDR in different census periods for male (urban)

Decomposition Period	Decomposition result
1981 to 1991	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}=0.007832$; $CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}=0.007156$ Original differences= $CDR^{1991}-CDR^{1981}$=0.007156-0.007832=-0.000676 Contribution of age compositional differences=-0.000390 Contribution of age specific rate differences=-0.000286 Total contribution=-0.000676 Proportion of difference attributable to differences in age composition =-0.000390/-0.000676=0.58=58% Proportion of difference attributable to differences in rate schedule =-0.000286/-0.000676=0.42=42%
1991 to 2001	$CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}=0.007156$; $CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}=0.003986$ Original differences= $CDR^{2001}-CDR^{1991}$=0.003986-0.007156=-0.00317 Contribution of age compositional differences=-0.000070 Contribution of age specific rate differences=-0.003100 Total contribution=-0.00317 Proportion of difference attributable to differences in age composition =-0.00007/-0.00317=0.02=2% Proportion of difference attributable to differences in rate schedule =-0.003100/-0.00317=0.98=98%
2001 to 2011	$CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}=0.003986$; $CDR^{2011}=\Sigma C_i^{2011}.M_i^{2011}=0.005436$ Original differences= $CDR^{2011}-CDR^{2001}$=0.005436-0.003986=0.00145 Contribution of age compositional differences=0.000737 Contribution of age specific rate differences=0.000713 Total contribution=0.00145 Proportion of difference attributable to differences in age composition =0.000737/0.00145=0.51=51% Proportion of difference attributable to differences in rate schedule =0.000713/0.00145=0.49=49%
1981 to 2011	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}=0.007832$; $CDR^{2011}=\Sigma C_i^{2011}.M_i^{2011}=0.005436$ Original differences= $CDR^{2011}-CDR^{1981}$=0.005436-0.007832=-0.002396 Contribution of age compositional differences=0.000797 Contribution of age specific rate differences=-0.003193 Total contribution=-0.002396 Proportion of difference attributable to differences in age composition =0.000797/-0.002396=-0.33=-33% Proportion of difference attributable to differences in rate schedule =-0.003193/-0.002396=1.33=133%

Table 5.10b: Decomposition of differences of CDR in different census periods for female (urban)

Decomposition Period	Decomposition result
1981 to 1991	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}=0.008711$; $CDR^{1991}= \Sigma C_i^{1991}.M_i^{1991}=0.007548$ Original differences= CDR^{1991}- CDR^{1981}=0.007548-0.008711=-0.001163 Contribution of age compositional differences=-0.001123 Contribution of age specific rate differences=-0.000041 Total contribution=-0.001163 Proportion of difference attributable to differences in age composition =-0.001123/-0.001163=0.966=97% Proportion of difference attributable to differences in rate schedule =-0.000041/-0.00163=0.03=3%
1991 to 2001	$CDR^{1991}=\Sigma C_i^{1991}.M_i^{1991}=0.007548$; $CDR^{2001}= \Sigma C_i^{2001}.M_i^{2001}=0.003956$ Original differences= CDR^{2001}- CDR^{1991}=0.003956-0.007548=-0.003591 Contribution of age compositional differences=-0.000085 Contribution of age specific rate differences=-0.003506 Total contribution=-0.003591 Proportion of difference attributable to differences in age composition =-0.000085/-0.003591=0.02=2% Proportion of difference attributable to differences in rate schedule =-0.003506/-0.003591=0.98=98%
2001 to 2011	$CDR^{2001}=\Sigma C_i^{2001}.M_i^{2001}=0.003956$; $CDR^{2011}= \Sigma C_i^{2011}.M_i^{2011}=0.004086$ Original differences= CDR^{2011}- CDR^{2001}=0.004086-0.003956=0.00013 Contribution of age compositional differences=0.000651 Contribution of age specific rate differences=-0.000521 Total contribution=0.00013 Proportion of difference attributable to differences in age composition =0.000651/0.00013=5=500% Proportion of difference attributable to differences in rate schedule =-0.000521/0.00013=4=-400%
1981 to 2011	$CDR^{1981}=\Sigma C_i^{1981}.M_i^{1981}=0.008711$; $CDR^{2011}= \Sigma C_i^{2011}.M_i^{2011}=0.004086$ Original differences= CDR^{2011}- CDR^{1981}=0.004086-0.008711=-0.004625 Contribution of age compositional differences=0.000094 Contribution of age specific rate differences=-0.004719 Total contribution=-0.004625 Proportion of difference attributable to differences in age composition =0.000094/-0.004625=-0.02=-2% Proportion of difference attributable to differences in rate schedule =-0.004719/-0.004625=1.02=102%

5.5 Summary

Analyzing the trends and differentials of mortality, this study indicates a substantial improvement in mortality as well as life expectancy at birth (e^0) during last two decades in Bangladesh. But still the mortality condition is not satisfactory compared to developed and some of the developing countries. A significant childhood mortality decline is happened over the last few decades, more noticeable in rural areas compared to urban areas. This has led to a narrowing of the gap between childhood mortality rates in rural and urban areas, though it is far from developed countries. The e^0 for males has decreased from 56.63 in 1981 to 56.39 in 1991 and then increased rapidly to 68.63 in 2011 and for females it has decreased from 56.56 in 1981 to 56.03 in 1991 and then increased rapidly to 69.81 in 2011. The pattern of e^0 in rural and urban areas is almost similar to national level. It is also evident that female mortality declines faster than male, which is the feature of universal trend. This is a great achievement for Bangladesh as the country has improved remarkably the maternal health care facilities which give tremendous outcome regarding maternal health. In fact, mortality situation has improved in all ages for both males and females.

This study has carried out the sensitivity analysis of e^0 to investigate age specific mortality impact on e^0 increase. The sensitivity analysis gives us the message that mortality decline in childhood and old age affect mostly to increase life expectancy at birth (e^0) than other age groups.

Again decomposition of differences of crude death rates between different census periods reveals that Proportion of difference attributable to differences in mortality rate schedule is higher than the Proportion of difference attributable to differences in age composition of population in most of the cases. That means the contribution of age specific mortality rate schedule is more to the differences of CDR than the contribution of age composition of population.

In spite of some development in mortality, it is still behind the developed and some of the developing countries due to the cause of high childhood mortality and early old age mortality. Therefore, it is necessary to take more steps to improve healthcare facilities in both rural and urban areas simultaneously.

Chapter VI

Modeling and Forecasting of Mortality in Bangladesh

Abstract

As a developing country, the life expectancy at birth (e^0) of Bangladesh has not increased yet with the expectation compared with the developed world as well as some of the developing countries, although the gradual progress has occurred in last two decades. In this circumstance, the aim of this chapter is to determine the future course of mortality distribution. With the view of this aim, the Lee-Carter mortality model is used in this chapter for modeling and forecasting the future course of mortality trend as well as the life expectancy in Bangladesh using Bangladesh Bureau of Statistics (BBS) published data from various reports.

In 1992, Lee and Carter presented a new method for modeling and forecasting age-specific mortality rates, which combines a demographic model with a statistical model of time series. Originally applied to USA mortality data, the Lee-Carter method has gained importance mainly because of the quality of its empirical results and has been applied to data for several countries. This study describes the application of the Lee-Carter model to age-specific death rates by gender in Bangladesh. These rates are available for the period that goes from 1981 to 2011. The autoregressive integrated moving average (ARIMA) model is used to forecast the general index of mortality for the time period that goes from 2012 to 2051 in order to project life expectancy at birth using life tables. The forecasted future mortality level by the Lee-Carter mortality model shows somewhat optimistic progress in e^0 and it has started to increase gradually but it is expected to be slower pace for Bangladeshi people in future. Regardless of this expected improvement in future mortality level in Bangladesh, one negative message is the forecasted high infant and child mortality will be continuing in future.

6.1 Introduction

In the last (20^{th}) Century a high decline in the mortality level of populations is observed specifically in the more developed countries. The positive development of mortality implied a considerable increase in the life expectancy, inspired in the first times by the infant and child mortality reduction and in the last years also by the reduction in the mortality rates of the old aged people.

The growing survival in higher ages connected to the smaller number of births implies more and more aged populations. A higher longevity has, in this way, direct impact on the costs of the social security public systems since there isn't a counterpart in terms of financial support of the contribution of a large young people.

In this demographic perspective, questions on the future of the human longevity have acquired a special meaning for the planning of public and economic policies and the study and forecasting of mortality have gained even more importance.

In this context, there have been many attempts to find an appropriate model that represents mortality. Traditionally, a parametric curve, like the ones suggested by DeMoivre (1725), Gompertz (1825), and Weibull (1939), is used to fit annual death rates.

Over the last few dacades, a great number of new approaches were developed in order to forecast mortality by using stochastic models, such as the ones presented by McNown and Rogers (1989, 1992), Bell and Monsell (1991), and Lee and Carter (1992). The Lee-Carter model became one of the most well-known models and it is applied in different countries around the world to forecast age specific death rates.

In the beginning of the decade of 90 of the last century, Ronald Lee and Lawrence Carter (1992) have presented a new method to extrapolate the trends and patterns of mortality, that has been known as the Lee-Carter method. Originally applied to USA mortality data, the Lee-Carter method has been applied to the study of mortality in several countries, namely, to Canada by Lee and Nault in 1993 (Lee, 2000), to Chile by Lee and Rofman in 1994 (Lee, 2000), to Japan by Wiltmoth in 1996 (Lee, 2000), to Brazil (Fígoli, 1998), to the G7 countries - USA, Canada, Japan, France, Germany, Italy and United Kingdom (Tuljapurkar et all, 2000) and to Austria (Carter e Prskwetz, 2001).

This chapter attempts to deal with modeling and forecasting of mortality in Bangladesh. Numerous studies have been done on the mortality forecasting in developed countries (Tujapurkar, Li and Boe, 2000; Booth, Maindonald and Smith, 2001, 2002; Carter and Prskawetz, 2001; Hollmann, Mulder and Kallan, 2000; Li, Lee and Tuljapurkar, 2004; Hyndman and Ullah, 2005; Wang and Lu, 2005; De Jong and Tickle, 2006; Booth et al., 2006) but there is no mentionable study regarding future course of mortality in Bangladesh. Some of the researchers have focused on infant and child and old-age mortality in developing countries but studies on complete mortality situation in developing countries is still lacking. So this research might be the leading one that examines age-specific mortality modeling and forecasting to investigate the future course of e^0. It will also use age-specific mortality forecasting depending on the present trend of mortality change and differentials males and females of national, rural and urban areas separately. Under these circumstances, this chapter uses the experiences of developed countries since there is no mentionable study on age-specific mortality modeling and forecasting in developing countries. Therefore, the aim of this chapter is to forecast age specific mortality to get a clear idea regarding future course of mortality as well as future life expectancy at birth (e^0) in Bangladesh.

6.2 Description of Lee-Carter mortality model

In 1992, Lee and Carter proposed a new method to modeling and forecasting age-specific mortality rates, which combines a demographic model with a statistical model of time series. The demographic model is estimated from historical age-specific mortality data getting a temporal index of the general level of mortality, which is modeled as a time series ARIMA (Autoregressive Integrated Moving Average) and, subsequently, projected. Following the forecast of the temporal index of mortality level, the forecasts for the mortality rates and the life expectancy are obtained.

It is an extrapolative method, that is, it is based on the behaviour of mortality in the past to predict the future. The Lee-Carter method has become more popular for its ease of application and better performance of the forecasting result of mortality than other forecasting methods. For this appreciation, this method or some extension of this method has been extensively used directly to forecast mortality data in various developed countries by numerous researchers (Lee and Rofman, 1994; Wilmoth, 1996; Tujapurkar, Li and Boe, 2000; Carter e Prskwetz, 2001;Booth, Maindonald and

Smith, 2001, 2002; Carter and Prskawetz, 2001; Hollmann, Mulder and Kallan, 2000; Lee and Miller, 2001; Li, Lee and Tuljapurkar, 2004; Hyndman and Ullah, 2005; Wang and Lu, 2005; De Jong and Tickle, 2006; Booth et al., 2006). Most probably, there is no use of this method in developing countries for complete mortality forecasting as yet. Lee-Carter method consists in decomposing the age-specific mortality change in two components, a time varying component (k_t) which is invariant over time and the age component (b_x) which is invariant over time (constant). The basic Lee-Carter model is as follows:

$$\text{Ln}(m_{x,t}) = a_x + b_x k_t + \varepsilon_{x,t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(6.1)$$

with restrictions such that the *b*'s are normalized to sum to one and the *k*'s sum to zero, so the *a*'s are average log rates.

Where $m_{x,t}$ is the central death rate for age x in year t, $a_{x,}$ b_x and k_t are parameters of the model and $\varepsilon_{x,t}$ is an error term. The set of coefficients $a_{x,}$ that constitutes a vector of age specific constants, describes the general shape across age of the mortality profile. The k_t is an index of the general level of mortality, that is, it captures the main temporal trend of mortality. The coefficients b_x determines how much changes in mortality at each age group when k_t changes, that is,

$$\frac{d\ln(m_{x,t})}{dt} = b_x \frac{dk}{dt},$$

The error term $\varepsilon_{x,t}$, with mean zero and variance σ_{ε}^2, reflects the age period effects not captured by the model.

The average age profile a_x is independent of time. The temporal mortality index k_t control the overall time trend in ln $m_{x,t}$ for all age groups. We can get a set of central death rates by using the every value of k_t and that is used to construct a life table for obtaining the e^0. The main proposition of the Lee-Carter model is that when k_t is linear in time, mortality at each age group changes at its own constant exponential rate. The coefficient b_x modifies main time trend along with the relative pace of change in mortality rates at particular age group. The higher value of b_x refers to faster decline of mortality rate and the smaller value of b_x indicates the slower decline of mortality rate at age x. according to Lee-Carter (1992) model the value of b_x may be negative for some ages indicating that age-specific mortality rate will rise at those ages when declining at other ages at the same time; in practice this does not seem to occur over the long run.

6.2.1 Advantage and disadvantage of Lee-Carter model

The model proposed by Lee-Carter (1992) has several advantages. It combines a rich, but parsimonious, demographic model with a model of time series, allowing probabilistic intervals to the respective forecasts, simultaneously it is based in a comparatively long set of historical information. Given the basic demographic model, the method allows the mortality rates to decline exponentially, not being required to set up an arbitrary higher limit or reduce in some way the deceleration of the life expectancy increases, since this deceleration occurs with no additional restrictions. They refer, also, the opportunity of obtaining the mortality indirectly for periods to which the age specific mortality rates are not available. This model is very popular for its simplicity because only one parameter k_t needs to be estimated and it does not make assumptions about the nature of trend in k_t . Also the assumption of the model is transparent and it is assumed that each age-specific mortality rate will continue to decline at its own constant exponential rate.

Despite the popularity of this model to forecast mortality, it has some disadvantages also. The structure and the evolution observed in the historical data may not hold in the future and the existence of probable structural changes won't be taken into account in terms of forecasting. Sometimes problem is found in the assumption of b_x coefficients as in Lee-Carter model it is utilized as a constant over time, that means invariant over time but so far many studies suggest that b_x might be vary over time (Lee and Miller, 2001). For the invariant constant b_x long term mortality forecasts might be too rigid. If traced back k_t 's assumption may meet problems as well, this means only in forward forecasting Lee-Carter model can perform better not in backward forecasting. Another disadvantage of the model is not to incorporate any extra information. However, the method doesn't have any attempt to integrate information about the medicine advances, about changes in the socio-economic context, about the life style changes or about the appearance of new diseases.

In spite of some disadvantages in the Lee-Carter model, still this method makes good forecasts for mortality over long time periods in many developed countries and give available necessary information about future mortality change (Tuljapurkar, Li and Boe, 2000; Lee and Miller, 2001). Probably, in developing countries there is no mentionable use to forecast mortality till now. This study aims to apply the Lee-Carter model for modeling and forecasting the mortality in Bangladesh.

6.2.2 Description of used data for Lee-Carter mortality forecasting model in Bangladesh

Although some improvements happen in mortality reduction over the last few decades in Bangladesh, that was not satisfactory due to high infant & child mortality. For forecasting mortality Lee-Carter model needs time series data for a long period to know about the pace of future course of mortality change. In this study we have used age and sex-specific mortality data in Bangladesh from Bangladesh Bureau of Statistics (BBS) during the period 1981-2011 to apply the Lee-Carter model. The mortality data are divided into 17 equal 5-year age groups, which are 0, 1-4, 5-9, 10-14,15-19, ………..,70-74, and 75 and over for males and females as well as rural and urban. Again population data also divided into 17 equal 5-year age groups, which are 0, 1-4, 5-9, 10-14,15-19, ………..,70-74, and 75 and over for males and females as well as rural and urban. We have estimated the model parameters a_x , b_x and k_t for the period 1981-2011 and forecasted k_t for the period 2012-2051 to investigate the future course of age-specific mortality change as well as e^0 in Bangladesh using Lee-Carter model. Prior to use the Lee-Carter model for modeling and forecasting the mortality in Bangladesh, we have examined the trends and differentials of age-specific mortality and also have done sensitivity analysis to investigate the effect of age-specific mortality change on e^0.

6.2.3 Lee-Carter model fitting methodology

Using the method of ordinary least squares to estimate the model parameters a_x, b_x and k_t for a given set of age-specific death rate's (ASDR) $m_{x,t}$ during the period 1981-

2011 for male and female separately in Bangladesh, the following equation is used:

$$\text{Ln}(m_{x,t}) = a_x + b_x k_t + \varepsilon_{x,t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(6.2)$$

The model written in the equation (6.2) is underdetermined which can be seen as follows. Let the vectors a, b, k are one solution. If c is any scalar then a-bc, b, k+c also must be a solution. It is also obvious that if a, b, k is a solution, then a, bc, k/c is also a solution. Thus, k is determined only up to a linear transformation, b is determined only up to a multiplicative constant and a is determined only up to an additive constant.

That's why, Lee-Carter (1992) normalized the b_x to sum to unity and the k_t to sum to '0', therefore, a_x are simply the averages over time of the $\ln(m_{x,t})$. In the model (6.2) there are no given regressors. Thus, ordinary least squares method cannot be applicable to fit the model. There are only parameters to be estimated and the unknown index k_t on the right side of the equation (6.2). For this restriction, the singular value decomposition (SVD) method can be used to find a least squares solution for the parameters a_x, b_x, and k_t of the model (6.2) when applied to the matrix of the logarithms of the mortality rates after having been subtracted the averages over time of the (log) age-specific mortality rates (Good, 1969; Wilmoth et al., 1989). After the above normalization, the first right and left vectors and leading values of SVD provide a unique solution.

When SVD is not obtainable, a close alternative approximation to the SVD solution for this application can be found as follows. The normalization used here is same as above, the sum of k_t 's to 0 and b_x 's to unity. Then a_x is equal to the average of $\ln(m_{x,t})$ over time. In addition, k_t is equal (very close) the sum over age of $(\ln(m_{x,t})-a_x)$, As the sum of the b_x 's has been preferred to be unity (this is not an exact relation, however, since the error terms will not in general sum to 0 for a given age). Then it requires estimating the b_x's. Each b_x can be obtained by regressing without constant term, $(\ln(m_{x,t})-a_x)$ on k_t separately for each age group x.

6.2.4 Estimation procedure of second stage K_t

Since the estimates of a_x, b_x and k_t are generated from the log mortality matrix, the number of fitted deaths, in general, does not equal the number of observed deaths. Lee and Carter (1992) introduced a new step in the estimation of k_t, adjusting it in such a way that, for the age structure of the population and for the coefficients a_x and b_x previously estimated, it produces exactly the total number of deaths observed in that specific year. One must find k_t such that the following holds:

$$D_t = \sum \left[N(x,t) \left\{ \exp\left(\hat{a}_x + \hat{b}_x \hat{k}_t \right) \right\} \right] \quad \text{.....................(6.3)}$$

Where, D_t is the total number of observed deaths in year t and *N(x,t)* corresponds to the total population at age x in year t.

Using the estimated value of the first stage, from equation (6.3) we may re-estimate the second stage k_t. The second stage estimated k_t by Lee-Carter (1992) provides the purpose of adjusting value of k_t . An iterative method has applied for searching the value of k_t. and this value may be somewhat different from the direct SVD estimates. The estimated second stage k_t has been shown in Figure 6.3a, 6.3b and 6.3c for national, rural and urban areas respectively for both sexes together and it is indicating approximately same direction for both sexes. Early of the period (1981 to 1985) k_t has increased slightly and then it has declined till 1987, then it has increased up to 1989, afterwards, it has declined smoothly for rest of the whole period. The picture of rural areas is approximately same as national level but a slight different picture is observed in the urban areas. After 2001 the picture of urban areas shows some irregularities.

6.2.5 Time series modeling and forecasting second stage mortality index K_t

After adjusted the demographic model, the next step is to model the estimated values of k_t as a stochastic process of time series. Using Box-Jenkins methodology, Lee and Curter (1992) fit an ARIMA (0,1,0) model, that is, a random walk with a drift,

$$k'_t = c + k'_{t-1} + \varepsilon_t; \quad \text{.................... (6.4)}$$

Where k'_t indicates the second stage estimates of k_t, c is the drift term, as usually takes negative value and stands for the linear trend component in the change in k_t'.

Later on a number of researchers apply this technique to forecast second stage k_t (Lee-Carter, 1992, Tuljapurkar, Li and Boe, 2000; Carter and Prskawetz, 2001; Lee and Miller, 2001). k_t is well fitted by a random walk drift model. In this study age -

specific mortality data of Bangladesh for both males and females for the period 1981-2011 are forecasted using Lee-Carter method and it has given a deterministic downward trend with time for mortality index k_t. Second stage estimated k_t model fitting is enough for diagnosis of residuals of the fitted time series model ARIMA (0, 1, 0).

6.2.6 Age-Specific death rates and life expectancy forecasting procedure

Forecasts for k_t from equation (6.4) can be used in equation (6.2), together with the estimated a_x and b_x, to forecast age-specific mortality rates and from these life expectancies. Jointly with the point forecasts we get probability intervals for the forecasts of k_t. This is one of the most important aspects of the Lee-carter model. To forecast age specific mortality rates for the next u years, the following equation is used to assure the smooth progress of forecasted age-specific mortality rate from the most recent observed trend:

$$\ln\left(m_{x,t+u}\right) = \ln\left(m_{x,t}\right) + b_x\left(k_{t+u} - k_t\right) \qquad \ldots\ldots\ldots\ldots\ldots. \quad (6.5)$$

The modification that replaced a_x by latest observation of $\ln(m_{x,t})$ in equation (6.5) has given better performance to the original Lee-Carter method (Bell, 1997). Where a_x is the average of the sequence of $\ln m_{x,t}$ over times. The projection of life expectancy can be possible by using the forecasted age-specific death rates $m_{x,t}$ from equation (6.5). It is required to forecast the probability of dying $q_{x,t}$ for u years to get the forecast of life expectancy for u years.

The estimated value of $q_{x,t}$ can be obtained by the following equation,

$$q_{x,t} = \frac{2m_{x,t}n}{2 + m_{x,t}n}; \quad where, \; m_{x,t} = \frac{ASDR}{1000} \quad and \quad n = width$$

Finally, we will be able to construct a life table to find the projection of e^0 for male and female separately for the next u years using the estimated value of $q_{x,t}$.

6.3 Result and discussion

6.3.1 Lee-Carter model parameter estimate

Table 6.1a, 6.1b and 6.1c depict the estimated values of a_x and b_x for males and females using Lee-Carter methodology for the case of national, rural and urban areas respectively. Their graphical presentations for national level, rural and urban areas are demonstrated in the figures 6.1a, 6.1b and 6.1c respectively for a_x as well as 6.2a, 6.2b and 6.2c respectively for b_x. The estimated values of k_t have has shown in the tables 6.2a, 6.2b and 6.2c for national, rural and urban areas respectively for the period 1981-2011 and they are plotted in the figures 6.3a, 6.3b and 6.3c. The a_x coefficient represents the general shape of mortality rates. It is observed that the a_x coefficients decrease sharply in the age groups 0 to 10-15 and achieved its lowest level of -6.74387 for male and -6.87334 for female. Then it is started increasing slowly and reached its highest level of -2.06864 for male and -2.02482 for female in the age group 75 and over. Figure 6.1a presents the pattern of estimated values of a_x. The pattern of a_x for rural (Table 6.1b) and urban (Table 6.1c) areas are almost alike with the national level which are shown in the figures 6.1b and 6.1c respectively.

The estimated values of b_x coefficients represent the relative sensitivity of death rates to the variation in mortality index k_t which are shown in the figures 6.2a, 6.2b and 6.2c for both males and females for the case of national, rural and urban areas respectively. The values of b_x indicate the slower or faster change of mortality rate from one age group to another. It is observed in the figure 6.2a that mortality of males declined faster than females in childhood age groups (5-9 and 10-14) and early old-age groups (before 75 and over), whereas in adulthood age groups and oldest age group (75 and over) mortality of females declined faster than males. The highest value of b_x (0.115) is found in the age group 1-4 and the lowest value of b_x (0.031) is found in the age group 75 and over for male. Whereas, the highest value of b_x (0.096) is found in the age group 1-4 and the lowest value of b_x (0.036) is found in the age group 75 and over for female. Mortality decline is faster for the larger value of b_x and slower for the lower value of b_x . The pattern of b_x for rural areas is almost same as national level. But the pattern of b_x for urban areas is a little different from national level. The highest value of b_x (0.094) for male is found in the age group 5-9 and the highest value of b_x (0.084) for female is found in the age group 40-44 in urban areas. Another difference in urban areas is that the female mortality decline rate is slower than that of male in the age group 75 and over which is reverse for rural areas as well as national level. b_x is assumed to be invariant over time and it explains how rates decline rapidly or slowly in response to change in k_t. But for long-term mortality changes for the age-period interactions this assumption might be challenging. In their study the problem age-period interactions of b_x were tried to alleviate by Lee and Miller (2001). They have shown remarkably that fixed b_x assumption has worked well when modeling mortality by age in United States by separating the whole time series into two parts. In a study Tuljapurkar et al. (2000) also recommended that when the total time-period is divided into two time-periods assuming fixed b_x performance is improved in last time-period rather than in first time-period. In Austrian mortality forecasts Carter and Prskawetz (2001) have also found the problem in their study.

The Lee-Carter method appears as a method with probabilistic support. Furthermore, it is of simple application and it generates multiple measures and results that describe current and future mortality. As discussed earlier in the case of developing country like Bangladesh, though infant and child mortality and early old-age mortality have more contribution to decline total mortality rate but other age groups are also contributed to total mortality rate decline. Since the Lee-Carter model is based exclusively on historical data of mortality, it is essential to have reliable information for considerable periods of time. For this reason, it might find that the changes in the historical age pattern of mortality decline over period of 1981-2011 are not so important. Possibly it indicates that the changing age pattern has no significant effect on total mortality rate forecasts. Therefore, in this study, it will assume fixed b_x over the period 1981-2011 to make forecasts. Higher value of b_x appears in the 1-4 age interval, which means that, in that interval, mortality varies substantially when the general mortality index kt changes. As regards older ages, the value of this parameter is lower, which means that mortality slightly varies in that period of time. The fitted index of the general level of mortality k_t presents a downward trend in mortality over time with slightly short term fluctuation. It is also alarming that reduction of early old-age group mortality has created ageing tendency of the population in Bangladesh.

Table 6.1a: Values of parameter a_x and b_x for mortality (National) in Bangladesh for the period 1981-2011

Age Group	Male		Female	
	a_x	b_x	a_x	b_x
0	-2.5809	0.052	-2.64202	0.045
1-4	-4.85593	0.115	-4.82187	0.096
5-9	-6.1972	0.101	-6.24866	0.069
10-14	-6.74387	0.054	-6.87334	0.043
15-19	-6.6272	0.054	-6.40843	0.054
20-24	-6.41497	0.037	-6.22457	0.056
25-29	-6.29084	0.054	-6.06872	0.068
30-34	-6.07974	0.061	-5.94344	0.074
35-39	-5.81281	0.063	-5.67963	0.073
40-44	-5.48725	0.051	-5.41135	0.067
45-49	-5.0147	0.063	-5.05071	0.073
50-54	-4.55553	0.062	-4.70289	0.058
55-59	-4.13164	0.058	-4.26759	0.061
60-64	-3.65121	0.054	-3.80323	0.045
65-69	-3.32443	0.05	-3.43702	0.042
70-74	-2.89721	0.04	-2.92493	0.04
75+	-2.06864	0.031	-2.02482	0.036

Table 6.1b: Values of parameter a_x and b_x for mortality (Rural) in Bangladesh for the period 1981-2011

Age Group	Male		Female	
	a_x	b_x	a_x	b_x
0	-2.5284	0.049	-2.59936	0.045
1-4	-4.81139	0.112	-4.80621	0.097
5-9	-6.22901	0.093	-6.23147	0.066
10-14	-6.69715	0.06	-6.82125	0.044
15-19	-6.50068	0.072	-6.32726	0.056
20-24	-6.31732	0.046	-6.14664	0.053
25-29	-6.25743	0.052	-6.02218	0.065
30-34	-6.04277	0.051	-5.93182	0.069
35-39	-5.80067	0.06	-5.69613	0.066
40-44	-5.4668	0.053	-5.33991	0.074
45-49	-4.97369	0.064	-5.01661	0.081
50-54	-4.57089	0.06	-4.73510	0.054
55-59	-4.17469	0.054	-4.30279	0.063
60-64	-3.68534	0.046	-3.82736	0.041
65-69	-3.28358	0.056	-3.43718	0.044
70-74	-2.89211	0.041	-2.91404	0.043
75+	-2.05692	0.03	-2.00565	0.038

Table 6.1c: Values of parameter a_x and b_x for mortality (Urban) in Bangladesh for the period 1981-2011

Age Group	Male		Female	
	a_x	b_x	a_x	b_x
0	-2.86374	0.057	-2.90105	0.039
1-4	-5.28248	0.093	-5.24636	0.073
5-9	-6.46714	0.094	-6.53932	0.067
10-14	-6.92286	0.043	-7.05589	0.055
15-19	-6.89299	0.07	-6.6123	0.044
20-24	-6.55609	0.042	-6.49373	0.072
25-29	-6.51462	0.052	-6.37736	0.073
30-34	-6.49642	0.073	-6.22985	0.074
35-39	-6.16152	0.045	-5.8685	0.077
40-44	-5.63571	0.06	-5.51758	0.084
45-49	-5.22545	0.071	-5.14632	0.073
50-54	-4.76197	0.062	-4.78599	0.068
55-59	-4.19402	0.064	-4.34051	0.058
60-64	-3.77631	0.056	-3.90619	0.052
65-69	-3.36059	0.058	-3.43455	0.045
70-74	-2.96134	0.032	-2.9605	0.033
75+	-2.15621	0.029	-2.19154	0.015

Table 6.2a: Fitted value of first stage and second stage mortality index (k_t) of Bangladesh for the period 1981-2011 (National)

Year	First stage mortality index (k_t)		Second stage mortality index (k_t)	
	Male	**Female**	**Male**	**Female**
1981	1.76387	3.20439	5.86126	6.24624
1982	3.13875	4.46974	6.03291	6.52197
1983	4.16693	5.41657	6.13947	6.74786
1984	4.92354	6.13875	6.19023	6.91149
1985	5.48948	6.66467	6.18661	7.00740
1986	4.14158	5.15682	5.71493	6.55238
1987	2.67227	4.98849	4.43964	6.09436
1988	6.22614	7.32330	5.82204	6.87375
1989	6.20549	7.28832	5.57322	6.68418
1990	5.27852	6.94783	4.52108	6.14925
1991	5.78998	6.75626	4.88590	5.90077
1992	5.44035	6.42266	4.45771	5.61271
1993	4.95621	5.87467	3.96101	5.06642
1994	4.31165	5.17771	3.34326	4.40816
1995	3.50785	4.31766	2.59701	3.62396
1996	-0.33199	0.18122	-0.51767	0.99753
1997	1.91301	3.30838	1.07270	2.29833
1998	1.67991	2.75125	1.00134	1.68343
1999	-6.62427	-5.00604	-6.11076	-3.89786
2000	-7.78705	-7.03338	-6.31825	-4.62768
2001	-7.84533	-7.76505	-6.63891	-5.90004
2002	-9.04528	-9.36393	-7.75800	-8.01954
2003	-3.72853	-4.85865	-3.50533	-4.33699

Table 6.2a (Continue)

Year	First stage mortality index (k_t)		Second stage mortality index (k_t)	
	Male	Female	Male	Female
2004	-5.11059	-6.73518	-3.68576	-5.56306
2005	-3.83863	-7.74697	-5.08883	-8.89554
2006	-3.21467	-5.20277	-3.41525	-6.03801
2007	-3.23735	-6.14979	-3.04467	-6.33428
2008	-3.69825	-6.38503	-3.98347	-6.59606
2009	-5.43978	-8.48426	-5.61552	-9.08515
2010	-5.02203	-7.00913	-4.61013	-6.55602
2011	-6.68178	-10.64851	-6.84915	-11.43971

Table 6.2b: Fitted value of first stage and second stage mortality index (k_t) of Bangladesh for the period 1981-2011 (Rural)

Year	First stage mortality index (k_t)		Second stage mortality index (k_t)	
	Male	**Female**	**Male**	**Female**
1981	1.80924	2.71998	6.00547	5.74446
1982	3.25821	4.12233	6.08674	6.08448
1983	4.30703	5.15472	6.11287	6.62784
1984	5.07144	5.81552	6.09883	6.54638
1985	5.60582	6.52693	6.03375	6.72771
1986	4.10841	4.99119	5.68850	6.35437
1987	2.70541	4.84787	4.49022	6.03386
1988	5.54008	7.16645	5.40667	6.85320
1989	6.54395	7.05880	5.40451	6.44216
1990	5.22336	6.85804	4.55598	6.09772
1991	6.27237	7.03644	5.37698	6.01373
1992	5.65214	7.30668	4.66754	5.88331
1993	3.92562	4.70476	3.26023	4.31257
1994	4.23071	4.85567	3.26019	4.26684
1995	2.73629	4.00604	1.77180	3.37540
1996	1.49937	2.88324	0.71673	2.41121
1997	0.11019	1.48991	-0.40456	1.27049
1998	-1.83777	-0.24983	-1.89998	-0.08348
1999	-5.33617	-4.52212	-4.83704	-3.66913
2000	-6.86697	-6.25288	-4.91523	-3.67916
2001	-7.18559	-6.88648	-5.61817	-4.48315
2002	-8.85290	-9.46315	-7.70314	-7.91584
2003	-3.28572	-5.23631	-2.88684	-4.54446

Table 6.2b (Continue)

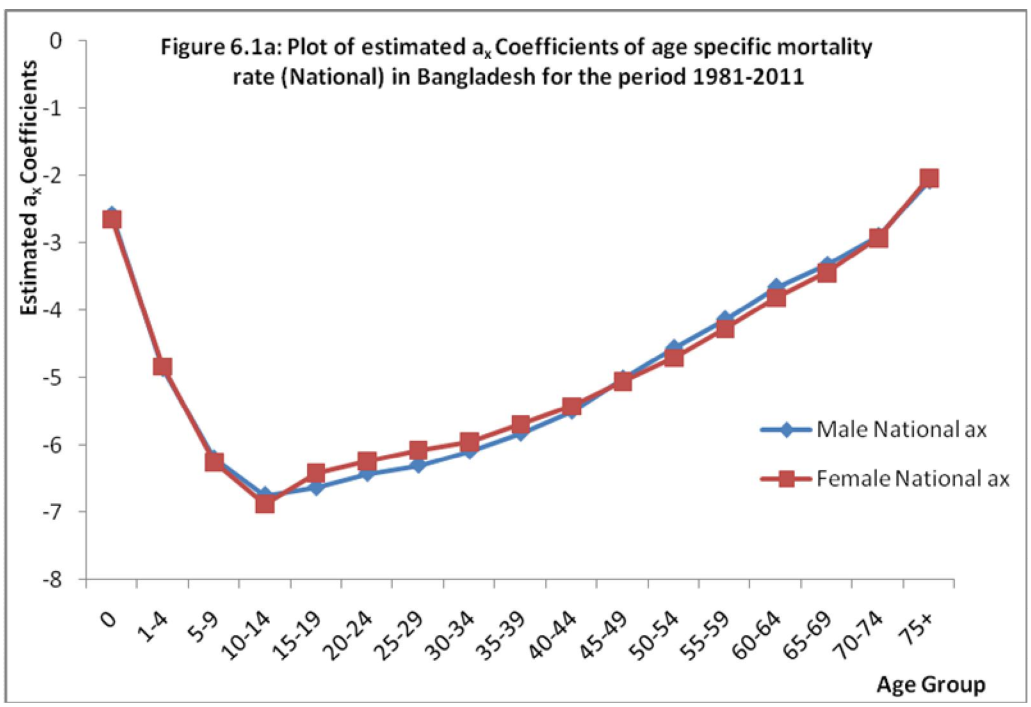
Year	First stage mortality index (k_t)		Second stage mortality index (k_t)	
	Male	Female	Male	Female
2004	-5.48649	-6.53091	-3.74851	-5.53865
2005	-4.28992	-7.53274	-5.56189	-8.66938
2006	-3.02685	-4.31451	-3.30275	-5.60183
2007	-3.07756	-5.95173	-2.95395	-6.41856
2008	-3.22242	-6.13466	-3.74653	-6.50533
2009	-4.79388	-7.77972	-5.74314	-8.49454
2010	-5.20738	-6.72758	-4.72441	-6.63432
2011	-6.13003	-9.96196	-6.86403	-11.01699

Table 6.2c: Fitted value of first stage and second stage mortality index (k_t) of Bangladesh for the period 1981-2011 (Urban)

Year	First stage mortality index (k_t)		Second stage mortality index (k_t)	
	Male	Female	Male	Female
1981	2.47161	4.74376	4.01479	5.78725
1982	3.82697	5.81754	4.88852	6.30888
1983	4.83941	6.60552	5.53774	6.71465
1984	5.60112	7.19361	6.01018	7.03241
1985	6.15311	7.61168	6.32898	7.25723
1986	3.00016	5.41221	7.20455	8.74608
1987	1.92898	5.85716	4.97860	7.28717
1988	6.77954	8.04279	6.43318	7.42039
1989	6.69088	7.95011	6.19875	7.31602
1990	6.31173	7.81917	5.47927	7.40532
1991	2.65755	4.97659	3.35325	5.59377
1992	3.43803	6.10683	3.87612	6.15970
1993	3.54910	6.44796	3.91076	6.24099
1994	3.56362	6.42270	3.85031	6.24282
1995	2.84285	3.89664	1.82718	3.49447
1996	1.63731	2.45153	0.65661	2.11174
1997	-0.05318	0.65532	-0.88304	-0.05263
1998	-1.75766	-1.59926	-2.49472	-2.78356
1999	-8.79620	-6.61065	-6.57400	-7.70940
2000	-7.60390	-8.23062	-7.10463	-10.46414
2001	-7.66341	-8.06321	-7.76481	-10.28944
2002	-9.52838	-8.93314	-7.79425	-10.21662
2003	-2.51358	-4.51415	-2.56694	-5.36660

Table 6.2c (Continue)

Year	First stage mortality index (k_t)		Second stage mortality index (k_t)	
	Male	Female	Male	Female
2004	-2.84501	-8.22798	-2.59011	-7.29433
2005	-1.15616	-7.05409	-2.11665	-10.50268
2006	-2.24354	-6.12173	-2.39520	-5.60991
2007	-2.59968	-6.62725	-1.94123	-5.79184
2008	-3.85199	-6.06762	-3.29877	-6.65957
2009	-5.87046	-9.30868	-3.16857	-12.79893
2010	-3.00793	-6.46250	-2.50781	-5.76874
2011	-5.80091	-10.19023	-4.56334	-14.10118



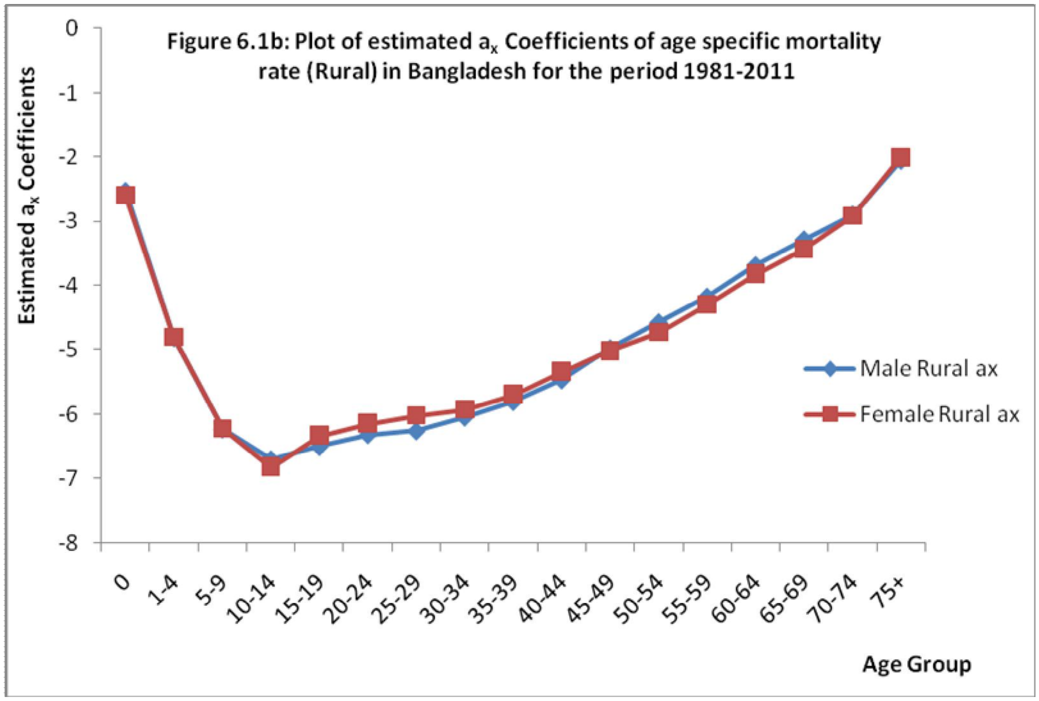


Figure 6.1b: Plot of estimated a_x Coefficients of age specific mortality rate (Rural) in Bangladesh for the period 1981-2011
Estimated a_x Coefficients
0
-1
-2
-3
-4
-5
-6
-7
-8
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group
Male Rural ax
Female Rural ax

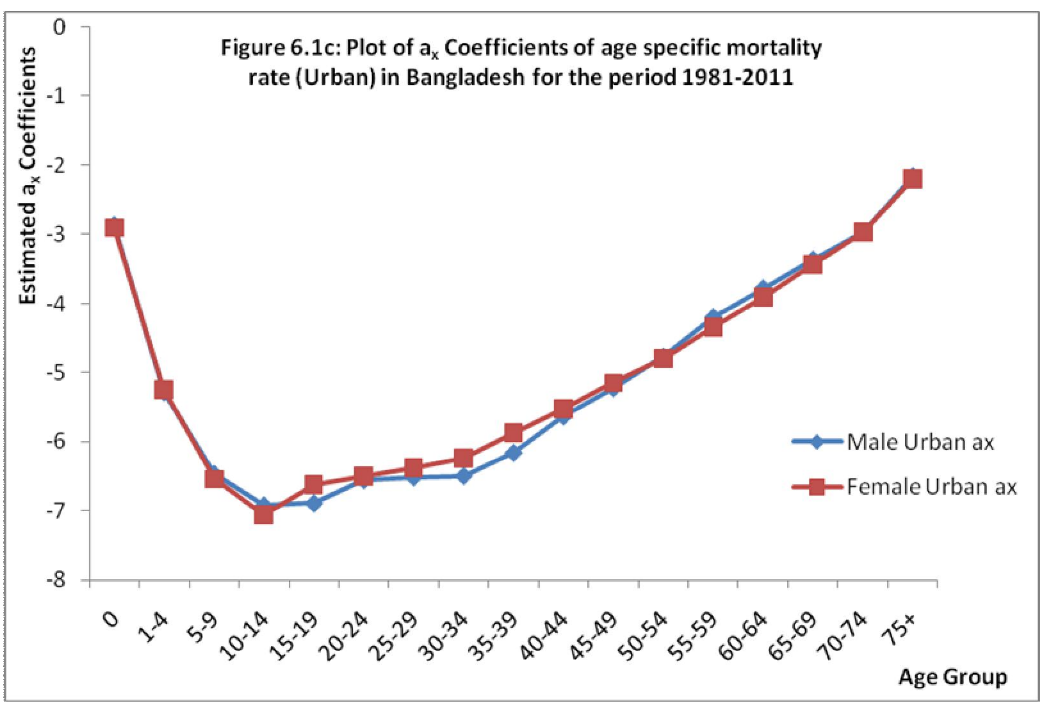


Figure 6.1c: Plot of a_x Coefficients of age specific mortality rate (Urban) in Bangladesh for the period 1981-2011
Estimated a_x Coefficients
0
-1
-2
-3
-4
-5
-6
-7
-8
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group
Male Urban ax
Female Urban ax

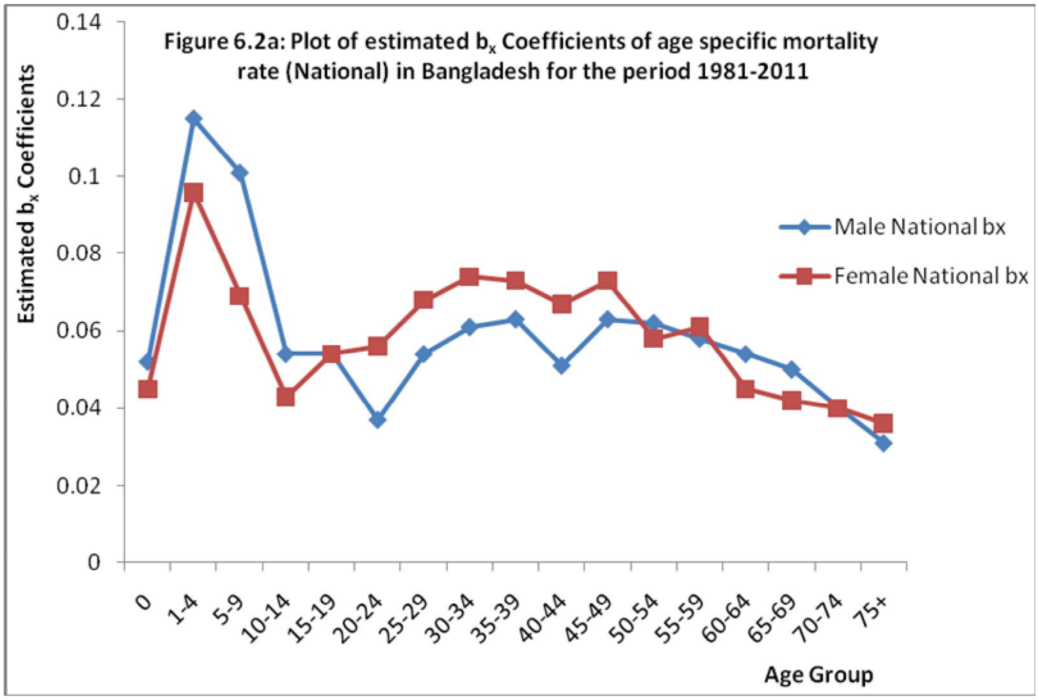


Figure 6.2a: Plot of estimated b_x Coefficients of age specific mortality rate (National) in Bangladesh for the period 1981-2011
Estimated b_x Coefficients
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Male National bx
Female National bx
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group

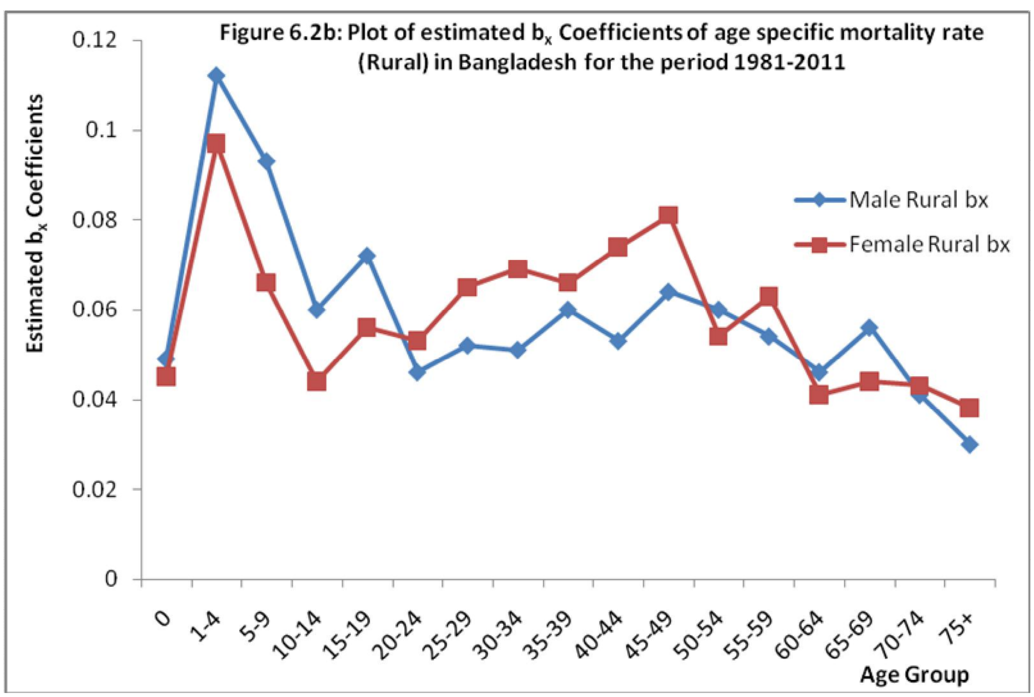


Figure 6.2b: Plot of estimated b_x Coefficients of age specific mortality rate (Rural) in Bangladesh for the period 1981-2011
Estimated b_x Coefficients
0.12
0.1
0.08
0.06
0.04
0.02
0
Male Rural bx
Female Rural bx
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+
Age Group

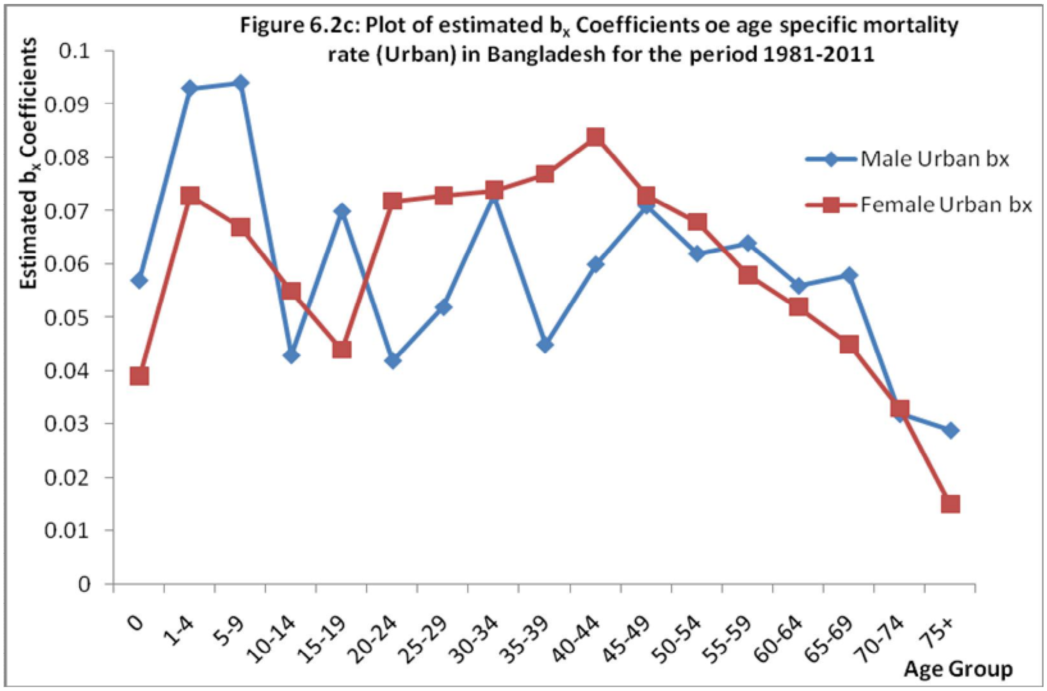


Figure 6.2c: Plot of estimated b_x Coefficients oe age specific mortality rate (Urban) in Bangladesh for the period 1981-2011
Estimated b_x Coefficients
Male Urban bx
Female Urban bx
Age Group
0
1-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75+

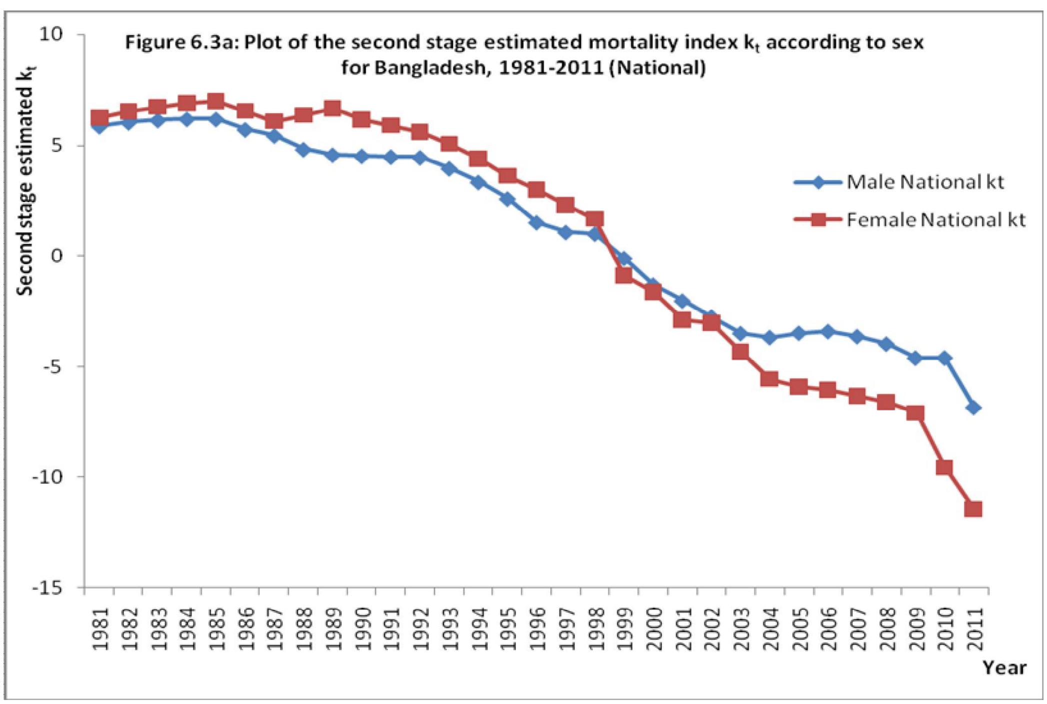


Figure 6.3a: Plot of the second stage estimated mortality index k_t according to sex for Bangladesh, 1981-2011 (National)
Second stage estimated k_t
Male National kt
Female National kt
Year

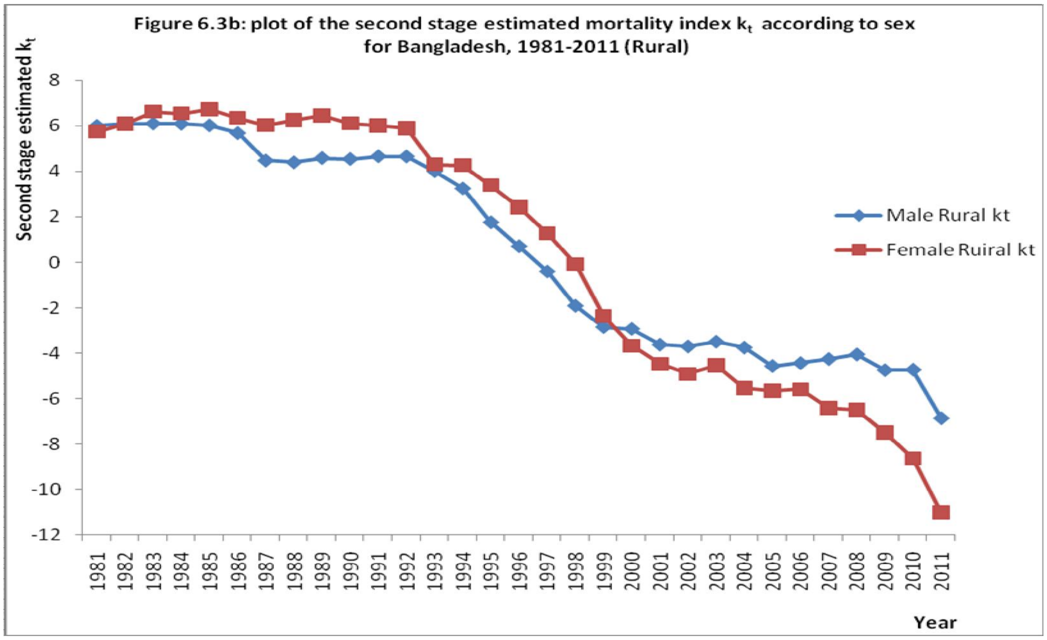


Figure 6.3b: plot of the second stage estimated mortality index k_t according to sex for Bangladesh, 1981-2011 (Rural)
Second stage estimated k_t
Male Rural kt
Female Ruiral kt
Year

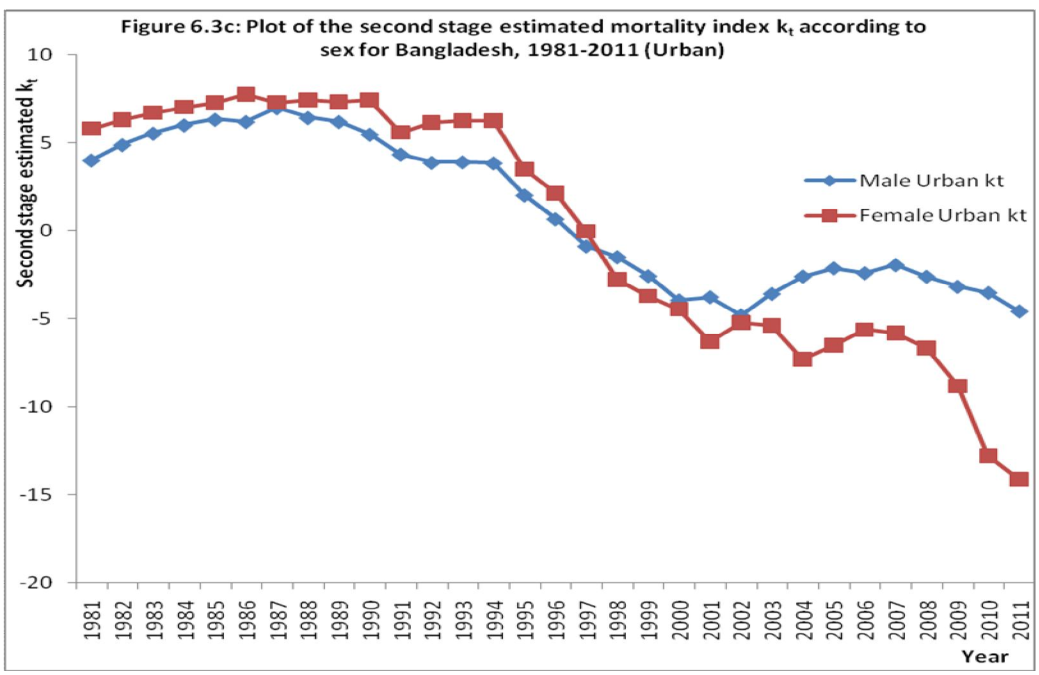


Figure 6.3c: Plot of the second stage estimated mortality index k_t according to sex for Bangladesh, 1981-2011 (Urban)
Second stage estimated k_t
Male Urban kt
Female Urban kt
Year

6.3.2 Future mortality index K_t modeling technique

To forecast the mortality index k_t from the estimated second stage k_t time series ARIMA (0,1,0) model is used separately for National, Rural and Urban by sex (both males and females).

The fitted ARIMA (0,1,0) models based on data 1981-2011 with standard errors in parentheses are as follows:

National: $k_t = k_{t-1} - 0.423680$ SE = 1.837332 (for male) ……… (6.6)

(0.335449)

$k_t = k_{t-1} - 0.589532$ SE = 1.949990 (for female) …….(6.7)

(0.356018)

Rural: $k_t = k_{t-1} - 0.428983$ SE = 1.482575 (for male) ……..(6.8)

(0.270680)

$k_t = k_{t-1} - 0.558715$ SE = 1.699807 (for female) …….(6.9)

(0.310341)

Urban: $k_t = k_{t-1} - 0.285937$ SE = 1.601831 (for male) …….. (6.10)

(0.292453)

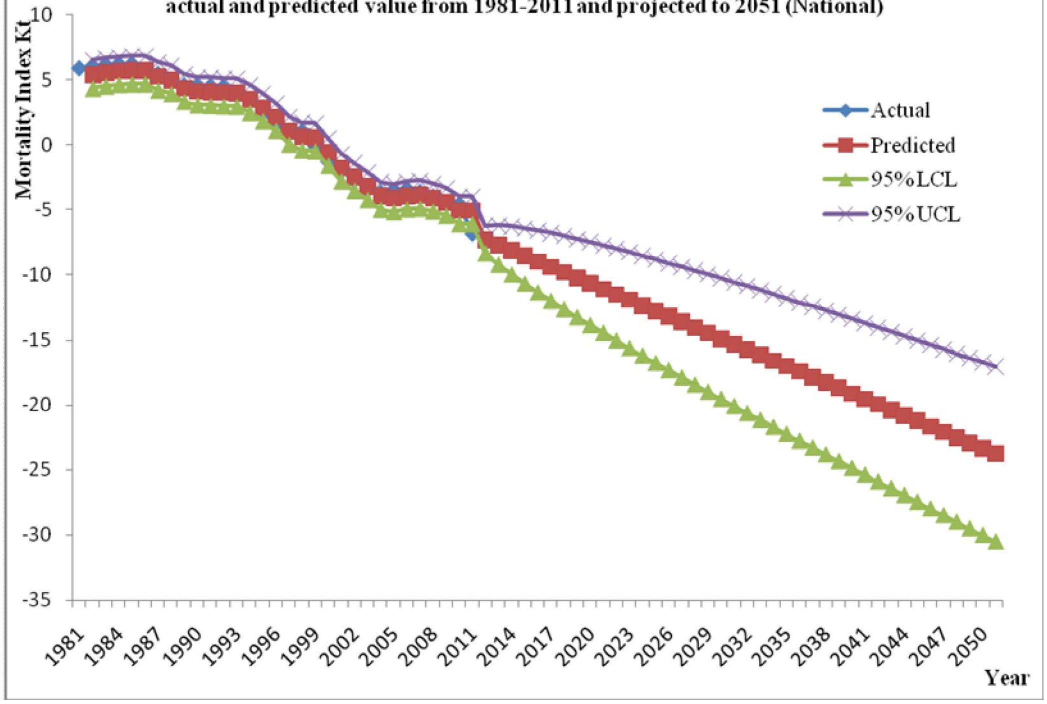
$k_t = k_{t-1} - 0.662948$ SE = 1.601831 (for female) …….(6.11)

(0.554700)

Here in the model (6.6) the constant term, -0.423680 specifies the average annual change in k, which drives the forecast of long-run change in mortality. We will forecast a decline in k of 40 times 0.423680 over a 40-year horizon. The uncertainty associated with a one year forecast is expressed by the standard error of the estimate (SE). Increasing the forecast horizon leads to grow the standard error with the horizon's square root. The estimated constant values for male (-0.423680) and female (-0.589532) indicate that female mortality declines slight faster than male mortality in Bangladesh.

By the time series ARIMA (0, 1, 0) model, we can extrapolate the future values of k_t. Figure 6.4a and 6.4b illustrates the past (1981-2011) values of k_t along with the forecasts of 40 years from 2012 to 2051 based on the time series model and the associated 95% confidence intervals for males and females respectively. In these figures we see that the forecasted k_t has declined linearly and the width of 95% confidence interval is increasing which is the feature of ARIMA (0,1,0) model. The figures 6.4a and 6.4b has also shown that at the estimated period 1981-2011, k_t declines approximately linearly (not exactly linear) for both males and females which are striking because the changing pattern of life expectancy is not exactly linear. Figures 6.4c and 6.4d depict the same for rural areas and it display the same picture like national level. Again figures 6.4e and 6.4f illustrate the same for urban areas and we see here that the 95% confidence interval of k_t for male is wider than that of rural areas and national level.

Figure 6.4a: Plot of mortality Index Kt for male with 95% confidence interval of actual and predicted value from 1981-2011 and projected to 2051 (National)



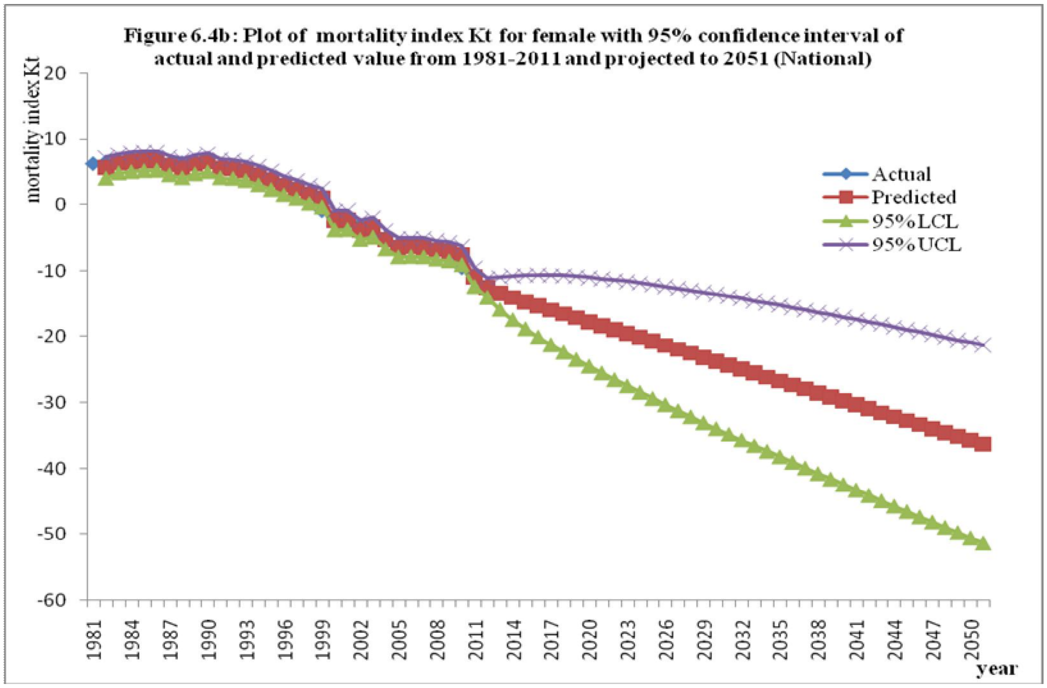


Figure 6.4b: Plot of mortality index Kt for female with 95% confidence interval of actual and predicted value from 1981-2011 and projected to 2051 (National)
mortality index Kt
year
Actual
Predicted
95%LCL
95%UCL

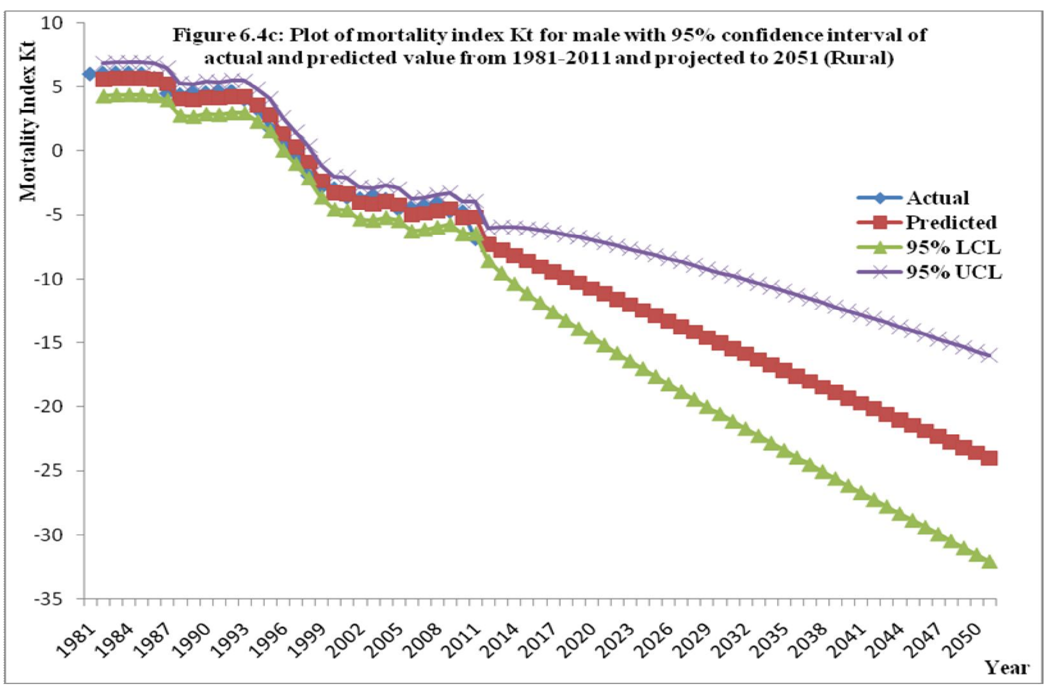


Figure 6.4c: Plot of mortality index Kt for male with 95% confidence interval of actual and predicted value from 1981-2011 and projected to 2051 (Rural)
Mortality Index Kt
Year
Actual
Predicted
95% LCL
95% UCL

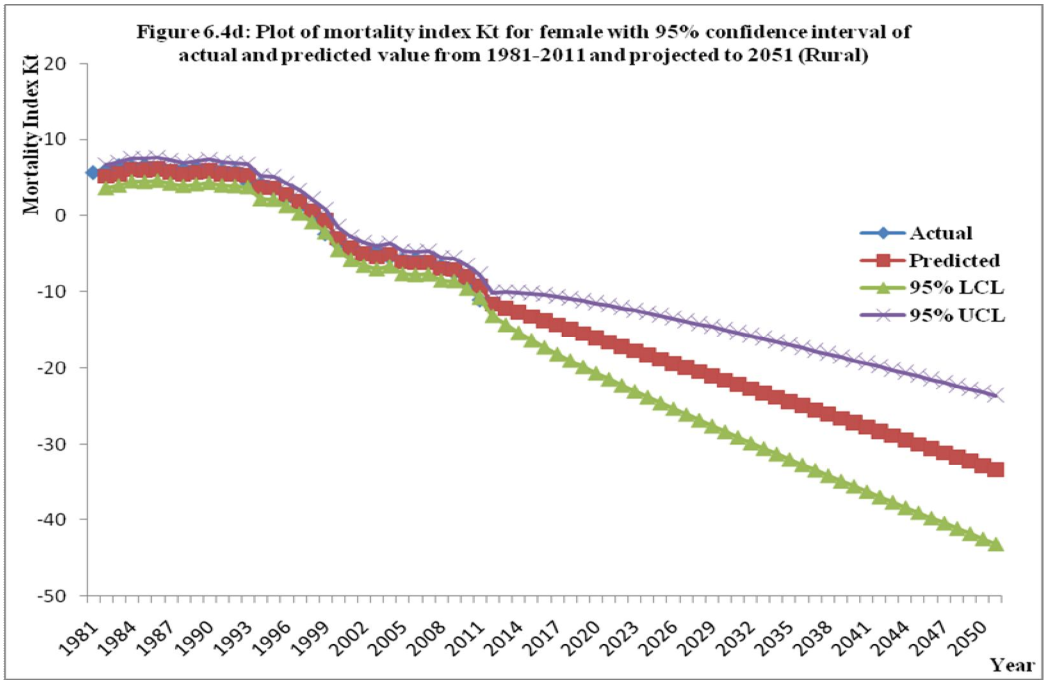


Figure 6.4d: Plot of mortality index Kt for female with 95% confidence interval of actual and predicted value from 1981-2011 and projected to 2051 (Rural)
Mortality Index Kt
Actual
Predicted
95% LCL
95% UCL
Year
20
10
0
-10
-20
-30
-40
-50
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050

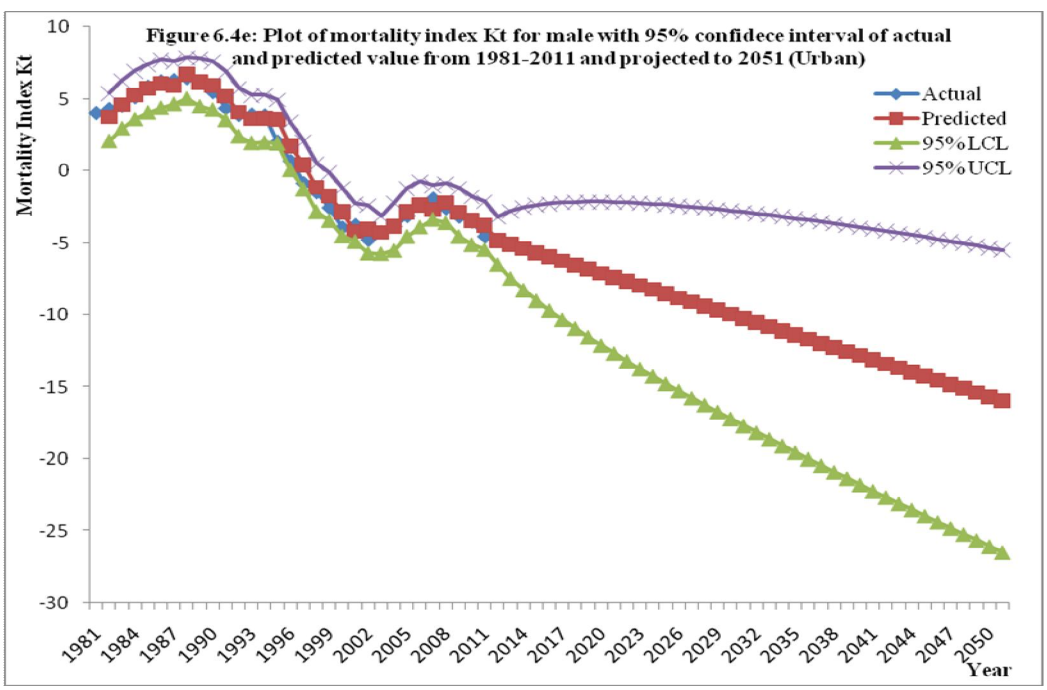
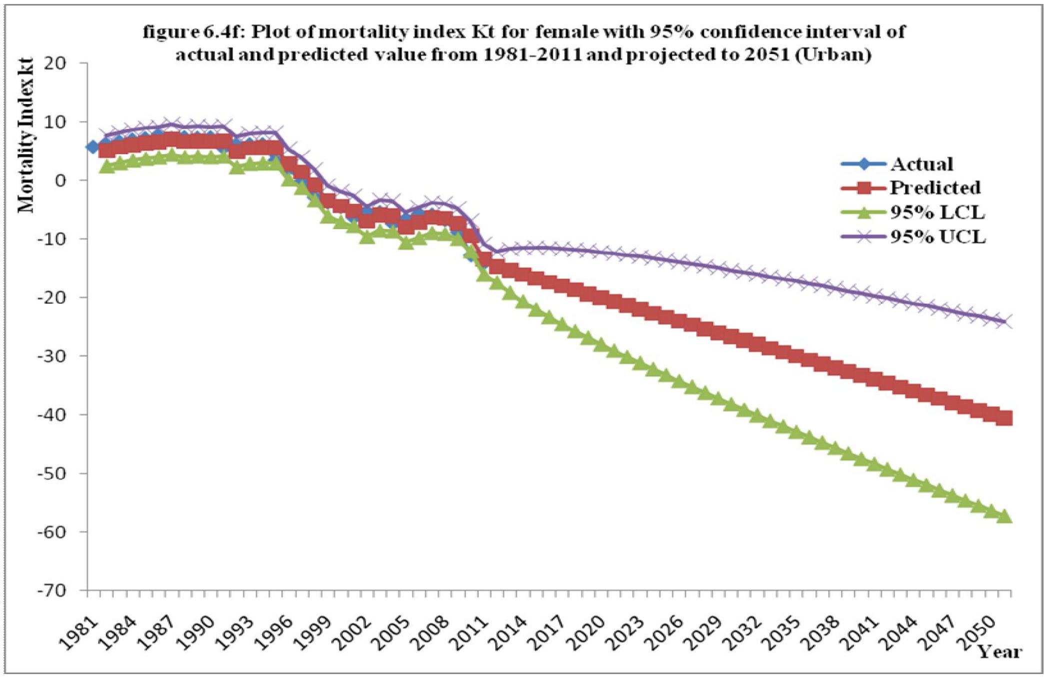


Figure 6.4e: Plot of mortality index Kt for male with 95% confidece interval of actual and predicted value from 1981-2011 and projected to 2051 (Urban)
Mortality Index Kt
Actual
Predicted
95%LCL
95%UCL
Year
10
5
0
-5
-10
-15
-20
-25
-30
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050



6.3.3 ARIMA model diagnostic procedure

It is obvious that projection cannot give the exact result but it gives a possible indication for the future which helps the policy-makers to take effective plan for the future. Therefore, it is essential to verify the forecasting result time to time to get more effective plan of action. Projection results may vary to a great extent depending on time and person. Consequently, it needs to minimize the variation regarding person and time as much as possible. To get more effective and significant forecasting result, it is very important to verify the accuracy of fitted model and rapidity of forecasting result. In this study Shapiro-Wilk test has been used to verify the accuracy of Lee-Carter model for forecasting mortality. By Shapiro-Wilk test we can test the significance of residual of ARIMA (0, 1, 0) models separately for males and females mortality at national level as well as rural and urban areas. Shapiro-Wilk test statistic values for male national, female national, male rural, female rural, male urban and female urban are 0.852, 0.925, 0.892, 0.937, 0.895 and 0.924 respectively with p-values 0.001, 0.037, 0.005, 0.076, 0.006 and 0.035 respectively for residual test of respective ARIMA (0, 1, 0) models. It is observed that P-value of both ARIMA (0, 1, 0) model for female rural is larger than α=0.05 significance level and for all the other models p-values are less than α=0.05. Therefore, we may conclude that the residual of female rural is normally distributed and all the other residuals are not normally distributed. But in time series data it is not so important the residuals to be normally distributed. The important thing is the residuals will not be auto-correlated. So, we may verify the independence assumption among residuals by the Box-Ljung test. Box-Ljung test shows p-value > α=0.05 for all the models, which means our hypothesis of H_0: $\rho_1=\rho_2=\rho_3= \dots \dots \dots = \rho_k = 0$ is not rejected at α=0.05 significance level. Hence, all the models follow the constant variance assumption. Therefore, we may conclude that the result we have got from forecasting might help the policy-makers to make effective plan to improve health facilities to meet up the increasing demand of population healthcare. Figures 6.5a, 6.5b, 6.5c, 6.5d, 6.5e and 6.5f plot graphically the standardized residuals with error bound for male national, female national, male rural, female rural, male urban and female urban respectively.

Figure 6.5a: Plot of Residuals against number of observations for male (National)

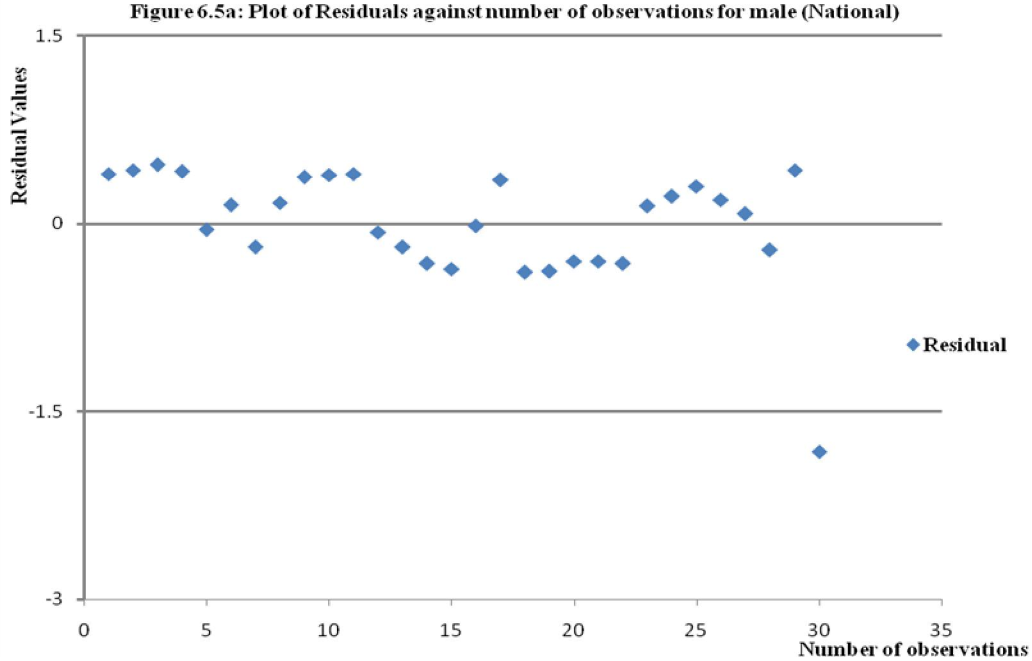


Figure 6.5b: Plot of Residuals against number of observations for female (National)

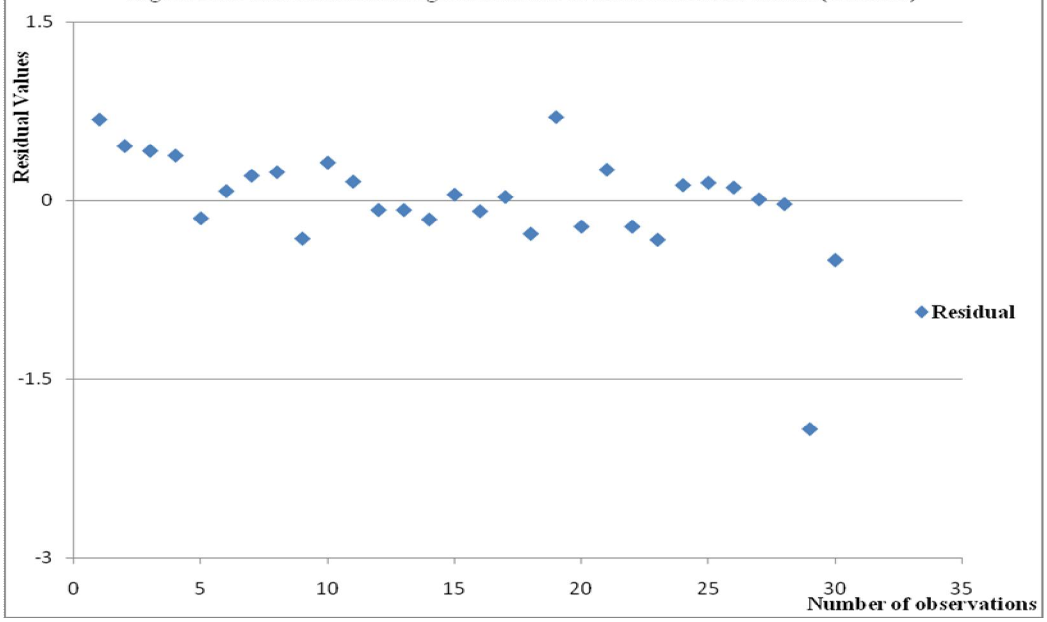


Figure 6.5c: Plot of Residuals against number of observations for male (Rural)

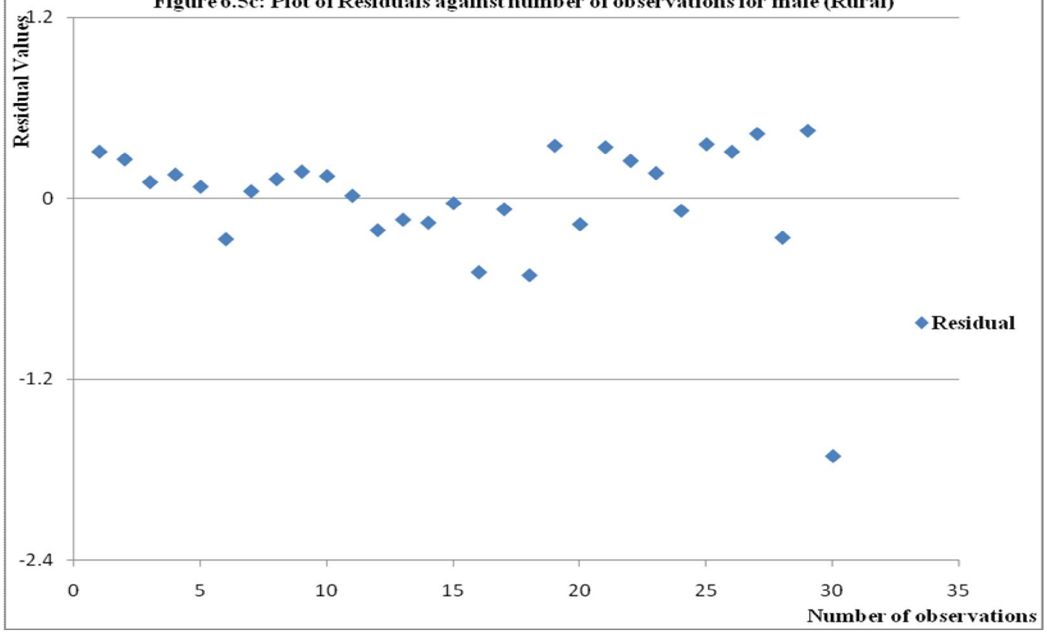


Figure 6.5d: Plot of residuals against number of observations for female (Rural)

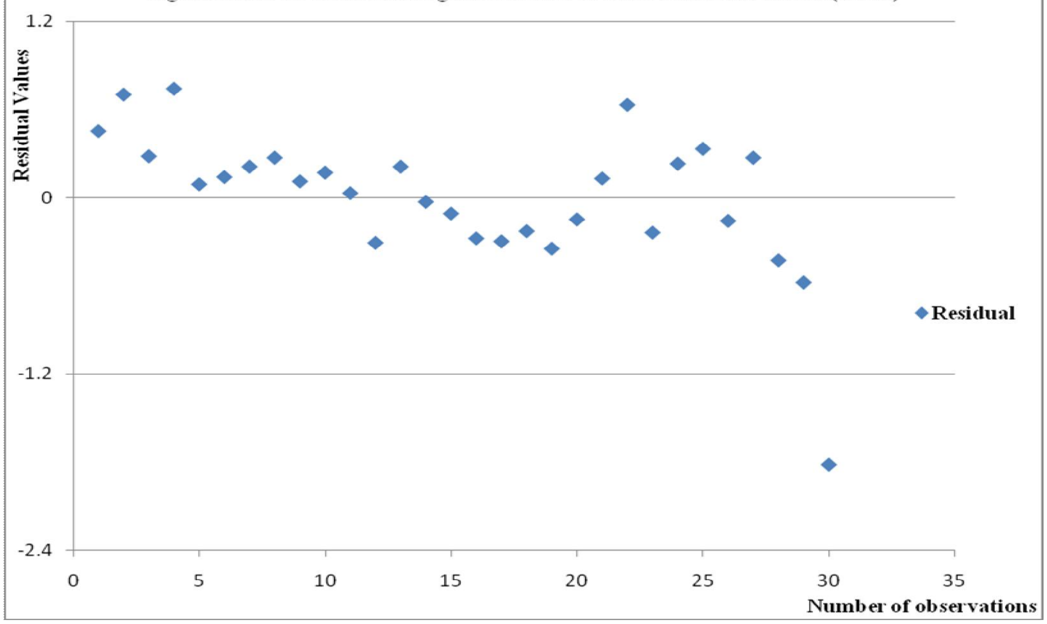
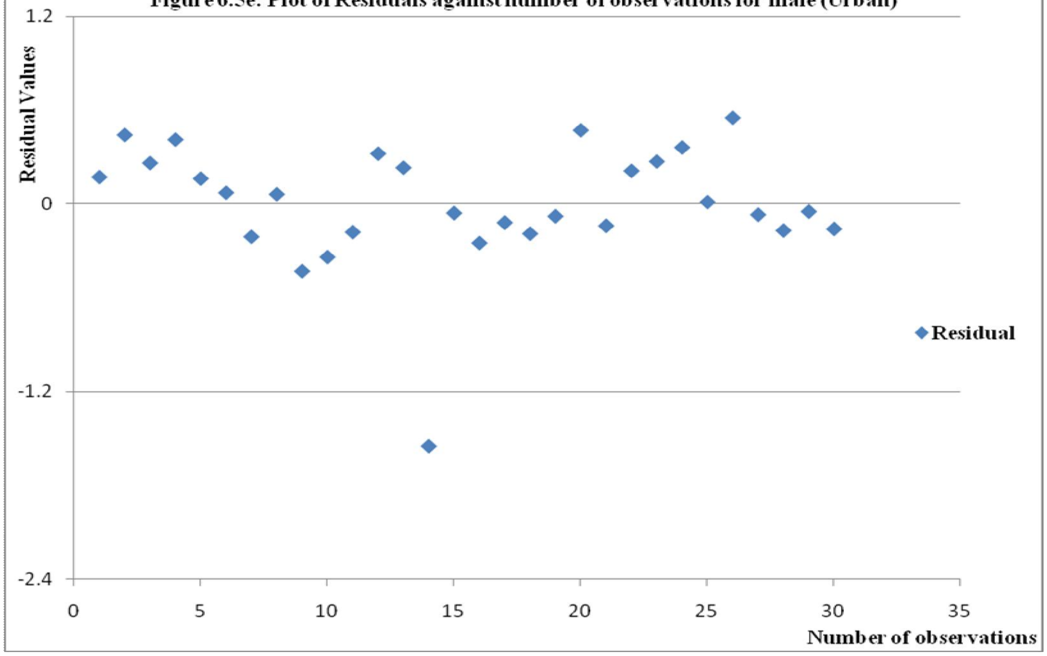
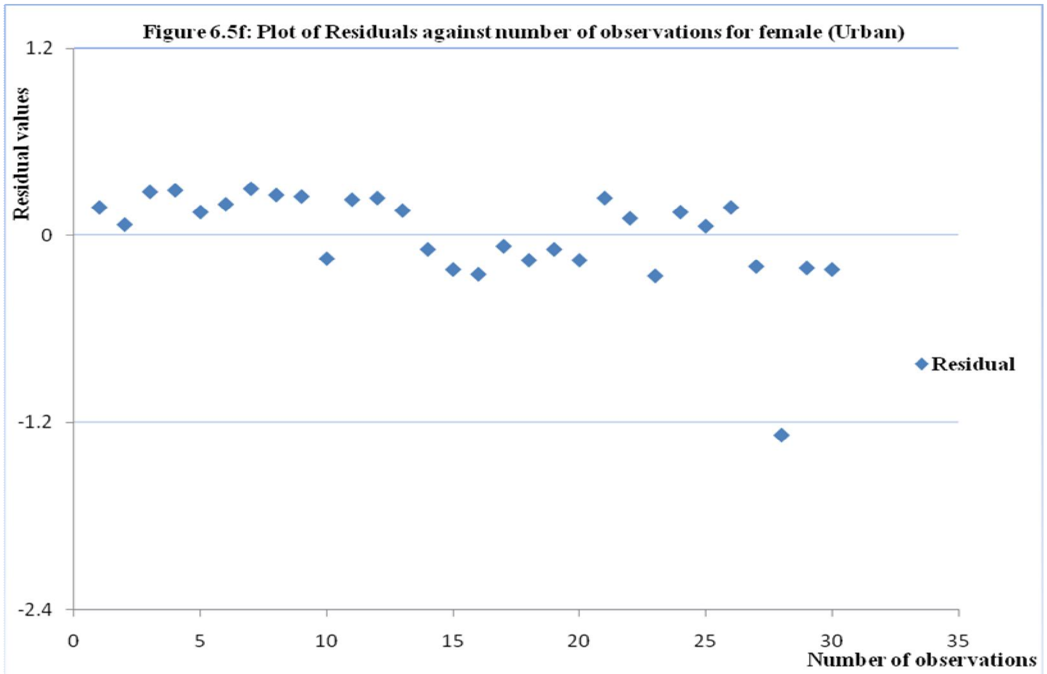


Figure 6.5e: Plot of Residuals against number of observations for male (Urban)





6.3.4 Projected age-specific death rates and life expectancy at birth

As the crude death rate is a vital factor to observe the pace of mortality change, it is important to measure the crude death rate. We can measure it by age-specific death rates. The developing countries whose infant and child mortality and old age mortality is still high, both these two groups mortality contribute mostly to their overall mortality. For the lack of improved and adequate health care facility most of the developing countries are still facing high rate of mortality in both groups. Their efforts are going on to develop their health sector for a long time and they started getting success to some extent in the early 1970's. However, in the context of Bangladesh the mortality rate is high in comparison to not only the developed countries but even to some of the developing countries like China, India and so on. Though, the mortality rate, mostly infant and child mortality and old-age mortality started to decrease gradually during last two decades due to some progress in the health sector. To fix up the future steps needed to improve the health facility in Bangladesh, it is necessary to observe the future course of age-specific mortality as well as e^0.

In this situation, it is essential to forecast the age-specific mortality rates and to calculate the life table functions using the forecasted age-specific mortality rates and the e^0 for future using the calculated life table functions. With the help of the forecasted second stage mortality index k_t we can generate the age-specific death rates for future. It needs to calculate the life table functions using the forecasted age-specific death rates for forecasting the e^0 and age groups life expectancy for the next 40 years.

After forecasting the k_t index using ARIMA (0, 1, 0) model, it is possible to obtain the death rates to the projected years. The forecast values of k_{n+h} are replaced in the formula:

$$\hat{m}_{x,n+h} = \hat{m}_{x,n} \exp\left\{\hat{b}_x \left(\hat{k}_{n+h} - \hat{k}_n\right)\right\}, \text{ h=1,2,….; x=1,2,…ω} \quad \text{……..(6.12)}$$

Where n is the last year from which data are available; h is the forecast horizon and x represents the age group.

Death rate forecasts with reference to the last death rate available are obtained through the (6.12) formula. Lee and Carter (1992) suggest using an approximate prediction interval to forecast death rates which is discussed earlier. Estimations of the b_x parameters and standard errors of the k_t projections are used to calculate the interval below:

$$\left\{m_{x,t} \exp\left(2b_x se_{k_t}\right); m_{x,t} \exp\left(-2b_x se_{k_t}\right)\right\} \quad \text{……… (6.13)}$$

Through the forecasted death rates, the classic method of Chiang C. L. (1984)

is applied so as to obtain life expectancy at birth.

$$e_x = \frac{T_x}{l_x}; \quad \text{………………. (6.14)}$$

Where T_x is the cumulative number of years lived by the cohort population in the age interval and all subsequent age intervals. The l_x value represents the number of living people at the beginning of the x age interval from a population of l_0 newborn babies. This is usually defined as l_0 =100,000.

6.3.4.1 Projected age-specific death rates and life expectancy at birth (National)

Table appendix A13 and appendix A14 demonstrate the forecasted age-specific death rates for males and females respectively for national level. It is seen that the declining tendency of the infant and child mortality rates and 65 and above age groups mortality rates is faster than all other age groups. It is also observed that the declining trends of age-specific mortality rates for males and females are almost alike. The forecasted life expectancy at birth (e^0) with 95% confidence interval is shown in the Table Appendix A7 and appendix B8 for males and females respectively. The e^0 increases from 56.63 to 68.63 years during the period 1981-2011 (Table 5.1) with an average increasing amount of, 0.4 year for male and for female average increasing amount is comparatively high, 0.44 year, from 56.56 years in 1981 to 69.81 years in 2011 (Table 5.1). However, from 56.63 years in 1981 the projected male e^0 becomes 82.97 years in 2051 with a yearly increment of 0.38 year and for female it is from 56.56 years in 1981 to 86.04 years in 2051 with a yearly increment of 0.42 year. The increment rate of female e^0 is slight faster than male e^0. Figures 6.6a and 6.6b depict the predicted e^0 with 95% confidence interval for males and females respectively. The increasing trends of both figures are showing more or less similar shape of e^0 for both males and females. However, it is notable that the increasing trend is faster during the first half of the whole forecasting period (2012-2051) for both males and females.

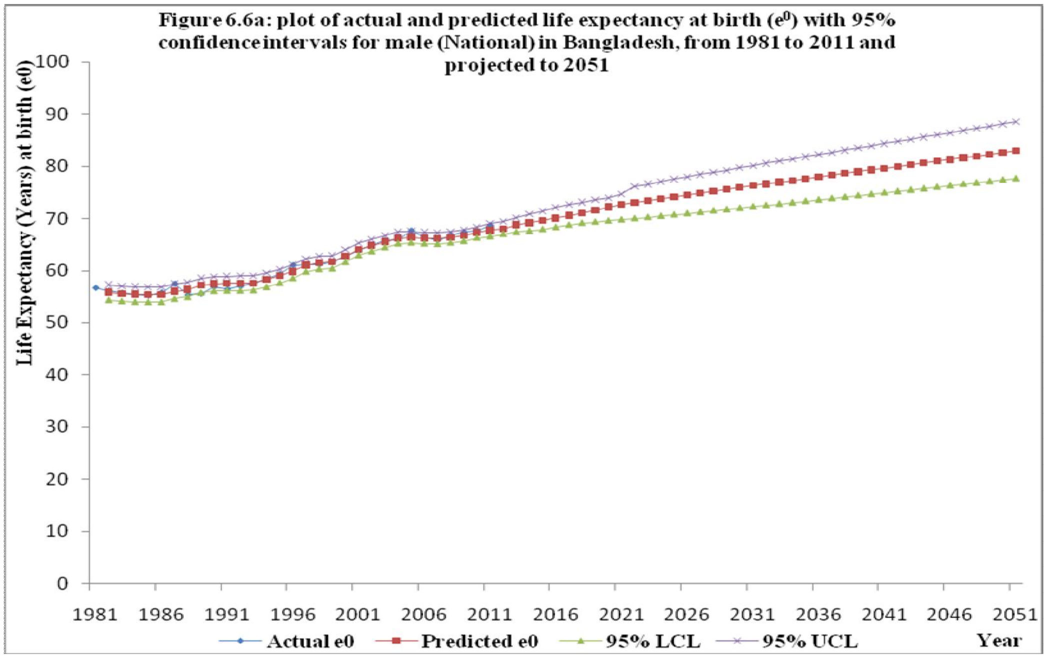


Figure 6.6a: plot of actual and predicted life expectancy at birth (e^0) with 95% confidence intervals for male (National) in Bangladesh, from 1981 to 2011 and projected to 2051
Life Expectancy (Years) at birth (e0)
100
90
80
70
60
50
40
30
20
10
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Actual e0
Predicted e0
95% LCL
95% UCL
Year

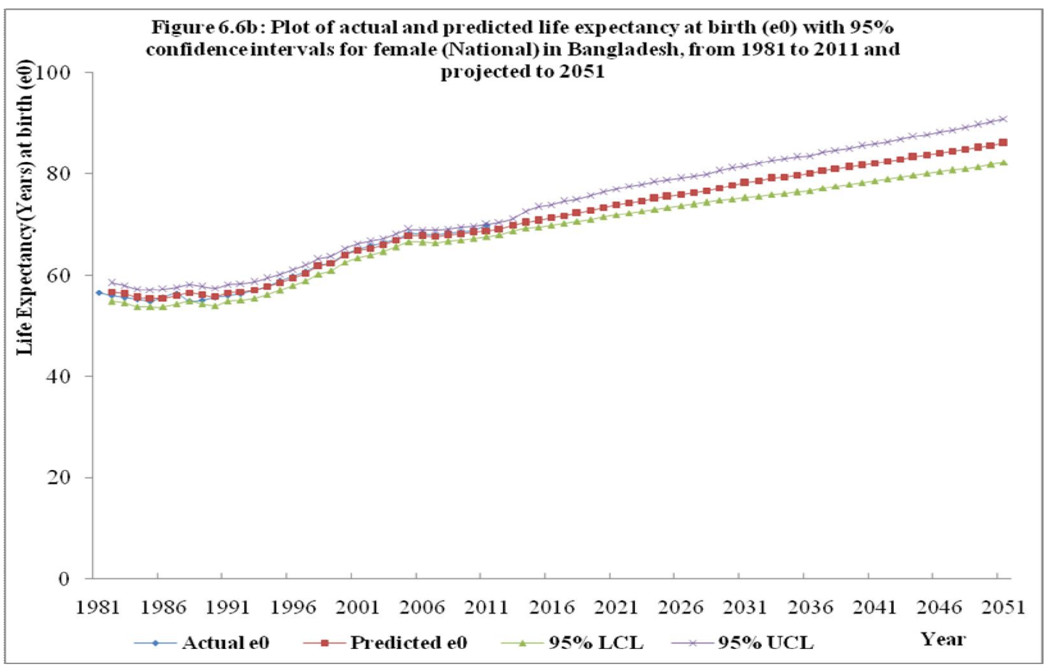


Figure 6.6b: Plot of actual and predicted life expectancy at birth (e0) with 95% confidence intervals for female (National) in Bangladesh, from 1981 to 2011 and projected to 2051
Life Expectancy(Years) at birth (e0)
100
80
60
40
20
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Actual e0
Predicted e0
95% LCL
95% UCL
Year

6.3.4.2 Projected age-specific death rates and life expectancy at birth (Rural)

Table appendix A15 and appendix A16 display the forecasted age-specific death rates for males and females respectively for rural areas. Here also it is seen that the declining tendency of the infant and child mortality rates and 65 and above age groups mortality rates is faster than all other age groups. It is also observed that the declining trends of age-specific mortality rates for males and females are not so different. The forecasted life expectancy at birth (e^0) with 95% confidence interval is shown in the Table Appendix A9 and appendix A10 for males and females respectively. The e^0 increases from 56.18 years to 67.99 years during the period 1981-2011 (Table 5.1) with an average increasing amount of, 0.39 year for male and for female average increasing amount is comparatively high, 0.44 year, from 56.12 years in 1981 to 69.19 years in 2011 (Table 5.1). However, from 56.18 years in 1981 the projected male e^0 becomes 82.39 years in 2051 with a yearly increment of 0.37 year and for female it is from 56.12 years in 1981 to 85.59 years in 2051 with a yearly increment of 0.42 year. The increment rate of female e^0 is slight faster than male e^0. Figures 6.7a and 6.7b depict the predicted e^0 with 95% confidence interval for males and females respectively. The increasing trends of both figures are showing roughly indistinguishable shape of e^0 for both males and females. However, it is remarkable that the increasing trend is faster during the first half of the whole forecasting period (2012-2051) for both males and females.

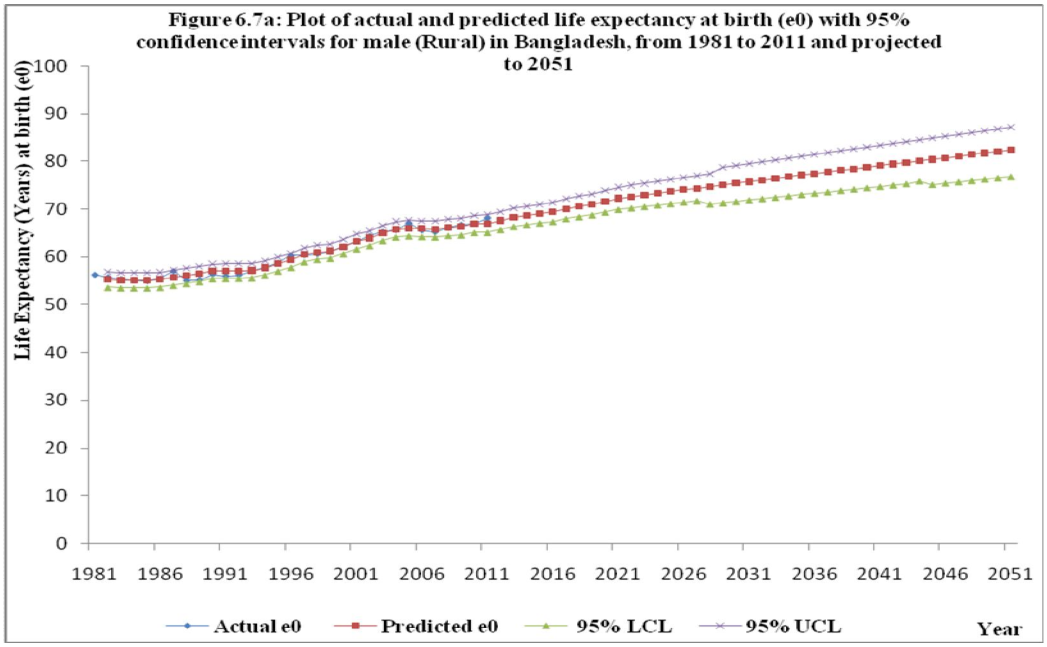


Figure 6.7a: Plot of actual and predicted life expectancy at birth (e0) with 95% confidence intervals for male (Rural) in Bangladesh, from 1981 to 2011 and projected to 2051
Life Expectancy (Years) at birth (e0)
100
90
80
70
60
50
40
30
20
10
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Actual e0
Predicted e0
95% LCL
95% UCL
Year

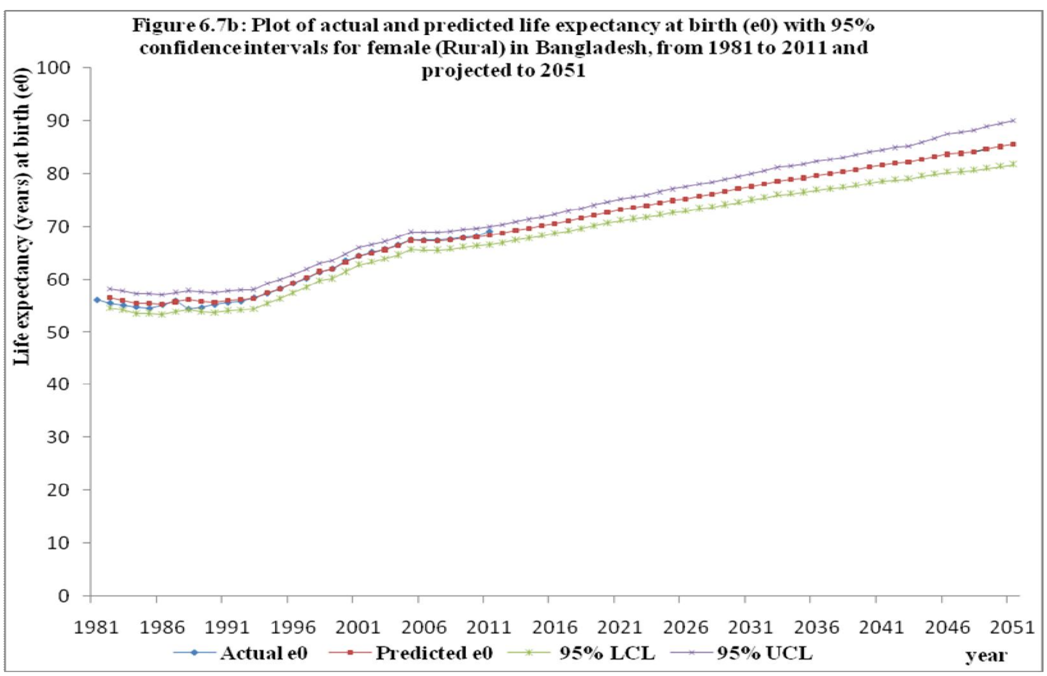


Figure 6.7b: Plot of actual and predicted life expectancy at birth (e0) with 95% confidence intervals for female (Rural) in Bangladesh, from 1981 to 2011 and projected to 2051
Life expectancy (years) at birth (e0)
100
90
80
70
60
50
40
30
20
10
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Actual e0
Predicted e0
95% LCL
95% UCL
year

6.3.4.3 Projected age-specific death rates and life expectancy at birth (Urban)

Table appendix A17 and appendix A18 display the forecasted age-specific death rates for males and females respectively for urban areas. Here also it is seen that the declining tendency of the infant and child mortality rates and 65 and above age groups mortality rates is faster than all other age groups. It is observed that the declining trends of age-specific mortality rates for males and females are almost alike. The forecasted life expectancy at birth (e^0) with 95% confidence interval is shown in the Table Appendix A11 and appendix A12 for males and females respectively. The e^0 increases from 61.58 years to 71.74 years during the period 1981-2011 (Table 5.1) with an average increasing amount of, 0.34 year for male and for female average increasing amount is comparatively high, 0.41 year, from 60.55 years in 1981 to 72.93 years in 2011 (Table 5.1). However, from 61.58 years in 1981 the projected male e^0 becomes 83.23 years in 2051 with a yearly increment of 0.31 year and for female it is from 60.55 years in 1981 to 86.35 years in 2051 with a yearly increment of 0.37 year. The increment rate of female e^0 is slight faster than male e^0. It is noticeable that the increment rate of e^0 in urban areas is a little bit slower than that of rural areas and national level. Because e^0 of urban areas was a bit high than that of rural areas as well as national level before started the projection period (2012-2051) due to its improved health and other infrastructural facilities. Figures 6.8a and 6.8b depict the predicted e^0 with 95% confidence interval for males and females respectively. The increasing trends of both figures are showing approximately identical shape of e^0 for both males and females. However, it is also remarkable that the increasing trend is faster during the first half of the whole forecasting period (2012-2051) for both males and females.

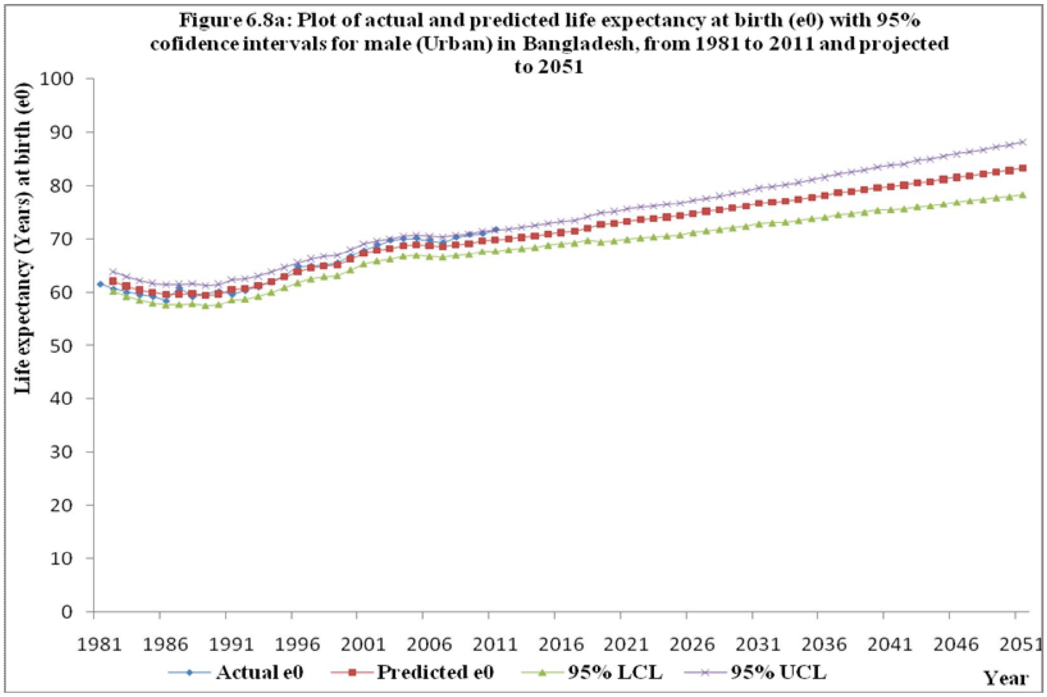


Figure 6.8a: Plot of actual and predicted life expectancy at birth (e0) with 95% cofidence intervals for male (Urban) in Bangladesh, from 1981 to 2011 and projected to 2051
Life expectancy (Years) at birth (e0)
100
90
80
70
60
50
40
30
20
10
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Actual e0
Predicted e0
95% LCL
95% UCL
Year

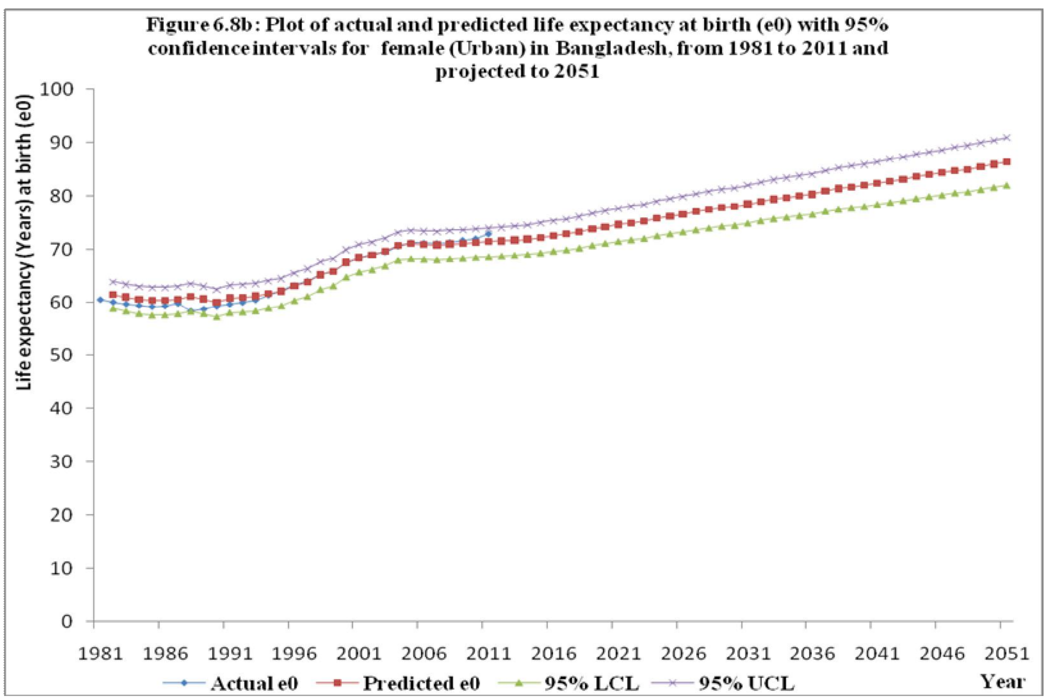


Figure 6.8b: Plot of actual and predicted life expectancy at birth (e0) with 95% confidence intervals for female (Urban) in Bangladesh, from 1981 to 2011 and projected to 2051
Life expectancy (Years) at birth (e0)
100
90
80
70
60
50
40
30
20
10
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Actual e0
Predicted e0
95% LCL
95% UCL
Year

6.4 Summary

This Chapter is performed modeling and forecasting of age specific mortality rates applying the Lee-Carter mortality model according to sex and locality (national, rural and urban areas) in Bangladesh. Used age and sex specific mortality data are available in BBS for the period 1981 to 2011. The index of the level of mortality for each sex by locality was obtained through the Lee-Carter method. The general index of mortality for 1981-2011 is forecasted using ARIMA (0, 1, 0) model. It is important to highlight that the period under study in this research represents the maximum period from which data are available. The behavior of the estimated parameters is similar to the one observed in most of the countries in which this analysis was carried out. The general mortality index (k_t) is a time series that presents low variability and it clearly shows a decreasing trend. Forecasts models such as ARIMA (0, 1, 0) with constant were used to project the k index present an adequate fit. In a second stage, age-specific death rates are predicted using forecasted k_t.

The modeling and forecasting of age-specific mortality by Lee-Carter mortality model provides a probabilistic concept regarding future age-specific mortality course and e^0 depending on the present trend of age-specific mortality in Bangladesh. This gives both positive and negative messages concerning mortality in Bangladesh. If we examine carefully the age-specific forecasted mortality, we can understand both messages. It is evident that all age groups mortality decreases gradually, while infant and child mortality does not show satisfactory improvement until 2051. In fact, comparatively high rate of infant and child mortality may be continuing in future. It is not a good indication regarding socio-economic attainment in Bangladesh in the future. In spite of this limitation e^0 will become more than 82 years for males and more than 86 years for females in 2051. With high infant and child mortality and low socio-economic development it will create a conflicting situation. Therefore, the forecasting result of e^0 is unmatched with the socio-economic development in Bangladesh and its impact on socio-economic development is contradictory. Our forecasting results regarding the future course of mortality and e^0 may suggest the policy-makers of Bangladesh to take proper initiatives to make future plan for minimizing the contradictory situation as much as possible in the future in Bangladesh. The findings of this study are not consistent with the assumption of higher e^0 because of infant and child mortality does not reach the same minimum stage as that of the developed countries and socio-economic development as well.

Therefore, we may conclude from the above discussion that to avoid the more complicated population problems, this is the proper time to implement the useful plans regarding Bangladesh population. Consequently, this study has tried to make an effective proposal for Bangladesh population with the focus of our findings. For the overall population policy we need to execute a strict and effective universal rule and also we need adequate socio-economic development to reach our goal. To get satisfactory socio-economic development it is strictly needed to reduce unstable political condition which is the common phenomenon for Bangladesh. Another important thing is to be noticed that almost half of the population of Bangladesh is female. Thus, it is essential to remove the discrimination between males and females to achieve our goal because without collective efforts it is not possible to achieve the goal.

Chapter VII

Impact of Forecasted Mortality on Future Population in Bangladesh

Abstract

The aim of this chapter is to look at the future of Bangladesh population and to investigate the forecasted mortality impact on future population. It is important to know the size and age composition of the future population to determine the policy regarding socio-economic, socio-cultural and socio-demographic demands of the rising population of a country, particularly, in developing country like Bangladesh. This chapter attempts to find a new set of population data by population projection using cohort component method. Population projection is done in two different scenarios for the next 40 years (2012-2051). Firstly, fertility and mortality is treated fixed as 2011 and secondly, fertility is fixed as 2011 and mortality is forecasted by Lee-Carter model. Recent declines in mortality rates and increases in life expectancy are producing a significant change in population age structure. Working age population will remain at a considerable proportion until 2051, the young age population is reducing and old-age population is increasing. The total dependency ratio (TDR) will decrease till 2021, thereafter slightly increase towards 2051. TDR shows a demographic dividend for Bangladesh to continue economic growth of the country. Decreasing young dependency ratio (YDR) and increasing old dependency ratio (ODR) will also remain at satisfactory level. However, the increasing trend of median age throughout the whole projection period indicates that ageing population problem will start in near future in Bangladesh.

7.1 Introduction

Projected mortality applying Lee-Carter method suggests a significant mortality decline in Bangladesh. Like developed countries and some of the developing countries mortality decline creates a dramatic demographic change in Bangladesh. Demographic change is contemporarily one of the key policy issues, as it influences many areas of social and economic life. Of those a special relevance is problem related to population ageing, i.e. increase of the share of the elderly in the population. As an imminent feature of the developed countries as well as some of the developing countries and also to some extent in Bangladesh, ageing is a process that will no doubt continue in the future. This population process has a significant impact on labour markets and economic growth allowing for mainly the social inequalities, as well as on many other features of life. That’s why it is of key importance to assess the most likely future development paths of demographic processes for the purpose of policymaking and planning, simultaneously with their rational ‘error margin’. This information is provided in a variety of population projections and forecasts which is done either by official statistical authorities, international organizations or by individual researchers. The outcomes of these projections and forecasts may give an important input for the design of future policies and finally for the political decisions.

Moreover, it is also very important to know the size and distribution of future population. Policy-makers can build up a possible future plan for the government regarding socio-economic, socio-cultural, socio-demographic demands of the growing population of a nation using this information. Bangladesh has experienced a large growth of population in the past and still remains high compared with its person-land ratio in the world even in South Asian country’s despite the decrease of the growth rate of population to 1.37 in 2011 from 2.61 in 1974. It is also noteworthy that because of this severe problem Bangladesh has recently been experiencing substantial social, economic and policy transformations and it will certainly have a major impact on its future population. A substantial change occurred in fertility and mortality rates during the last few decades. The fertility declined considerably from a high rate of 6.3 children per woman in 1974 to 2.11 children per woman in 2011 (BBS, 2012). At the same time a considerable mortality decline has taken place during the period in Bangladesh. It is also important that the proportion of elderly population in the total population has been rising with a modest pace due to the change in fertility and mortality rates, and working-age population has been increasing at a faster pace compared to the old-age population. Owing to this fact, total dependency ratio (TDR) has started to decline.

As a result of the above discussion, an important matter is to examine the corresponding impact of decreasing trend in mortality rates in the future population in Bangladesh. In this chapter, we are going to forecast the population by sex and residence in different five year age groups using cohort component method based on the forecasted mortality to focus on the impact of projected future population changes on various aspects of social and economic life, and on deriving relevant policy implications.

Different assumptions in projection are considered in this chapter for obtaining a clear idea regarding future course of population in Bangladesh. The future changes in mortality are expressed in the previous chapter in terms of life expectancy at birth for males and females at national level, rural and urban areas in Bangladesh. The projection of mortality is done by Lee-Carter model. The model produces a significant gain in life expectancy at birth for both males and females in Bangladesh. We try to show both the positive and negative outcomes of the mortality decline related demographic changes: not only threats, but also challenges and opportunities for the future generations.

7.2 Impact of projected mortality on future broad age group population

To determine the impact of projected mortality on future broad age group population we have forecasted the population in two different scenarios. In scenario-I, the population projection is done using both fertility and mortality fixed as the base year 2011. Again in scenario-II, the population projection is done using fixed fertility as the base year 2011 and forecasted mortality by Lee-carter mortality model. The changes in age composition of the projected population can be measured in two ways: firstly, the proportion of total population can be examined in different age groups and secondly, the total number of population can be compared in different age groups. Mainly we concentrate to population broad age groups. Broad age groups are defined as under 15, 15-59 or 15-64 and 60 and over or 65 and over. The middle broad age group (15-59 or 15-64) and the last broad age groups (60 and over or 65 and over) are selected depending on the retirement age of people from job in Bangladesh. So far, in most of the developing countries the retirement age is under 60 and they are using middle broad age group as 15-59 and last broad age group as 60 and over. Whereas, in developed countries the middle broad age is treated as 15-64 and last broad age group as 65 and over as their retirement age is over 60.

Since Bangladesh is a developing country, its retirement age is under 60 in all government jobs and some other jobs, but there are also some government autonomous organizations and many private organizations whose retirement age is over 60. Therefore, we use both types of middle and last broad age groups in the present study to get a better proportional result. The projected broad age groups population is shown in Table appendix-B1a, B1b, B1c by sex for national, rural and urban areas respectively according to scenario-I for the period 2011-2051. Figures 7.1a, 7.1b and 7.1c display the projected broad age group population percentage by sex according to scenario-I for national, rural and urban areas in Bangladesh. While, Table appendix- B2a, B2b, B2c and figures 7.2a, 7.2b, 7.2c depict the same according to scenario-II.

It is evident that in both the scenarios the projected percentage of working-age population (age group 15-59 and 15-64) has increased till 2021, afterward; it will start to decrease at a slow pace in both the projections. May be it is because of population momentum due to the past high TFR and continuation of the above replacement level fertility rate during the whole projection period. However, the projected high percentage of working-age population during the whole projection period (2012-2051) will remain as a demographic gift or bonus, regardless of a very slow decreasing trend in working-age population after attaining the peak in 2021. In scenario-I the percentage of working-age (15-59) population will increase from 60.23% in the base year 2011 to 65.18% in 2021 for male and then start declining and will reach 61.11% in 2051 at national level (Table appendix-B1a). While for the female it will increase from 62.08% in the base year 2011 to 66.01% in 2021 and then start decreasing towards 2051 and will reach 57.70% (Table appendix-B1a). Whereas, the working age (15-64) population will increase from 62.79% in the base year 2011 to 68.80% in 2021 for male and then start declining and will reach 66.49% in 2051 at national level (Table appendix-B1a). While for the female it will increase from 64.29% in the base year 2011 to 69.60% in 2021 and then start decreasing towards 2051 and will reach 64.09% (Table appendix-B1a). The same upward and downward tendency is apparent in both the working age groups (15-59 and 15-64). Obviously the proportion of population in the latter working age group (15-64) is much higher than the former (15-59) and the difference is getting wider in the latter projection years which are clearly demonstrated graphically in the figure 7.1a. The proportion of both the working age group (15-59 and 15-64) population in rural and urban areas is approximately same as national level during the whole projection period (Table appendix B1b and B1c, Figure- 7.1b and 7.1c).

On the other hand, in scenario-II the working age group population (15-59) for male is increased from 60.23% in the base year 2011 to 65.18% in 2021, afterwards it is started decreasing slowly in the rest of the projection periods and will become 58.23% in 2051 at national level, while for the female it will increase from 62.08% in 2011 to 65.89% in 2021 and then gradually decreased to 54.82% in 2051 (Table appendix B2a). Whereas, the male working age group (15-64) population will increase from 62.79% in 2011 to 68.87% in 2021 and then decreased slowly to 63.72% in 2051 (Table appendix B2a) at national level; for the female it is increased from 64.29% in 2011 to 69.52% in 2021 and then slowly decreased to 61.11% in 2051 (Table appendix B2a). The graphical presentation gives the clear picture in the figure 7.2a. The proportion of both the working age group (15-59 and 15-64) population for rural and urban areas is more or less alike as national level (Table appendix B2b and B2c, Figure 7.2b and 7.2c). It is evident that though a slow declining in working age group population is apparent in Bangladesh after 2021, it is still very encouraging that a huge portion of population will remain as working as group population until 2051, which is really a demographic dividend for Bangladesh.

Again, the percentage of young age (0-14) population is declined sharply till 2021 then gradually towards rest of the period for both males and females. In scenario-I, the young age population is declined from 32.56% in 2011 to 19.09% in 2051 for male and from 31.23% in 2011 to 18.40% in 2051 for female at national level (Table appendix B1a). The declining pattern is clearly illustrated in the figure 7.1a. The young age population proportion pattern in the rural and urban areas are approximately same as that of national level (Table appendix B1b and B1c, figure 7.1b and 7.1c). On the other hand in scenario-II, the young age (0-14) population is declined from 32.56% in 2011 to 18.63% in 2051 for male and from 31.23% in 2011 to 17.93% in 2051 for female at national level (Table appendix B2a). The pattern is shown graphically in the figure 7.2a. The proportion of young age population in rural and urban areas is also approximately same in this projection (Table appendix B2b and B2c, Figure 7.2b and 7.2c). In both the scenarios the declining of young age population continues in the same manner throughout the whole projection period. This is the sign of significant improvement in infant and child mortality in Bangladesh.

Again, the percentage of both type of old age group (60+ and 65+) population is increased remarkably in both the scenarios. In scenario-I, the old age group (60+) population is increased from 7.21% in the base year 2011 to 19.80% in the last projection year 2051 for male and from 6.68% in 2011 to 23.89% in 2051 for female at national level. While the old age group (65+) population is increased from 4.65% in 2011 to 14.42% in 2051 for male and from 4.48% in 2011 to 17.51% in 2051 for female (Table appendix B1a). It is apparent that the increasing pace of old age group population proportion of female is faster than male. Figure 7.1a demonstrates the picture clearly. The proportion of population of both the old age group (60+ and 65+) of the rural and urban areas is approximately same as that of national level (Table appendix B1b and B1c, Figure 7.1b and 7.1c). On the other hand in scenario-II, the old age group (60+) population is increased from 7.21% in 2011 to 23.14% in 2051 for male and from 6.68% in 2011 to 27.25% in 2051 for female at national level. While the old age group (65+) population is increased from 4.65% in 2011 to 17.64% in 2051 for male and from 4.48% in 2011 to 20.96% in 2051 for female (Table appendix B2a). The proportion of old age group population in rural and urban areas is more or less alike with that of national level (Table appendix B2b and B2c, Figure 7.2b and 7.2c). It is apparent that the projected proportion of both the old age group population is significantly rising during the whole projection period and also the female proportion is rising faster than male. This is mostly because of the forecasted mortality declining as well as increasing life expectancy at birth (e^0) pattern.

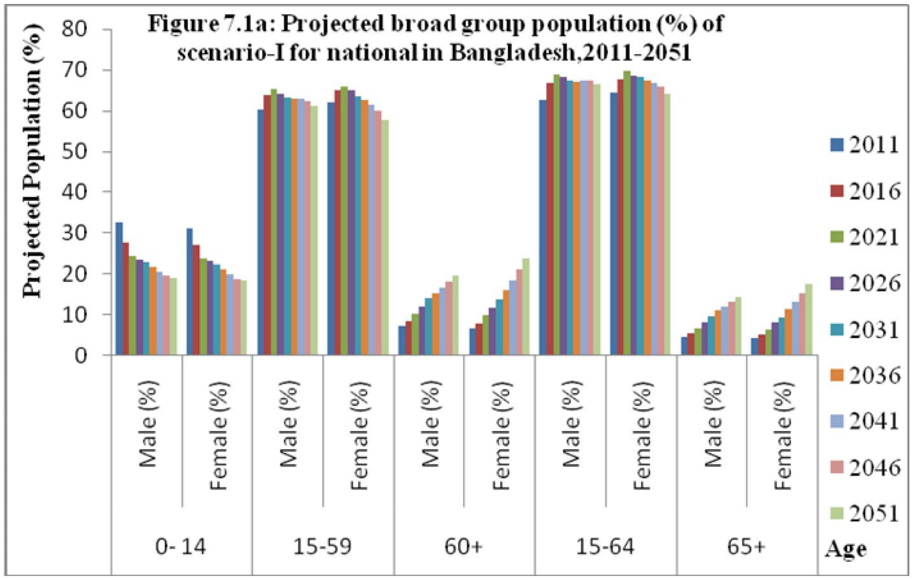


Figure 7.1a: Projected broad group population (%) of scenario-I for national in Bangladesh,2011-2051
Projected Population (%)
80
70
60
50
40
30
20
10
0
Male (%)
Female (%)
0- 14
15-59
60+
15-64
65+
Age
2011
2016
2021
2026
2031
2036
2041
2046
2051

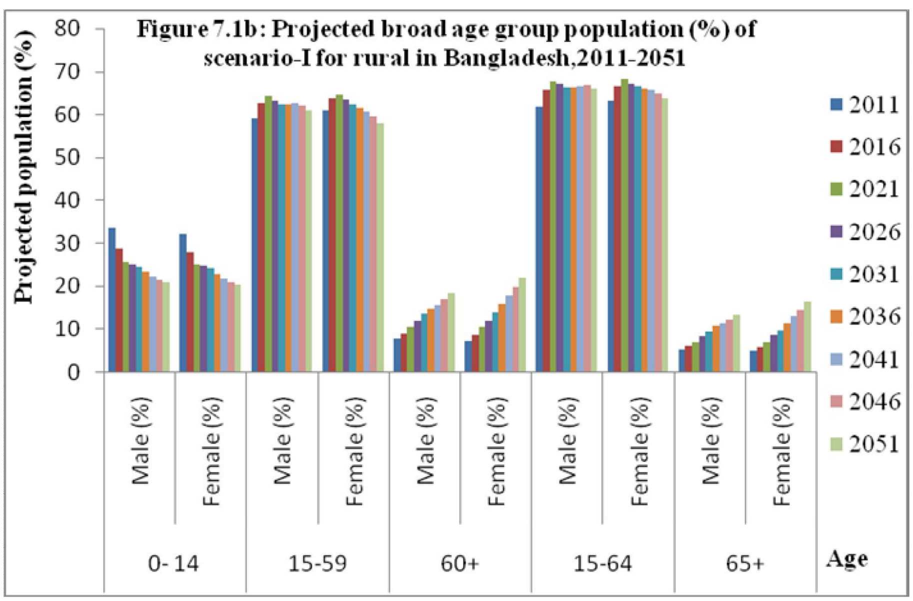


Figure 7.1b: Projected broad age group population (%) of scenario-I for rural in Bangladesh,2011-2051
Projected population (%)
80
70
60
50
40
30
20
10
0
Male (%)
Female (%)
0- 14
15-59
60+
15-64
65+
Age
2011
2016
2021
2026
2031
2036
2041
2046
2051

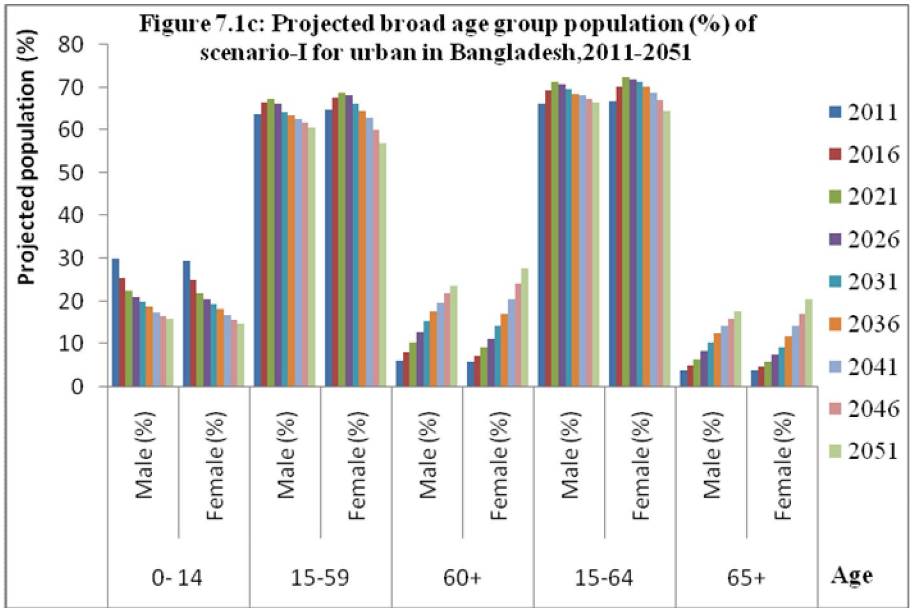


Figure 7.1c: Projected broad age group population (%) of scenario-I for urban in Bangladesh,2011-2051
Projected population (%)
80
70
60
50
40
30
20
10
0
Male (%)
Female (%)
0- 14
15-59
60+
15-64
65+
Age
2011
2016
2021
2026
2031
2036
2041
2046
2051

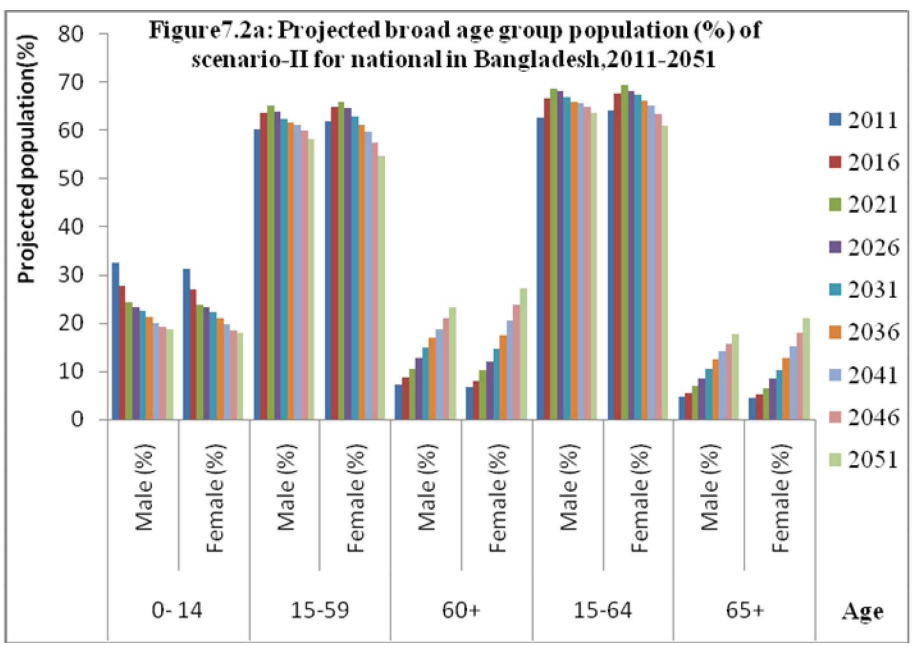


Figure7.2a: Projected broad age group population (%) of scenario-II for national in Bangladesh,2011-2051
Projected population(%)
80
70
60
50
40
30
20
10
0
Male (%)
Female (%)
0- 14
15-59
60+
15-64
65+
Age
2011
2016
2021
2026
2031
2036
2041
2046
2051

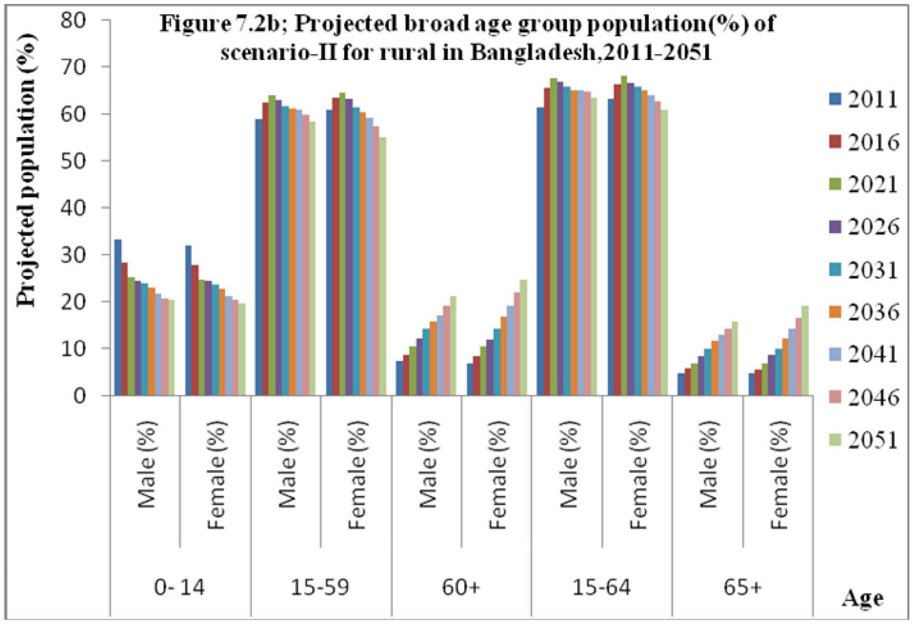


Figure 7.2b; Projected broad age group population(%) of scenario-II for rural in Bangladesh,2011-2051
Projected population (%)
80
70
60
50
40
30
20
10
0
Male (%)
Female (%)
0- 14
15-59
60+
15-64
65+
Age
2011
2016
2021
2026
2031
2036
2041
2046
2051

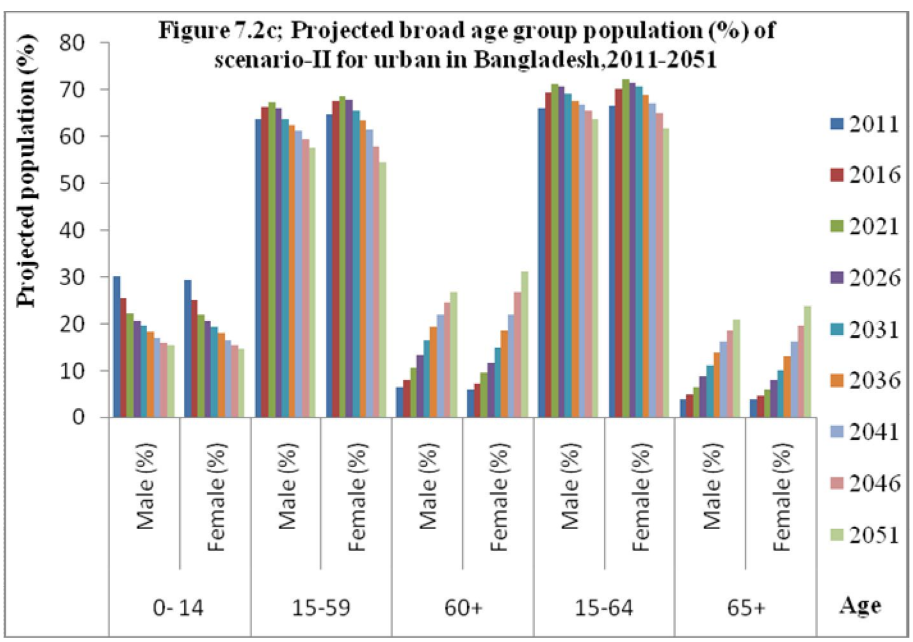


Figure 7.2c; Projected broad age group population (%) of scenario-II for urban in Bangladesh,2011-2051
Projected population (%)
80
70
60
50
40
30
20
10
0
Male (%)
Female (%)
0- 14
15-59
60+
15-64
65+
Age
2011
2016
2021
2026
2031
2036
2041
2046
2051

7.3 Projected mortality impact on old age population and its consequence of ageing population in Bangladesh

Two significant characteristics of the projected population, dependency ratio and median age for two different scenarios are displayed in the Table appendix-B3a, B3b and B3c at national level, rural and urban areas respectively for the period 2011-2051. The most important characteristic of the new population projection is that the age composition of population will experience a significant change in future, no matter what the assumptions are with regard to the population components. The key change will happen in the proportion of working age group (15-59 and 15-64) population. And a significant decline will occur in the proportion of the young age group (0-14) population. These changes evidently imply a considerable decrease in TDR and increase in the median age of population. Though a substantial percentage of declining occur for young age population during the whole projection period, it is important to know that it does not mean that the total number will decline in the same proportion. In fact, according to both the scenarios, the total number of young-age population will continue decreasing very slowly towards 2051 and remain nearly stagnant. It is merely positive message that the supply of working age people will continue from the young age during the whole projection period.

Two different types of total dependency ratio (TDR) are measured in this study. Firstly, TDR* is measured by the ratio of the dependent age group (0-14 and 60+) population to the working age group (15-59). Secondly, TDR** is measured by the ratio of the dependent age group (0-14 and 65+) population to the working age group (15-64). In scenario-I, TDR* is decreased from 63.57% in 2011 to 52.48% in 2021, then starts increasing slowly towards rest of the projection period and will become 68.30% in 2051 and TDR** is decreased from 57.43% in 2011 to 44.52% in 2021, then again starts increasing slowly and reached 53.15% in 2051 at national level (Table appendix B3a). It is apparent that after 2021 the slight increasing of TDR will happen due to increasing life expectancy at birth (e^0) and increasing number of old-age population. It will be still encouraging for Bangladesh as TDR will be at reasonable level in 2051. On the other hand, in scenario-II, TDR* is decreased from 63.57% in 2011 to 52.61% in 2021, then starts increasing slowly towards rest of the period and become 76.93% in 2051 at national level and TDR** is decreased from 57.43% in 2011 to 44.53% in 2021, then increasing slowly throughout the rest of the projection period and in 2051 it will be 60.23% at national level (Table appendix B3a). In spite of a little increasing tendency of TDR after 2021, it seems that until 2051 working age population will be much higher than dependent population and that is a positive message for the future development of Bangladesh. The pattern of TDR* and TDR** for rural and urban areas is approximately same which is demonstrated in Table appendix B3b and B3c respectively for both the scenarios.

To see the young age dependency, we use two types of young dependency ratios, YDR* and YDR** due to two types of working age groups (15-59 and 15-64) population. YDR* is defined as the ratio of 0-14 age group population to the working age group, 15-59 and YDR** is defined as the ratio of 0-14 age group population to working age group, 15-64. It is apparent that YDR* and YDR** is decreasing throughout the whole projection period in both the scenarios but the decreasing pace is much slower after 2021. In scenario-I, YDR* is decreased from 52.20% in 2011 to 31.55% in 2051 and YDR** is decreased from 50.24% in 2011 to 28.71% in 2051 at national level (Table appendix B3a). Whereas in scenario-II, YDR* is decreased from 52.20% in 2011 to 32.34% in 2051 and YDR** is decreased from 50.24% in 2011 to 29.29% in 2051 at national level (Table appendix B3a). It is evident that YDR* and YDR** for rural and urban areas are almost same as national level in both the scenarios. Table appendix B3b and B3c illustrate pattern of YDR* and YDR** for rural and urban areas respectively for both the scenarios.

Again, we obtain the old-age dependency ratio (ODR) to know the pattern of old-age dependency on working age group population. Here also two types of old-age dependency ratios (ODR* and ODR**) are calculated for two types of working age group (15-59 and 15-64) and old-age group (60+ and 65+) population. ODR* is the ratio of 60+ age group population to 15-59 age group population and ODR** is the ratio of 65+ age group population to 15-64 age group population. Both ODR* and ODR** are increased during the whole projection period in both the scenarios, but the pace of increasing is slight faster after 2016. In scenario-I, ODR* is increased from 11.37% in 2011 to 36.75% in 2051 and ODR** is increased from 7.19% in 2011 to

24.44% in 2051 at national level (Table appendix B3a). On the other hand, in scenario-II, ODR* is increased from 11.37% in 2011 to 44.59% in 2051 and ODR** is increased from 7.19% in 2011 to 30.94% in 2051 at national level (Table appendix B3a). It is evident that both ODR* and ODR** is increased more rapidly in scenario-II than scenario-I. It is also apparent that the pattern of ODR* and ODR** in rural and urban areas are more or less alike as national level which is displayed in the Table appendix B3b and B3c respectively. The increasing ODR does not affect TDR because of simultaneous decreasing of YDR and it is obviously a positive sign for future economic development in Bangladesh. Figures 7.3a, 7.4a, 7.5a, 7.6a, 7.7a and 7.8a illustrate the TDR*, YDR* and ODR* at national level, rural and urban areas respectively for both the scenarios. Again, figures 7.3b, 7.4b, 7.5b, 7.6b, 7.7b and 7.8b depict the TDR**, YDR** and ODR** at national level, rural and urban areas respectively for both the scenarios. Similar trend is apparent for all the ratios in all the figures.

The median age of population is displayed in the Table appendix B3a, B3b and B3c at national level, rural and urban areas respectively for both the scenarios. It has been seen that the median age is increased significantly in both the scenarios for both males and females. Moreover, median age for female is a little bit higher than that of male in both the scenarios. In scenario-I, the median age is increased from 23.93 years in 2011 to 38.72 years in 2051 for males and from 24.60 years in 2011 to 40.17 years in 2051 for females at national level. Whereas, in scenario-II, the median age is increased from 23.93 years in 2011 to 40.58 years in 2051 for males and from 24.60 years in 2011 to 41.98 years in 2051 for females at national level (Table appendix B3a). The median age of rural and urban areas is shown in the Table appendix B3b and B3c respectively. The increasing trend in median age of the population is obviously a consequence of the declining trend of fertility and mortality. It is apparent that the median age of rural and urban areas is also increasing throughout the whole period and it is also noticeable that the median age of urban areas is somewhat greater than that of rural areas. It may be because of high mortality reduction and high life expectancy at birth (e^0) in urban areas than those of rural areas. Figure 7.9a, 7.10a and 7.11a illustrate the median age at national level, rural and urban areas respectively in scenario-I. Again, figure 7.9b, 7.10b and 7.11b depict the median age at national level, rural and urban areas respectively in scenario-II.

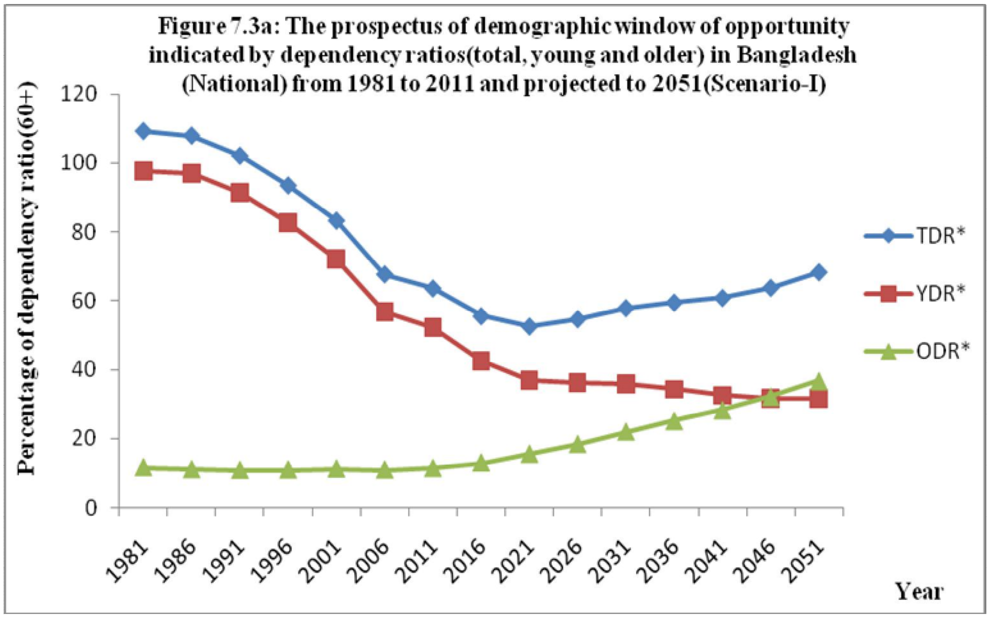


Figure 7.3a: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (National) from 1981 to 2011 and projected to 2051(Scenario-I)
Percentage of dependency ratio(60+)
120
100
80
60
40
20
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Year
TDR*
YDR*
ODR*

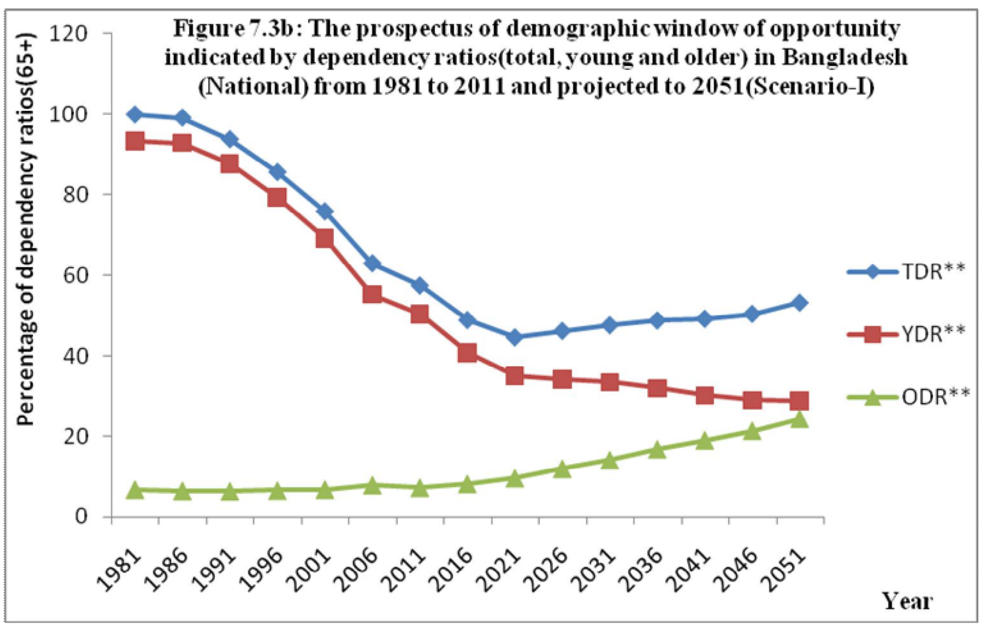


Figure 7.3b: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (National) from 1981 to 2011 and projected to 2051(Scenario-I)
Percentage of dependency ratios(65+)
120
100
80
60
40
20
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Year
TDR**
YDR**
ODR**

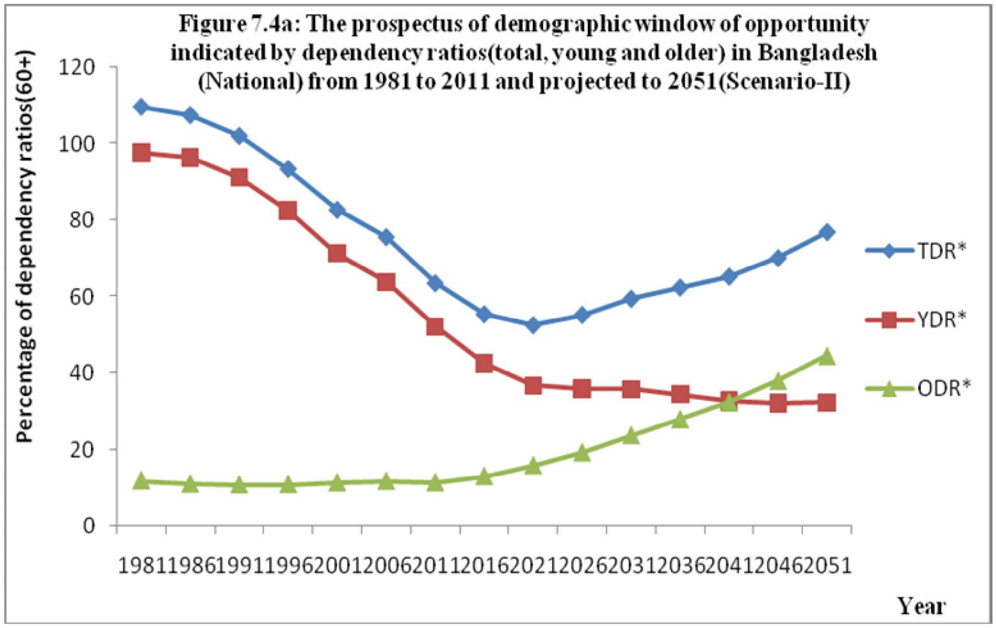


Figure 7.4a: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (National) from 1981 to 2011 and projected to 2051(Scenario-II)
Percentage of dependency ratios(60+)
120
100
80
60
40
20
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Year
TDR*
YDR*
ODR*

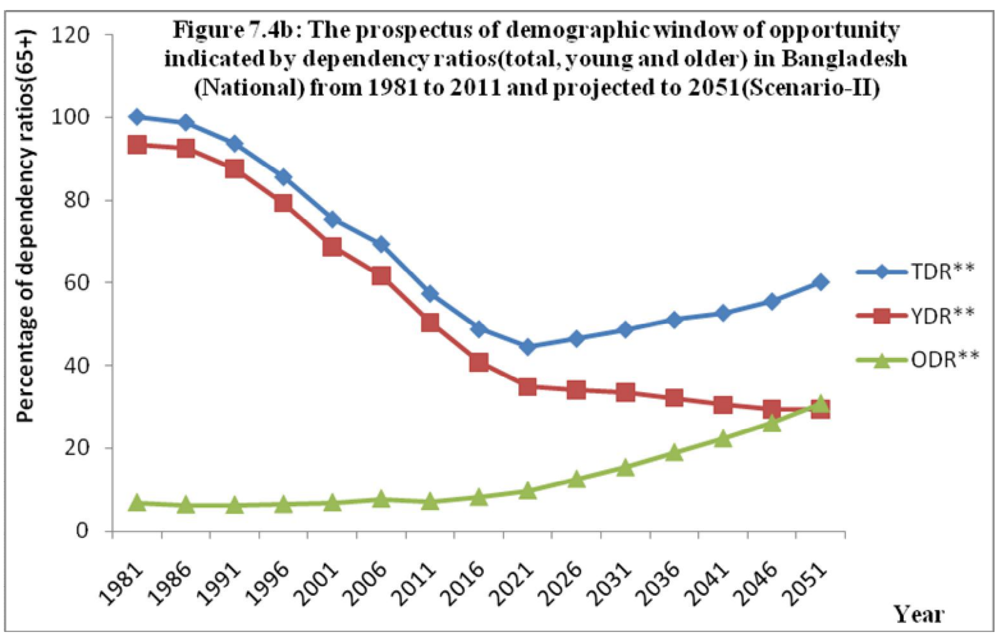


Figure 7.4b: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (National) from 1981 to 2011 and projected to 2051(Scenario-II)
Percentage of dependency ratios(65+)
120
100
80
60
40
20
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Year
TDR**
YDR**
ODR**

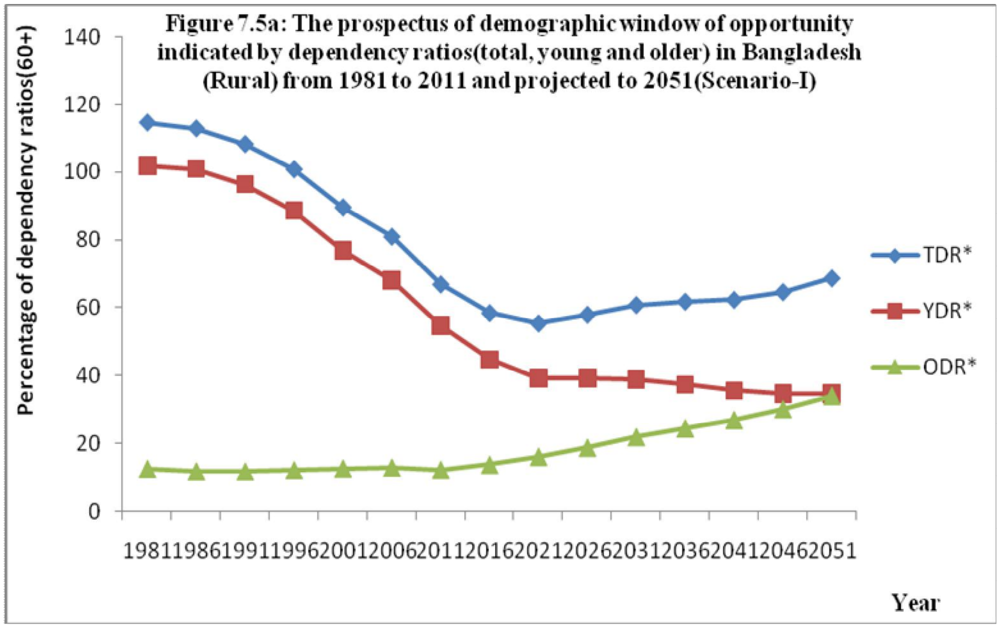


Figure 7.5a: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (Rural) from 1981 to 2011 and projected to 2051(Scenario-I)
Percentage of dependency ratios(60+)
140
120
100
80
60
40
20
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Year
TDR*
YDR*
ODR*

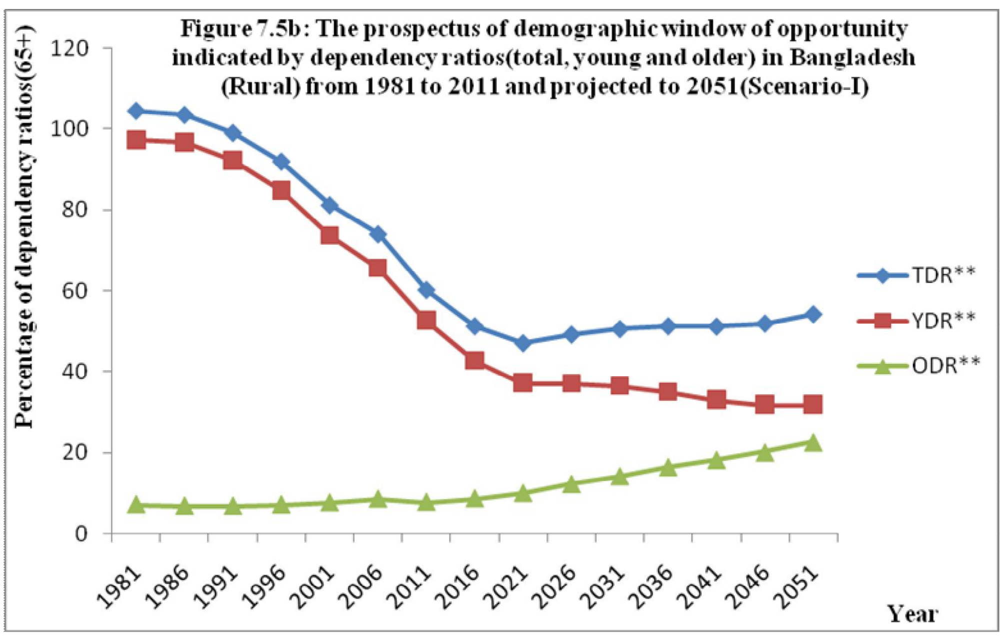


Figure 7.5b: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (Rural) from 1981 to 2011 and projected to 2051(Scenario-I)
Percentage of dependency ratios(65+)
120
100
80
60
40
20
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Year
TDR**
YDR**
ODR**

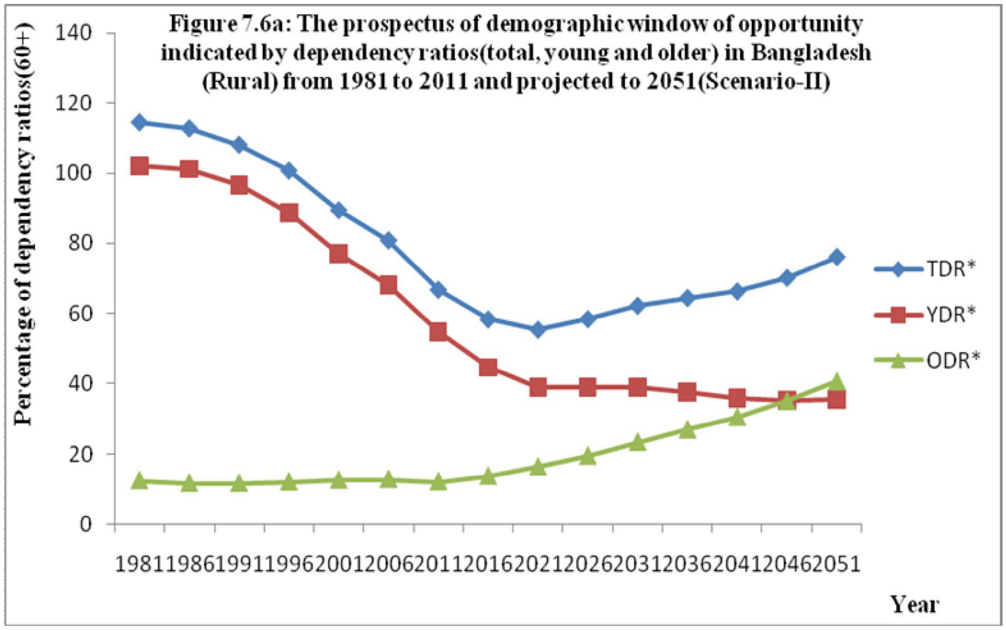


Figure 7.6a: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (Rural) from 1981 to 2011 and projected to 2051(Scenario-II)
Percentage of dependency ratios(60+)
140
120
100
80
60
40
20
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Year
TDR*
YDR*
ODR*

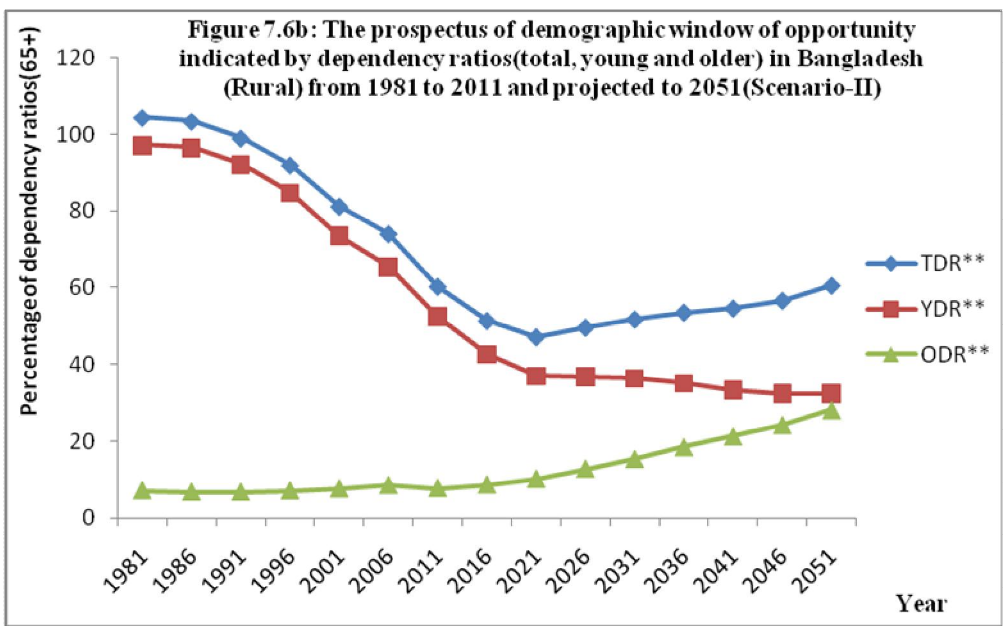


Figure 7.6b: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (Rural) from 1981 to 2011 and projected to 2051(Scenario-II)
Percentageof dependency ratios(65+)
120
100
80
60
40
20
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Year
TDR**
YDR**
ODR**

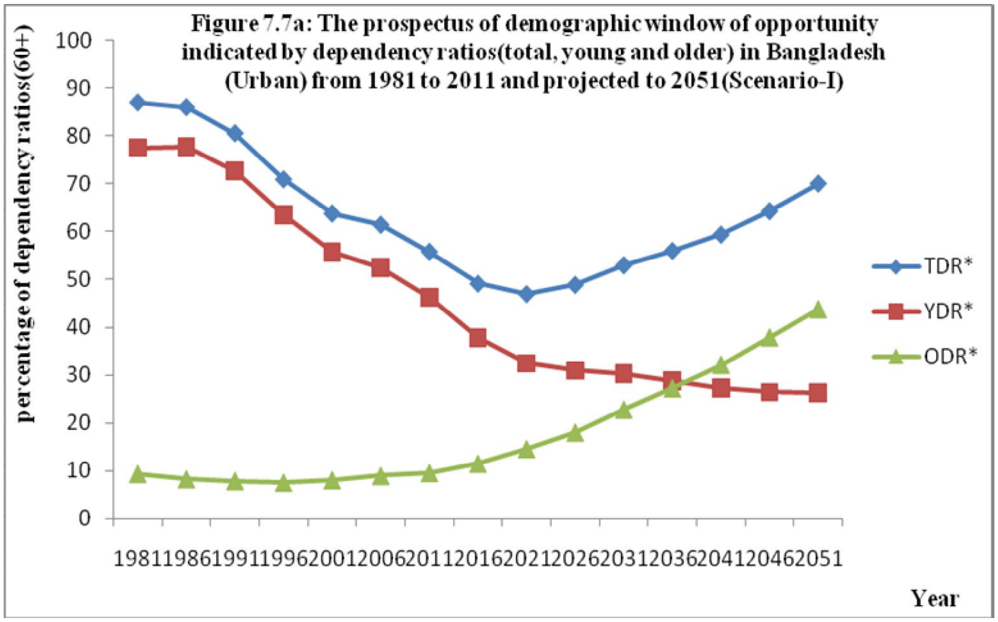


Figure 7.7a: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (Urban) from 1981 to 2011 and projected to 2051(Scenario-I)
percentage of dependency ratios(60+)
100
90
80
70
60
50
40
30
20
10
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Year
TDR*
YDR*
ODR*

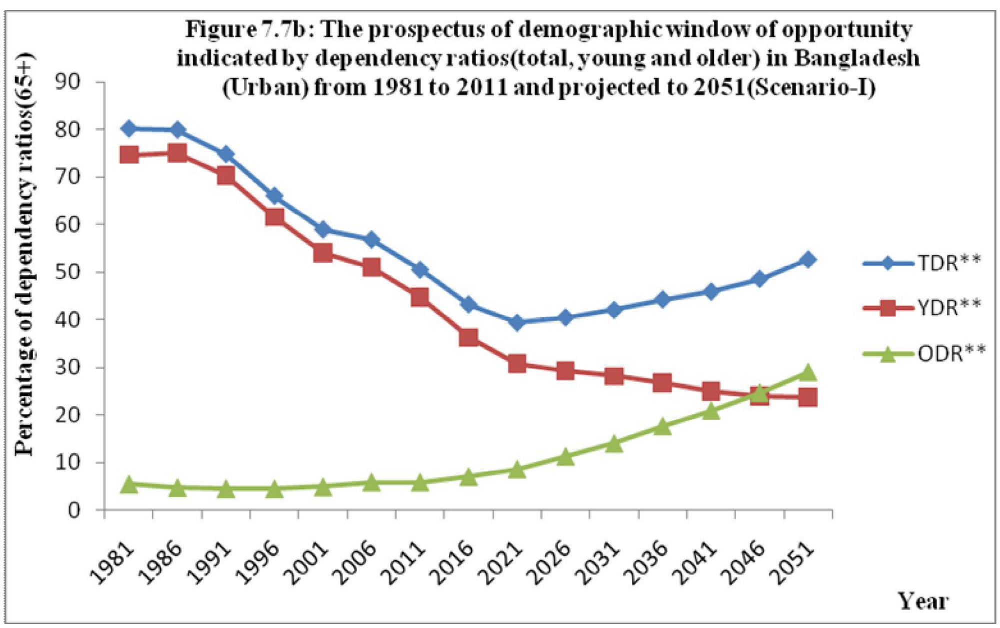


Figure 7.7b: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (Urban) from 1981 to 2011 and projected to 2051(Scenario-I)
Percentage of dependency ratios(65+)
90
80
70
60
50
40
30
20
10
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Year
TDR**
YDR**
ODR**

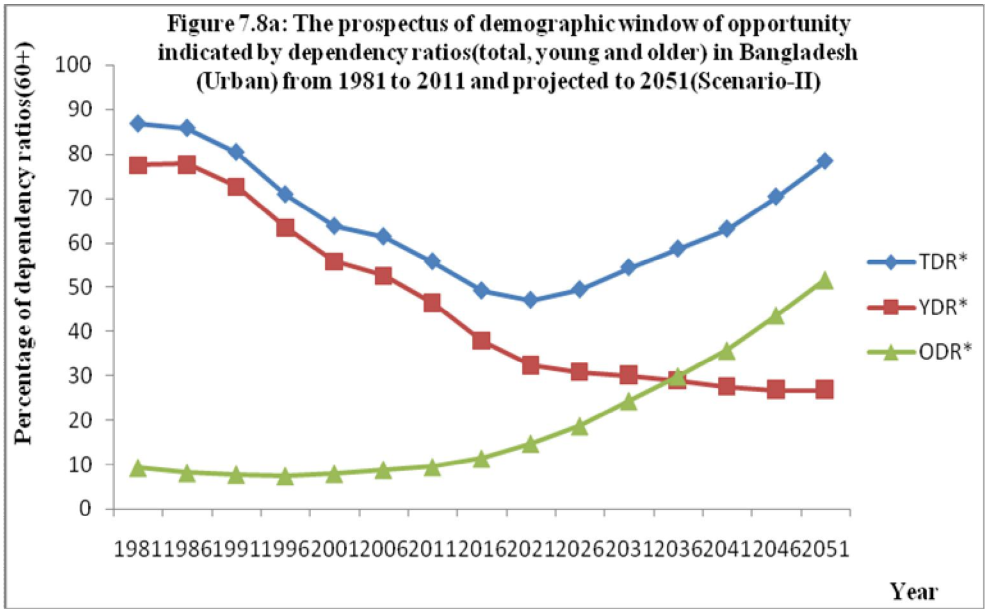


Figure 7.8a: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (Urban) from 1981 to 2011 and projected to 2051(Scenario-II)
Percentage of dependency ratios(60+)
100
90
80
70
60
50
40
30
20
10
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Year
TDR*
YDR*
ODR*

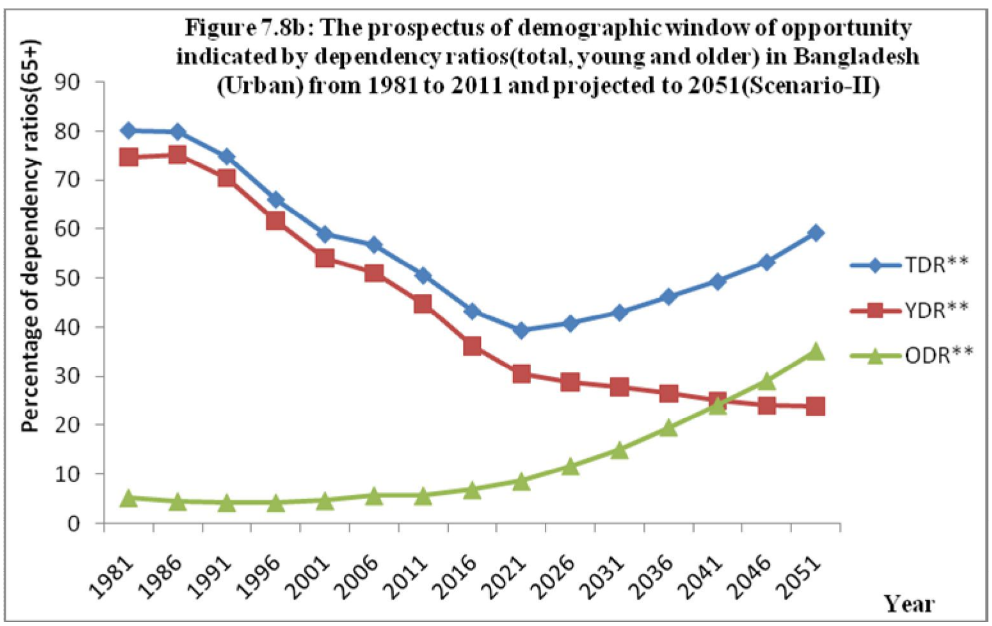


Figure 7.8b: The prospectus of demographic window of opportunity indicated by dependency ratios(total, young and older) in Bangladesh (Urban) from 1981 to 2011 and projected to 2051(Scenario-II)
Percentage of dependency ratios(65+)
90
80
70
60
50
40
30
20
10
0
1981 1986 1991 1996 2001 2006 2011 2016 2021 2026 2031 2036 2041 2046 2051
Year
TDR**
YDR**
ODR**

Figure 7.9a: Pattern of median age of population (male, female and both) in Bangladesh (National) from 1981 to 2011 and projected to 2051 (Scenario-I)

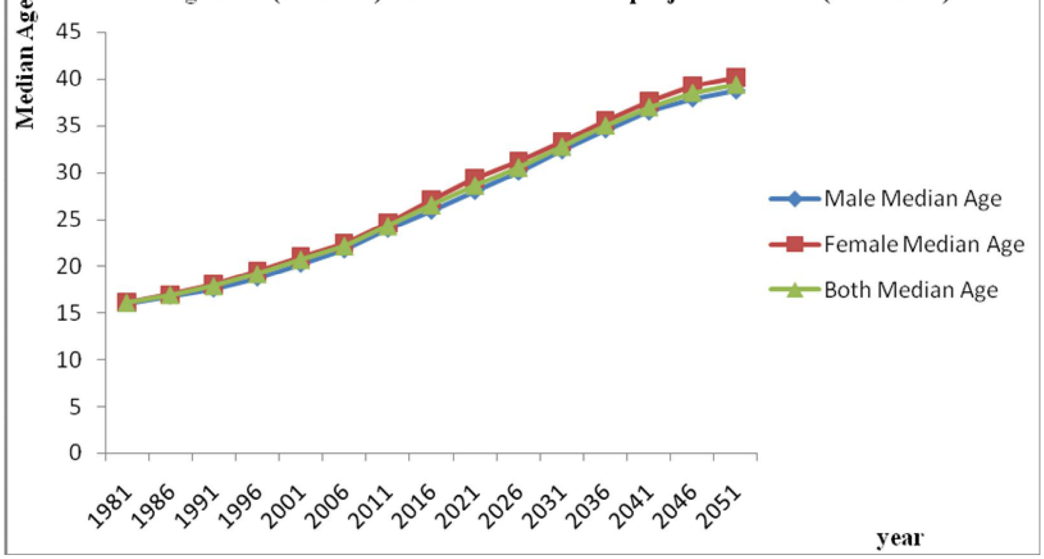
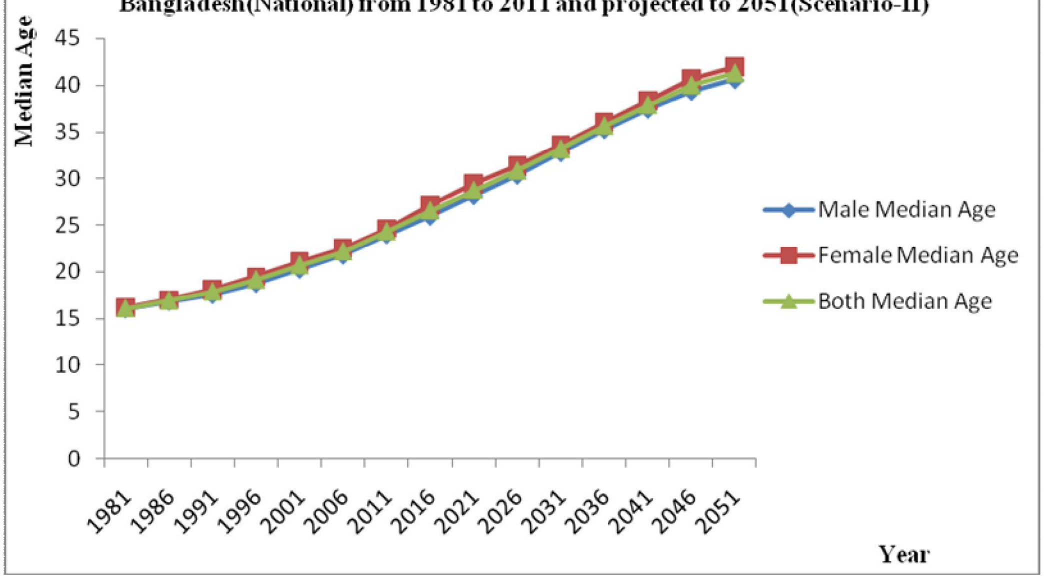


Figure 7.9b: Pattern of median age of population (male, female and both) in Bangladesh(National) from 1981 to 2011 and projected to 2051(Scenario-II)



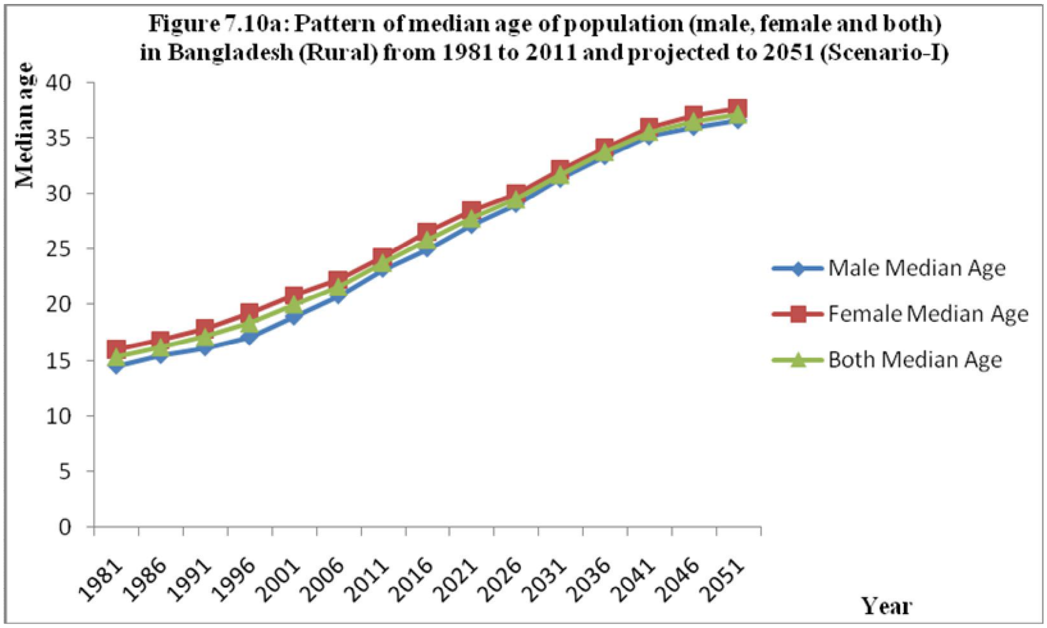


Figure 7.10a: Pattern of median age of population (male, female and both)
in Bangladesh (Rural) from 1981 to 2011 and projected to 2051 (Scenario-I)
Median age
40
35
30
25
20
15
10
5
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Year
Male Median Age
Female Median Age
Both Median Age

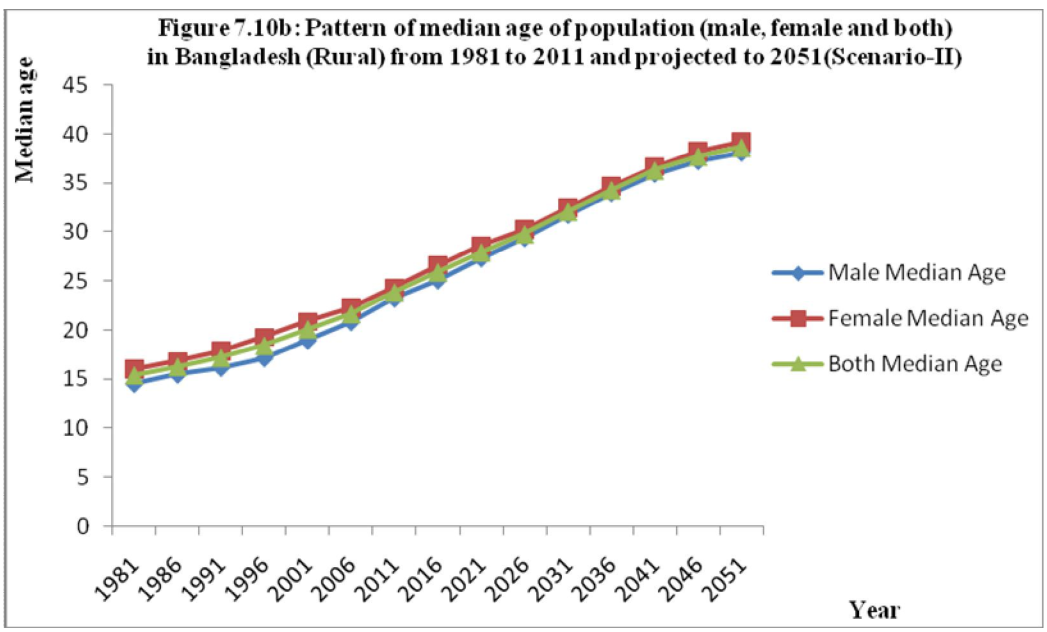


Figure 7.10b: Pattern of median age of population (male, female and both)
in Bangladesh (Rural) from 1981 to 2011 and projected to 2051(Scenario-II)
Median age
45
40
35
30
25
20
15
10
5
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Year
Male Median Age
Female Median Age
Both Median Age

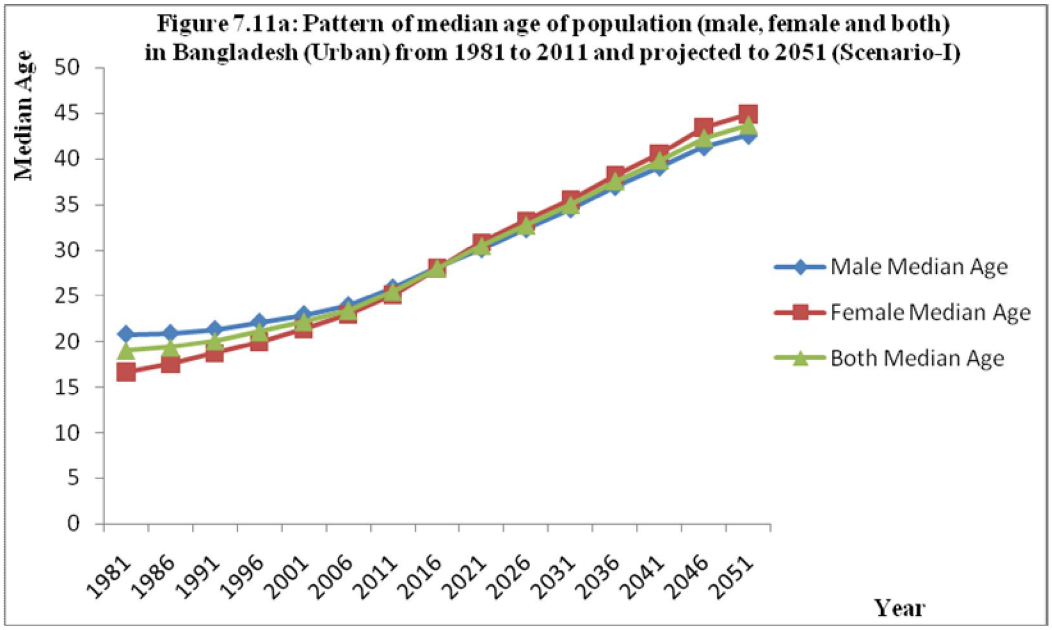


Figure 7.11a: Pattern of median age of population (male, female and both)
in Bangladesh (Urban) from 1981 to 2011 and projected to 2051 (Scenario-I)
Median Age
50
45
40
35
30
25
20
15
10
5
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Year
Male Median Age
Female Median Age
Both Median Age

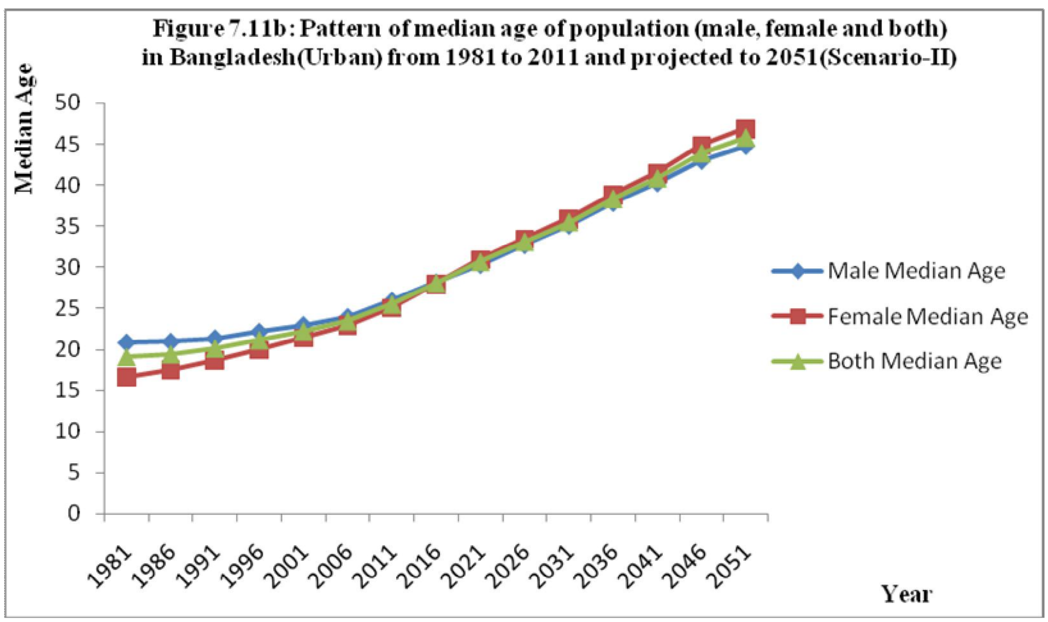


Figure 7.11b: Pattern of median age of population (male, female and both)
in Bangladesh(Urban) from 1981 to 2011 and projected to 2051(Scenario-II)
Median Age
50
45
40
35
30
25
20
15
10
5
0
1981
1986
1991
1996
2001
2006
2011
2016
2021
2026
2031
2036
2041
2046
2051
Year
Male Median Age
Female Median Age
Both Median Age

7.4 Summary

A substantial mortality decline is apparent in the mortality forecasting carried out in the previous chapter which results a significant increase in e^0. Based on this forecasted mortality population projection is done in this chapter in two different scenarios. Scenario-I performs population projection taking both fertility and mortality fixed as the base year 2011 and scenario-II takes the fertility fixed as 2011 and mortality forecasted by Lee-Carter method. Both the scenarios give the similar encouraging message that during the whole projection period the huge proportion of working age (15-59 and 15-64) population will exist for both males and females irrespective of residence (national, rural and urban) in Bangladesh. Though after reaching at the peak in 2021 both the working age population (for 15-59, male-65.18% and female-66.01%; for 15-64, male-68.80% and female-69.60%) will start declining slowly towards rest of the period and reach at 61.11% (15-59) and 66.49% (15-64) for male, while 57.70% (15-59) and 64.09% (15-64) for female in 2051. This high proportion of working age population is really a demographic dividend for Bangladesh if the country could employ them properly in economic development. A satisfactory result is found in all the dependency ratios (TDR, YDR and ODR) as well. TDR is decreased till 2021, then slowly increased in rest of the period but will still remain at appreciable level until 2051. YDR is remarkably decreasing during the whole projection period and ODR is increasing gradually towards the whole period. ODR is increasing because of significant increment of life expectancy at birth (e^0) as well as increasing portion of elderly population. It is also evident that the median age of the population is rising considerably for both males and females in both the scenarios towards the whole period. This is a sign of future population ageing in Bangladesh. Currently the e^o is much higher than the retirement age in Bangladesh and the difference will become wider in the latter part of the projection period. That means a large number of elderly people will present in the country. This will create negative side-effects on the social and economic life of the future population.

Specially increasing public expenditure on pensions, social security and health services will create overall economic burden on the working age population.

Although at present these issues are not critical yet in Bangladesh, certain policy measures require to be executed as soon as possible, in order to avoid severe problems related to ageing of population in the future. Ageing is therefore a vital policy challenge, concerning many areas of life: health care, economy, social security systems, education as well as changes in the attitudes and practices towards the elderly and their role in the society.

Chapter VIII

Summary, Discussion and Recommendations

8.1 Introduction

Remarkable mortality decline is apparent during the last few decades in Bangladesh. It is mostly because of infant and child mortality reduction. Old age mortality is also declined to some extent. It is evident that about 50% reduction in Crude Death Rate (CDR) is happened during the period 1981-2011. On the other hand, the Infant Mortality Rate (IMR) has reduced about 70% in the same period. Although, both CDR and IMR reduction is not satisfactory compared to developed countries. Still CDR and IMR are high in comparison with developed countries and some of the developing countries (e.g. China and SriLanka). Poor socio-economic condition is the main hindrance for that. Long colonial reign was the major barrier regarding all kinds of development. After being independence windows are opened for all sorts of development in Bangladesh and the country is now developing in all aspects. This study is examined the trends and differentials of mortality between the study periods 1981-2011. Based on the present trends, it is forecasted the mortality and life expectancy at birth (e^0) by Lee-Carter method for the next 40 years (2012-2051) to know the future course of life expectancy at birth. To carry out the projection this study used the data from different census reports of Bangladesh Bureau of Statistics (BBS) and also the reports of SVRS in 2001, 2003, 2010, 2011 and 2012. To observe the impact of forecasted mortality on the future population, a further projection is done for population in two scenarios. To carry out these investigations, this study also looks into the present condition of socio-economic development and demographic change in Bangladesh.

8.2 Major findings and discussion

The present situation of socio-economic development and demographic change in Bangladesh has observed in chapter IV. It is revealed that the population of Bangladesh is increased to 150.6 million in 2011 from 89.9 million in 1981. The literacy rate is increased gradually to 55.8% in 2011 from 26.8% in 1974 for 7+ year's population and to 58.8% in 2011 from 25.8% in 1974 for 15+ year's population. The increase of literacy rate is happened both in rural and urban areas and the pace of increase is faster after 1991, when the country gets back democracy from the military ruler. Contraceptive prevalence rate has been increased dramatically from 7.7% in 1975 to 58.3% in 2011. Female labour force participation is increasing and young age (0-14 age group) labour force participation is decreasing day by day due to increasing rate of schooling. That is indeed a good sign for the country's socio-economic development. GDP per capita and GDP growth rate is increasing gradually. From 1996 GDP growth rate continues with more than 5% and from 2006 it continues with more than 6% consistently. Now Bangladesh is one of the high GDP growth rate countries in the world. A notable development is taken place in sectoral shares in GDP. Typically Bangladesh was known as agriculture based country. About 59.26% of its total GDP was contributed by agriculture in 1974 and it decreased to 20.01% in 2011. At the same time industry's contribution increased to 30.38% in 2011 from 7.19% in 1974 and service sector became stable around 50% after 1974. Annual growth rate of population has decreased to 1.37% in 2011 from 2.61% in 1974, population density has become 1015 per square kilometer in 2011 from 518 per square kilometer in 1974 and it creates the nation as one of the most densely populated countries in the world. Urban population percentage is increased gradually to 25.90% in 2011 from 8.78% in 1974. Median age of the population is increasing day by day. It is also evident that the increasing trend of female median age is higher than that of male at national level and rural areas but male median age is higher than that of female in urban areas. The Crude Birth Rate is decreased to 19.2 per thousand people in 2011 from 48.3 per thousand people in 1974; the Crude Death Rate becomes 5.5 per thousand in 2011 from 19.4 per thousand in 1974 and the Infant Mortality Rate to 35 per thousand in 2011 from 128 per thousand in 1974. The Total Fertility Rate (TFR) is reduced to 2.11 in 2011 from 6.30 in 1974, which is very close to replacement fertility (2.1). It is noteworthy that urban TFR has achieved the replacement fertility but rural TFR is still somewhat far from replacement level. This is because of city dwellers are more aware about small family. Mean age at first marriage is increasing because people are interested to build up a solid career first then get married. It is perceptible that though a substantial improvement in socio-economic development and demographic change are apparent in the last few decades in Bangladesh, still this is not good enough. A long way is to go to achieve the target level. Till now, overall mortality is high compared to developed countries and also IMR is in the same condition.

Trends and differentials of mortality are analyzed in chapter V. It is observed that life expectancy at birth (e^0) is increasing gradually though a slight decline is happened at the start of study period (1981-2011). The e^0 is increased to 68.63 years in 2011 for male from 56.63 years in 1981 and 69.81 years in 2011 for female from 56.56 years in 1981. It is evident that e^0 in urban areas is a bit higher than that of rural. The e^{60} and e^{65} are also increasing for both males and females. From 13.25 years in 1981 e^{60} becomes 18.95 years for males in 2011 and from 13.72 years in 1981 to 21.84 years in 2011 for females. Whereas, from 10.16 years in 1981 e^{65} becomes 15.72 years for males in 2011 and from 10.54 years in 1981 to 18.47 years in 2011 for females. The pattern of change of e^{60} and e^{65} in rural and urban areas are more or less similar. A notable decline is observed in the age-specific mortality rate throughout the whole study period in all ages. However, the pace of decline in infant and old age mortality is somewhat faster than other age groups for both males and females. Same pattern of mortality reduction is apparent in rural and urban areas. Sex difference of mortality rate is demonstrated the global pattern that reduction of female mortality is more rapid than male. The patterns of sex difference of mortality in rural and urban areas are a bit alike. This study is carried out a sensitivity analysis of life expectancy at birth due to mortality change to know the consequence of change in age-specific mortality rates on e^0. It is investigated that the declines in childhood mortality and old age mortality have more effect on e^0 increase than the mortality reduction of other age groups. It is true for both males and females in rural and urban areas as well. Decomposition of changes in mortality rates between various census periods has clearly shown that in most of the cases age specific mortality rate effect is more attributable than age composition population effect.

Age-specific mortality modeling and forecasting is done in chapter VI applying Lee-Carter mortality model (Lee and Carter, 1992) according to sex and locality (national, rural and urban). This chapter also forecasts life expectancy at birth (e^0) using forecasted mortality. It is evident that mortality is decreasing gradually in all ages during the whole projection period (2012-2051). But one negative message is that infant and child mortality will be continuing with high rate compared to developed countries throughout the whole projection period. That means, infant and child mortality will remain comparatively high until 2051. Therefore, achieving the goal of socio-economic development for the country it is not pleasant news. A substantial increase will take place in the life expectancy at birth (e^0) all over the period. The e^0 will become 82.97 years for male in 2051 from existing 68.63 years in 2011 and 86.04 years for female in 2051 from 69.81 years in 2011. Female e^0 will be higher over the whole period which is a global phenomenon. According to models of biological risk behaviour, female susceptibility should be higher than male (Poppel, 1978). It is found an inconsistency between e^0 increase and socio-economic development in Bangladesh. The e^0 is surprisingly increasing at a higher pace than socio-economic development. In fact, e^0 increase is not matched with the socio-economic condition. From the above findings it seems that the number of elderly people will increase in future. This would create more complex situation for the country in future. So, the policy makers should pay attention to mitigate this situation. Both in rural and urban areas e^0 will increase but urban e^0 will somewhat higher than that of rural. It may be the reason that the urban people enjoy more facilities in all aspects of life than rural people.

The future of Bangladesh looks seriously precarious gives no proper initiatives regarding population matters are taken. So, in this regards the official population estimates are not really good enough foreshadow the future prospect of population. So, a new set of population projection has been prepared in chapter VII to have an idea regarding the impact of forecasted mortality on future population. It can be noted that most population scientists and demographers agree that such projection may fail to show the exact result. Despite this fact, we hope this new population projection can give a clear idea regarding the future trend of population age distribution. To investigate the impact of forecasted mortality on future population, population is projected for 40 years (2012-2051) in two scenarios using population data of BBS. In scenario-I, projection is performed by taking both fertility and mortality fixed as the base year 2011 and in scenario-II, fertility is taken fixed as 2011 and also used forecasted mortality by Lee-Carter method. The population projection of both the scenarios gives encouraging picture regarding population age distribution. It has observed that the working age population (age group 15-59 and 15-64) is increased outstandingly in both the scenarios. At the same time the young age (age group 0-14) population is decreasing rather satisfactorily and old age (age group 60+ and 65+) population is increasing gradually. In scenario-I, working age population is increasing till 2021 and then start decreasing at a very slower pace (almost stagnant) throughout rest of the projection period. Attaining its highest level 65.18% for male and 66.01% for female in 2021, it will decrease to 61.11% for male and 57.70% for female in 2051(age group 15-59). Whereas, reaching 68.80% for male and 69.60% for female in 2021, it will decease to 66.49% for male and 64.09% for female in 2051 (age group 15-64). The percentage of young age population will decrease sharply till 2021 and will then gradually towards rest of the projection period. It will reach 19.09% for male in 2051 from 32.56% in 2011 and 18.40% for female in 2051 from 31.23% in 2011. The percentage of old age population (age group 60+ and 65+) will increase gradually during the whole projection period. In scenario-II, the percentage of working age population and old age population will rise in a similar way and also percentage of young age population will decline in the same manner like scenario-I. Both the scenarios reveal that a large percentage of working age population will remain until 2051. This is really a demographic gift or dividend and also a challenge for Bangladesh to employ them properly.

An encouraging message is also found in the dependency ratios. The total dependency ratio (TDR) has a downward trend towards 2021 and will then increase slowly in rest of the period. As because the decreasing pace of young age population percentage is relatively higher till 2021 than increasing pace of old age population percentage. Attaining its lowest level of 52.48% in 2021 TDR* (taking working age group as 15-59 and old age group as 60+) will become 63.75% in 2046 and 68.30% in 2051. Again, TDR** (taking working age group as 15-64 and old age group as 65+) will attain its lowest level of 44.52% in 2021 and then slowly increased to 50.36% in 2046 and 53.15% in 2051. This is because of the increase of old age population and a slow decrease of working age population. It is apparent that TDR* and TDR** attained the favourable level of economic growth in the year 2011, despite the lowest level will reach in 2021. And this economically favourable level of TDRs will last until 2046 and 2051 for TDR* and TDR** respectively. That is the duration of favourable window of economic growth is only 30 or 40 years, obviously that is not so long period. The lowest value of TDR as a factor favouring economic growth will be possible only when the upward trend of working age group population is comparatively higher than dependent age group. This economically favourable TDR value is defined as the demographic window of opportunity, gift or bonus (Williamson, 2001; Vallin, 2002). The demographic window is treated as open when the TDR is 50% (that means, the ratio of the dependent to the working age population is 1:2) (Robin et. al., 2003). In the very next year Golilni (2004) has proposed an alternative threshold level of 66% (that is, 2:3 ratio of dependent to working age). Taking into account the above author's opinion, it can be said that the duration of the window of opportunity in Bangladesh may have a little variation in response to the variation in starting and ending periods.

Thus, TDR is an important indicator of a country's possible economic development. A downward tendency of TDR means the percentage of working age population increase over the dependent population (total of young age and old age). From the above findings, it may be said that the period favourable to economic growth, or the demographic window of opportunity, will start somewhat before 2011 and will continue until 2051. The findings also suggest that an enormous opportunity of economic development is waiting for Bangladesh if the huge number of working age population can make as human resource. The young dependency ratio (YDR) is decreasing throughout the whole projection period and the old dependency ratio ODR) is rising over the whole period. However, the decreasing rate of YDR is somewhat faster till 2021 than that of rest of the period and the increasing rate of ODR is a bit slower towards 2021 than that of rest of the period. The median age is increasing during the whole projection period for both males and females. Male median age will reach at 36.65 years in 2051 from 23.26 years in the base year 2011.

On the other hand, the female median age will reach at 37.75 years in 2051 from 24.35 years in 2011. The projected median age clearly indicates that the ageing population problem will start very soon. So, without wasting any more time the planners should think about the matter.

Throughout the whole study rural urban discrimination is apparent in all the socio-economic and demographic indicators. Rural people are a bit backward in all aspects of life than urban people. It would be because of people of rural areas are not getting proper healthcare services. It needs not to be mentioned that without proper healthcare services for all citizens it is impossible for a nation to develop. Another important thing is to be noticed that in a country like Bangladesh all sorts of development work and economic activities are done in city based. Therefore, rural people are to go to urban areas to meet their most of the needs. As a result urban population proportion is getting higher day by day.

8.3 Recommendations

Based on our findings, we recommend some suggestions for the policy makers to mitigate the shortcomings. There is no doubt that without quality healthcare services for everyone a nation can never achieve the satisfactory mortality level and its socio-economic development. The females of reproductive age are specially taken care of to ensure a better health for the new born child as the infant and child mortality is still high in Bangladesh compared to developed world. As more than 70% people live in the rural areas, better healthcare facilities should expand in rural areas as priority basis to ensure necessary treatment for the rural people. Communication system should be improved so that in case of any major complication people can move for better treatment quickly. To ensure such advancement government efforts are the first priority to be achieved. For the government of Bangladesh, it is the first and foremost responsibility to secure investment environment which would attract funding from not only the government sectors, but also from the private sectors. As a developing country the people of Bangladesh have not enough ability to have the accessibility to private healthcare services for its comparatively high cost. So, the government should come forward to provide low cost and free healthcare services. Out of the primary demands in daily life, education is a crucial one which is a major factor in any development of the necessary healthcare facilities. Especially, female education, which still lags behind, is a must to be ensured. No other than an educated mother, with the knowledge and access to the necessary healthcare services, can play a vital role in reducing child mortality as well as control over population growth. To ensure and make the working age population more skilled education and healthcare services are the most important elements. Skilled numbers of the working age population can contribute to the benefit in term of economic growth. So, they are to be utilized properly through better and suitable job facilities. After 46 years of independence in Bangladesh, in spite of government effort to pursue some policies, satisfactory socioeconomic development is not assured only for the constant instability in national policies. It is a common phenomenon in Bangladesh that after changing government, policies are also changed. This is one of the major barriers of the country's development. This attitude should be prohibited. Yet, in Bangladesh we think the present study will be helpful for policymakers and planners seeking to draw up a plan to respond to population ageing and developed infant mortality. As a result, it can be concluded that to achieve the purpose economic emancipation through socioeconomic expansion, the government of Bangladesh should take farm initiatives to execute an effective and sophisticated population policy as soon as possible. The elderly people are generally weak in health. So, additional healthcare facilities should be provided for them. Creating soft job (less physical work) to make them active and pension skim is needed for those who are not able to do any kind of job. To provide such facilities to the elderly people the nation should have to be economically strong.

Besides, present study has also found that the population age distribution has started viewing hopeful changes. Since the TDR is growing toward a descending trend, which will be very important for speeding up future economic expansion if the government of Bangladesh can make appropriate use of this prospect. De-facto, the tendency for an uphill population trend looks like a frightening signal for future economic growth owing to the lack of suitable handling of this opportunity. Proper education especially vocational education, technical education and training is needed to make these demographic dividend (huge number of working age population) to be human resource. Nevertheless, by taking proper steps to generate an accomplished labour force can result in the population being regarded as skilled human resource rather than a threat or burden of a densely populated country like Bangladesh.

This study has not considered the modeling and forecasting of fertility and migration to investigate the future trend. Because the present study is mainly on mortality trends, differentials and modeling for mortality forecasting in Bangladesh. For this reason, it is not possible to use forecasted fertility (base year fertility is used) and migration in population projection to see the impact of forecasted mortality on future population. It would be better if forecasted fertility, mortality and migration are used together in population projection. So, there is a scope for farther study using forecasted values of fertility, mortality and migration for population projection.

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Appendix

Appendix-A

Table Appendix A1: 95% confidence limits of forecasted *kt* from ARIMA (0, 1, 0) models by sex for Bangladesh, for the period 2002-2051(National)

Year	Male		Female	
	Lower limit of kt	Upper limit of kt	Lower limit of kt	Upper limit of kt
2012	-8.3406	-6.2050	-13.9781	-11.1734
2013	-9.2066	-6.1864	-15.8325	-10.9662
2014	-9.9696	-6.2707	-17.3951	-10.7897
2015	-10.6794	-6.4083	-18.7760	-10.6857
2016	-11.3552	-6.5799	-20.0390	-10.6540
2017	-12.0067	-6.7757	-21.2216	-10.6837
2018	-12.6400	-6.9898	-22.3462	-10.7634
2019	-13.2587	-7.2185	-23.4269	-10.8837
2020	-13.8656	-7.4589	-24.4731	-11.0370
2021	-14.4626	-7.7093	-25.4914	-11.2177
2022	-15.0510	-7.9682	-26.4864	-11.4215
2023	-15.6322	-8.2344	-27.4615	-11.6450
2024	-16.2069	-8.5071	-28.4196	-11.8855
2025	-16.7759	-8.7854	-29.3628	-12.1409
2026	-17.3398	-9.0689	-30.2928	-12.4096
2027	-17.8991	-9.3569	-31.2109	-12.6900
2028	-18.4543	-9.6491	-32.1184	-12.9811
2029	-19.0056	-9.9452	-33.0163	-13.2817
2030	-19.5534	-10.2447	-33.9055	-13.5912
2031	-20.0980	-10.5475	-34.7865	-13.9087
2032	-20.6396	-10.8533	-35.6602	-14.2336
2033	-21.1784	-11.1618	-36.5270	-14.5653
2034	-21.7147	-11.4729	-37.3875	-14.9035
2035	-22.2485	-11.7864	-38.2420	-15.2475
2036	-22.7800	-12.1023	-39.0910	-15.5971
2037	-23.3095	-12.4202	-39.9348	-15.9519
2038	-23.8368	-12.7402	-40.7737	-16.3116
2039	-24.3623	-13.0620	-41.6080	-16.6759
2040	-24.8860	-13.3857	-42.4379	-17.0445
2041	-25.4080	-13.7111	-43.2637	-17.4173
2042	-25.9284	-14.0381	-44.0856	-17.7939
2043	-26.4472	-14.3666	-44.9039	-18.1743
2044	-26.9645	-14.6967	-45.7185	-18.5582
2045	-27.4804	-15.0281	-46.5299	-18.9455
2046	-27.9950	-15.3609	-47.3380	-19.3359
2047	-28.5083	-15.6950	-48.1430	-19.7295
2048	-29.0204	-16.0303	-48.9451	-20.1259
2049	-29.5312	-16.3668	-49.7444	-20.5252
2050	-30.0409	-16.7044	-50.5410	-20.9272
2051	-30.5496	-17.0431	-51.3350	-21.3318

Appendix

Table Appendix A2: 95% confidence limits of forecasted *kt* from ARIMA (0, 1, 0) models by sex for Bangladesh, for the period 2002-2051(Rural)

Year	Male		Female	
	Lower limit of kt	Upper limit of kt	Lower limit of kt	Upper limit of kt
2012	-8.5663	-6.0197	-13.1153	-10.0361
2013	-9.5227	-5.9213	-14.3117	-9.9571
2014	-10.3564	-5.9456	-15.3598	-10.0265
2015	-11.1266	-6.0334	-16.3311	-10.1726
2016	-11.8561	-6.1618	-17.2532	-10.3679
2017	-12.5569	-6.3190	-18.1405	-10.5980
2018	-13.2358	-6.4981	-19.0014	-10.8546
2019	-13.8973	-6.6945	-19.8414	-11.1321
2020	-14.5448	-6.9050	-20.6642	-11.4266
2021	-15.1804	-7.1273	-21.4728	-11.7355
2022	-15.8059	-7.3598	-22.2691	-12.0566
2023	-16.4227	-7.6010	-23.0549	-12.3882
2024	-17.0318	-7.8499	-23.8314	-12.7292
2025	-17.6341	-8.1055	-24.5997	-13.0783
2026	-18.2303	-8.3673	-25.3606	-13.4349
2027	-18.8210	-8.6346	-26.1148	-13.7980
2028	-19.4067	-8.9068	-26.8631	-14.1672
2029	-19.9879	-9.1836	-27.6058	-14.5419
2030	-20.5649	-9.4645	-28.3435	-14.9216
2031	-21.1381	-9.7493	-29.0766	-15.3060
2032	-21.7077	-10.0377	-29.8053	-15.6947
2033	-22.2740	-10.3294	-30.5301	-16.0873
2034	-22.8372	-10.6241	-31.2511	-16.4838
2035	-23.3975	-10.9218	-31.9686	-16.8837
2036	-23.9551	-11.2221	-32.6829	-17.2869
2037	-24.5102	-11.5250	-33.3940	-17.6931
2038	-25.0629	-11.8303	-34.1023	-18.1023
2039	-25.6132	-12.1379	-34.8078	-18.5142
2040	-26.1615	-12.4476	-35.5107	-18.9287
2041	-26.7077	-12.7594	-36.2112	-19.3457
2042	-27.2520	-13.0731	-36.9093	-19.7650
2043	-27.7944	-13.3886	-37.6052	-20.1866
2044	-28.3350	-13.7059	-38.2989	-20.6102
2045	-28.8740	-14.0249	-38.9906	-21.0360
2046	-29.4114	-14.3455	-39.6804	-21.4636
2047	-29.9472	-14.6676	-40.3683	-21.8931
2048	-30.4816	-14.9912	-41.0545	-22.3244
2049	-31.0146	-15.3163	-41.7389	-22.7574
2050	-31.5461	-15.6426	-42.4217	-23.1921
2051	-32.0764	-15.9703	-43.1029	-23.6283

Appendix

Table Appendix A3: 95% confidence limits of forecasted *kt* from ARIMA (0, 1, 0) models by sex for Bangladesh, for the period 2002-2051(Urban)

Year	Male		Female	
	Lower limit of kt	Upper limit of kt	Lower limit of kt	Upper limit of kt
2012	-6.5055	-3.1858	-17.3699	-12.1583
2013	-7.4787	-2.7840	-19.1122	-11.7419
2014	-8.2919	-2.5421	-20.6034	-11.5766
2015	-9.0223	-2.3830	-21.9646	-11.5414
2016	-9.6998	-2.2769	-23.2427	-11.5892
2017	-10.3397	-2.2083	-24.4617	-11.6960
2018	-10.9511	-2.1682	-25.6361	-11.8475
2019	-11.5400	-2.1506	-26.7751	-12.0344
2020	-12.1105	-2.1515	-27.8851	-12.2503
2021	-12.6655	-2.1679	-28.9709	-12.4904
2022	-13.2073	-2.1973	-30.0361	-12.7511
2023	-13.7378	-2.2382	-31.0833	-13.0298
2024	-14.2582	-2.2891	-32.1148	-13.3242
2025	-14.7698	-2.3489	-33.1325	-13.6324
2026	-15.2735	-2.4165	-34.1376	-13.9532
2027	-15.7700	-2.4914	-35.1315	-14.2851
2028	-16.2600	-2.5727	-36.1153	-14.6273
2029	-16.7440	-2.6600	-37.0897	-14.9788
2030	-17.2227	-2.7527	-38.0556	-15.3388
2031	-17.6963	-2.8504	-39.0136	-15.7066
2032	-18.1653	-2.9527	-39.9644	-16.0818
2033	-18.6299	-3.0594	-40.9083	-16.4637
2034	-19.0906	-3.1701	-41.8459	-16.8520
2035	-19.5474	-3.2846	-42.7777	-17.2462
2036	-20.0008	-3.4026	-43.7039	-17.6459
2037	-20.4508	-3.5239	-44.6248	-18.0508
2038	-20.8977	-3.6483	-45.5409	-18.4606
2039	-21.3416	-3.7757	-46.4523	-18.8751
2040	-21.7827	-3.9059	-47.3593	-19.2940
2041	-22.2212	-4.0388	-48.2622	-19.7171
2042	-22.6572	-4.1742	-49.1610	-20.1441
2043	-23.0907	-4.3120	-50.0561	-20.5749
2044	-23.5219	-4.4521	-50.9476	-21.0093
2045	-23.9510	-4.5943	-51.8357	-21.4471
2046	-24.3780	-4.7387	-52.7205	-21.8882
2047	-24.8029	-4.8851	-53.6021	-22.3325
2048	-25.2260	-5.0334	-54.4807	-22.7798
2049	-25.6472	-5.1835	-55.3564	-23.2300
2050	-26.0666	-5.3354	-56.2293	-23.6829
2051	-26.4843	-5.4890	-57.0996	-24.1386

Appendix

Table Appendix A4: Forecasted value of second stage *kt* and their standard errors from ARIMA (0,1, 0) models according to sex for Bangladesh, for the period 2012-2051(National)

Year	Male		Female	
	Forecasted kt	Stancard error	Forecasted kt	Stancard error
2012	-7.2728	0.5307	-12.0292	0.7459
2013	-7.6965	0.7505	-12.6188	1.0548
2014	-8.1202	0.9192	-13.2083	1.2919
2015	-8.5439	1.0614	-13.7978	1.4917
2016	-8.9675	1.1867	-14.3874	1.6678
2017	-9.3912	1.3000	-14.9769	1.8270
2018	-9.8149	1.4041	-15.5664	1.9734
2019	-10.2386	1.5011	-16.156	2.1096
2020	-10.6623	1.5921	-16.7455	2.2376
2021	-11.0859	1.6782	-17.335	2.3586
2022	-11.5096	1.7601	-17.9246	2.4738
2023	-11.9333	1.8384	-18.5141	2.5838
2024	-12.3570	1.9135	-19.1036	2.6893
2025	-12.7807	1.9857	-19.6931	2.7908
2026	-13.2043	2.0554	-20.2827	2.8887
2027	-13.6280	2.1228	-20.8722	2.9835
2028	-14.0517	2.1881	-21.4617	3.0753
2029	-14.4754	2.2516	-22.0513	3.1644
2030	-14.8991	2.3133	-22.6408	3.2512
2031	-15.3227	2.3734	-23.2303	3.3356
2032	-15.7464	2.4320	-23.8199	3.4180
2033	-16.1701	2.4892	-24.4094	3.4984
2034	-16.5938	2.5452	-24.9989	3.5770
2035	-17.0175	2.5999	-25.5885	3.6540
2036	-17.4411	2.6535	-26.178	3.7293
2037	-17.8648	2.7061	-26.7675	3.8032
2038	-18.2885	2.7576	-27.3571	3.8756
2039	-18.7122	2.8082	-27.9466	3.9468
2040	-19.1359	2.8579	-28.5361	4.0166
2041	-19.5595	2.9068	-29.1257	4.0853
2042	-19.9832	2.9548	-29.7152	4.1528
2043	-20.4069	3.0021	-30.3047	4.2193
2044	-20.8306	3.0487	-30.8943	4.2847
2045	-21.2543	3.0945	-31.4838	4.3491
2046	-21.6779	3.1397	-32.0733	4.4126
2047	-22.1016	3.1842	-32.6628	4.4752
2048	-22.5253	3.2281	-33.2524	4.5369
2049	-22.9490	3.2715	-33.8419	4.5978
2050	-23.3727	3.3142	-34.4314	4.6579
2051	-23.7964	3.3565	-35.021	4.7173

Table Appendix A5: Forecasted value of second stage *kt* and their standard errors from ARIMA (0,1, 0) models according to sex for Bangladesh, for the period 2012-2051(Rural)

Year	Male		Female	
	Forecasted kt	Stancard error	Forecasted kt	Stancard error
2012	-7.2930	0.632683	-11.5757	0.766761
2013	-7.7220	0.894748	-12.1344	1.084363
2014	-8.1510	1.095838	-12.6931	1.328069
2015	-8.5800	1.265365	-13.2518	1.533521
2016	-9.0090	1.414721	-13.8106	1.714529
2017	-9.4379	1.549750	-14.3693	1.878173
2018	-9.8669	1.673921	-14.9280	2.028658
2019	-10.2959	1.789497	-15.4867	2.168727
2020	-10.7249	1.898048	-16.0454	2.300282
2021	-11.1539	2.000718	-16.6041	2.424710
2022	-11.5829	2.098371	-17.1629	2.543058
2023	-12.0118	2.191677	-17.7216	2.656137
2024	-12.4408	2.281170	-18.2803	2.764595
2025	-12.8698	2.367282	-18.8390	2.868956
2026	-13.2988	2.450369	-19.3977	2.969652
2027	-13.7278	2.530731	-19.9564	3.067043
2028	-14.1568	2.608617	-20.5151	3.161435
2029	-14.5857	2.684245	-21.0739	3.253090
2030	-15.0147	2.757800	-21.6326	3.342233
2031	-15.4437	2.829443	-22.1913	3.429058
2032	-15.8727	2.899316	-22.7500	3.513739
2033	-16.3017	2.967545	-23.3087	3.596427
2034	-16.7307	3.034239	-23.8674	3.677255
2035	-17.1596	3.099499	-24.4261	3.756345
2036	-17.5886	3.163413	-24.9849	3.833804
2037	-18.0176	3.226061	-25.5436	3.909728
2038	-18.4466	3.287515	-26.1023	3.984206
2039	-18.8756	3.347842	-26.6610	4.057316
2040	-19.3046	3.407100	-27.2197	4.129133
2041	-19.7335	3.465346	-27.7784	4.199721
2042	-20.1625	3.522628	-28.3371	4.269143
2043	-20.5915	3.578993	-28.8959	4.337454
2044	-21.0205	3.634485	-29.4546	4.404705
2045	-21.4495	3.689142	-30.0133	4.470945
2046	-21.8785	3.743001	-30.5720	4.536218
2047	-22.3074	3.796096	-31.1307	4.600564
2048	-22.7364	3.848458	-31.6894	4.664023
2049	-23.1654	3.900118	-32.2482	4.726631
2050	-23.5944	3.951102	-32.8069	4.788419
2051	-24.0234	4.001436	-33.3656	4.849421

Table Appendix A6: Forecasted value of second stage *kt* and their standard errors from ARIMA (0,1, 0) models according to sex for Bangladesh, for the period 2012-2051 (Urban)

Year	Male		Female	
	Forecasted kt	Stancard error	Forecasted kt	Stancard error
2012	-4.8457	0.824972	-14.7641	1.294925
2013	-5.1313	1.166687	-15.4271	1.831300
2014	-5.4170	1.428894	-16.0900	2.242876
2015	-5.7027	1.649945	-16.7530	2.589850
2016	-5.9883	1.844695	-17.4159	2.895540
2017	-6.2740	2.020762	-18.0789	3.171905
2018	-6.5597	2.182672	-18.7418	3.426049
2019	-6.8453	2.333375	-19.4048	3.662600
2020	-7.1310	2.474917	-20.0677	3.884774
2021	-7.4167	2.608792	-20.7307	4.094912
2022	-7.7023	2.736124	-21.3936	4.294780
2023	-7.9880	2.857788	-22.0566	4.485751
2024	-8.2737	2.974481	-22.7195	4.668918
2025	-8.5593	3.086764	-23.3824	4.845165
2026	-8.8450	3.195105	-24.0454	5.015222
2027	-9.1307	3.299890	-24.7083	5.179699
2028	-9.4163	3.401449	-25.3713	5.339112
2029	-9.7020	3.500062	-26.0342	5.493901
2030	-9.9877	3.595972	-26.6972	5.644446
2031	-10.2733	3.689389	-27.3601	5.791080
2032	-10.5590	3.780499	-28.0231	5.934091
2033	-10.8447	3.869464	-28.6860	6.073736
2034	-11.1303	3.956429	-29.3490	6.210241
2035	-11.4160	4.041523	-30.0119	6.343810
2036	-11.7017	4.124862	-30.6749	6.474624
2037	-11.9873	4.206551	-31.3378	6.602847
2038	-12.2730	4.286683	-32.0008	6.728627
2039	-12.5587	4.365344	-32.6637	6.852098
2040	-12.8443	4.442613	-33.3267	6.973384
2041	-13.1300	4.518560	-33.9896	7.092595
2042	-13.4157	4.593252	-34.6526	7.209836
2043	-13.7013	4.666749	-35.3155	7.325201
2044	-13.9870	4.739106	-35.9785	7.438777
2045	-14.2727	4.810375	-36.6414	7.550644
2046	-14.5583	4.880603	-37.3043	7.660878
2047	-14.8440	4.949835	-37.9673	7.769549
2048	-15.1297	5.018112	-38.6302	7.876720
2049	-15.4153	5.085472	-39.2932	7.982453
2050	-15.7010	5.151951	-39.9561	8.086803
2051	-15.9867	5.217584	-40.6191	8.189824

Appendix

Table Appendix A7: Predicted life expectancy at birth (e_0) of **Male** with 95% confidence intervals in Bangladesh, for the period 1982–2051(National)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
1982	55.83	54.42	57.18
1983	55.6	54.19	56.97
1984	55.47	54.05	56.83
1985	55.4	53.98	56.77
1986	55.4	53.98	56.77
1987	56.01	54.62	57.36
1988	56.37	54.98	57.7
1989	57.15	55.79	58.45
1990	57.46	56.11	58.75
1991	57.52	56.18	58.82
1992	57.56	56.22	58.86
1993	57.6	56.26	58.89
1994	58.21	56.89	59.48
1995	58.95	57.66	60.19
1996	59.82	58.56	61.04
1997	61.05	59.84	62.23
1998	61.55	60.35	62.71
1999	61.63	60.43	62.79
2000	62.84	61.68	63.96
2001	64.1	62.99	65.19
2002	64.84	63.74	65.91
2003	65.56	64.49	66.61
2004	66.3	65.24	67.32
2005	66.47	65.42	67.49
2006	66.28	65.23	67.31
2007	66.21	65.15	67.24
2008	66.43	65.38	67.46
2009	66.76	65.72	67.78
2010	67.36	66.34	68.36
2011	67.76	66.63	68.96
2012	68.03	67.06	69.38
2013	68.81	67.44	70.14
2014	69.19	67.62	70.81
2015	69.66	67.94	71.41
2016	70.09	68.38	72.08
2017	70.61	68.79	72.63
2018	71.07	69.17	73.06
2019	71.64	69.38	73.57
2020	72.24	69.6	73.86
2021	72.76	69.82	74.55

Table Appendix A7: (Continued)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
2022	73.11	70.05	76.03
2023	73.47	70.29	76.49
2024	73.82	70.53	76.96
2025	74.17	70.78	77.41
2026	74.52	71.02	77.86
2027	74.87	71.28	78.31
2028	75.22	71.53	78.75
2029	75.56	71.78	79.18
2030	75.9	72.04	79.62
2031	76.25	72.3	80.05
2032	76.59	72.56	80.47
2033	76.93	72.82	80.9
2034	77.17	73.08	81.32
2035	77.6	73.35	81.75
2036	77.94	73.61	82.17
2037	78.28	73.87	82.59
2038	78.61	74.14	83.01
2039	78.95	74.4	83.43
2040	79.29	74.67	83.85
2041	79.62	74.94	84.26
2042	79.96	75.2	84.68
2043	80.29	75.47	85.1
2044	80.62	75.74	85.52
2045	80.96	76.01	85.94
2046	81.29	76.28	86.36
2047	81.63	76.55	86.79
2048	81.97	76.81	87.21
2049	82.3	77.08	87.64
2050	82.64	77.35	88.06
2051	82.97	77.62	88.49

Table Appendix A8: Predicted life expectancy at birth (e_0) of **female** with 95% confidence intervals in Bangladesh, for the period 1982–2051(National)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
1982	56.64	54.79	58.42
1983	56.27	54.56	57.92
1984	55.54	53.82	57.2
1985	55.47	53.74	57.13
1986	55.49	53.76	57.15
1987	56.01	54.31	57.65
1988	56.55	54.87	58.17
1989	56.09	54.38	57.73
1990	55.75	54.03	57.41
1991	56.53	54.85	58.14
1992	56.68	55	58.29
1993	57.03	55.37	58.63
1994	57.79	56.15	59.36
1995	58.58	56.98	60.13
1996	59.51	57.95	61.03
1997	60.42	58.88	61.92
1998	61.71	60.19	63.17
1999	62.35	60.87	63.77
2000	63.96	62.57	65.3
2001	64.91	63.53	66.26
2002	65.35	64.01	66.66
2003	66.01	64.65	67.32
2004	66.87	65.56	68.15
2005	67.79	66.51	69.05
2006	67.76	66.47	69.01
2007	67.71	66.43	68.97
2008	67.94	66.66	69.19
2009	68.18	66.91	69.43
2010	68.48	67.22	69.72
2011	68.77	67.56	69.97
2012	69.16	67.97	70.35
2013	69.86	68.79	71.09
2014	70.34	69.29	72.58
2015	70.69	69.55	73.42
2016	71.26	69.82	73.95
2017	71.72	70.25	74.52
2018	72.15	70.65	74.98
2019	72.74	70.96	75.76
2020	73.35	71.55	76.4
2021	73.86	71.93	76.93

Table Appendix A8: (Continued)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
2022	74.25	72.28	77.55
2023	74.68	72.66	77.96
2024	75.06	72.99	78.37
2025	75.42	73.3	78.76
2026	75.84	73.67	79.09
2027	76.26	73.98	79.49
2028	76.68	74.35	79.98
2029	77.21	74.73	80.53
2030	77.75	74.97	81.12
2031	78.19	75.26	81.61
2032	78.63	75.59	82.09
2033	79.08	75.91	82.56
2034	79.43	76.12	82.97
2035	79.72	76.37	83.28
2036	80.05	76.68	83.63
2037	80.62	77.23	84.25
2038	80.98	77.55	84.66
2039	81.28	77.84	85.03
2040	81.67	78.22	85.47
2041	82.09	78.61	85.93
2042	82.47	78.96	86.35
2043	82.88	79.35	86.88
2044	83.28	79.73	87.31
2045	83.71	80.15	87.82
2046	84.07	80.49	88.33
2047	84.42	80.72	88.73
2048	84.78	81.07	89.25
2049	85.14	81.38	89.67
2050	85.62	81.83	90.33
2051	86.04	82.22	90.87

Table Appendix A9: Predicted life expectancy at birth (e_0) of M**ale** with 95% confidence intervals in Bangladesh, for the period 1982–2051(Rural)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
1982	55.27	53.61	56.86
1983	55.16	53.5	56.76
1984	55.13	53.47	56.73
1985	55.15	53.49	56.74
1986	55.23	53.57	56.82
1987	55.67	54.03	57.25
1988	56.05	54.41	57.63
1989	56.46	54.82	58.04
1990	57.02	55.43	58.54
1991	57.07	55.49	58.59
1992	57.09	55.51	58.61
1993	57.15	55.57	58.67
1994	57.71	56.16	59.23
1995	58.52	57	59.98
1996	59.32	57.79	60.78
1997	60.48	58.95	61.94
1998	60.97	59.43	62.45
1999	61.21	59.67	62.7
2000	62.14	60.62	63.67
2001	63.22	61.68	64.77
2002	63.9	62.33	65.48
2003	64.98	63.38	66.59
2004	65.77	64.14	67.42
2005	66.02	64.37	67.7
2006	65.88	64.21	67.59
2007	65.82	64.14	67.54
2008	66.15	64.44	67.9
2009	66.31	64.56	68.1
2010	66.87	65.08	68.7
2011	66.95	65.11	68.83
2012	67.59	65.7	69.52
2013	68.29	66.35	70.27
2014	68.67	66.73	70.6
2015	69.05	67.05	71.04
2016	69.42	67.36	71.47
2017	70.09	67.97	72.2
2018	70.55	68.38	72.71
2019	70.98	68.76	73.19
2020	71.62	69.35	73.88
2021	72.24	69.92	74.57

Table Appendix A9: (Continued)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
2022	72.6	70.23	74.98
2023	72.95	70.53	75.38
2024	73.31	70.84	75.79
2025	73.66	71.14	76.19
2026	74.03	71.46	76.61
2027	74.35	71.73	76.98
2028	74.7	71.03	77.38
2029	75.04	71.29	78.77
2030	75.38	71.58	79.18
2031	75.73	71.88	79.58
2032	76.06	72.16	79.96
2033	76.4	72.45	80.35
2034	76.74	72.74	80.74
2035	77.08	73.03	81.13
2036	77.41	73.31	81.51
2037	77.75	73.6	81.89
2038	78.08	73.88	82.27
2039	78.41	74.16	82.65
2040	78.75	74.45	83.04
2041	79.08	74.73	83.42
2042	79.41	75.01	83.8
2043	79.74	75.29	84.18
2044	80.07	75.85	84.56
2045	80.4	75.13	84.94
2046	80.73	75.41	85.32
2047	81.06	75.69	85.7
2048	81.39	75.97	86.08
2049	81.73	76.26	86.47
2050	82.06	76.53	86.85
2051	82.39	76.81	87.23

Table Appendix A10: Predicted life expectancy at birth (e_0) of Fem**ale** with 95% confidence intervals in Bangladesh, for the period 1982–2051(Rural)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
1982	56.51	54.66	58.29
1983	56.11	54.24	57.91
1984	55.46	53.56	57.28
1985	55.56	53.66	57.37
1986	55.34	53.43	57.16
1987	55.79	53.9	57.6
1988	56.17	54.3	57.96
1989	55.91	54.03	57.71
1990	55.68	53.79	57.5
1991	56.09	54.22	57.89
1992	56.19	54.33	57.99
1993	56.35	54.49	58.14
1994	57.52	55.56	59.31
1995	58.22	56.44	59.94
1996	59.23	57.48	60.9
1997	60.28	58.58	61.93
1998	61.51	59.85	63.11
1999	61.92	60.25	63.52
2000	63.21	61.53	64.81
2001	64.47	62.79	66.07
2002	65.02	63.34	66.62
2003	65.64	63.95	67.25
2004	66.4	64.71	68.01
2005	67.43	65.74	69.04
2006	67.35	65.66	68.96
2007	67.28	65.59	68.89
2008	67.52	65.83	69.13
2009	67.92	66.23	69.53
2010	68.12	66.42	69.74
2011	68.35	66.62	69.99
2012	68.76	67.01	70.42
2013	69.26	67.49	70.95
2014	69.65	67.85	71.38
2015	70.14	68.32	71.89
2016	70.62	68.76	72.4
2017	71.16	69.27	72.98
2018	71.61	69.68	73.47
2019	72.16	70.19	74.06
2020	72.76	70.75	74.69
2021	73.29	71.24	75.26

Table Appendix A10: (Continued)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
2022	73.58	71.49	75.58
2023	73.95	71.81	76
2024	74.47	72.28	76.57
2025	74.95	72.71	77.1
2026	75.27	72.98	77.47
2027	75.78	73.44	78.03
2028	76.08	73.69	78.38
2029	76.59	74.15	78.94
2030	77.11	74.62	79.51
2031	77.62	75.08	80.07
2032	78.04	75.45	80.54
2033	78.67	76.03	81.22
2034	78.92	76.23	81.52
2035	79.23	76.49	81.88
2036	79.67	76.87	82.36
2037	80.02	77.17	82.76
2038	80.37	77.47	83.16
2039	80.82	77.87	83.66
2040	81.28	78.28	84.17
2041	81.65	78.6	84.59
2042	81.96	78.86	84.97
2043	82.21	79.06	85.3
2044	82.8	79.59	86
2045	83.24	79.96	86.63
2046	83.72	80.34	87.62
2047	83.91	80.43	87.92
2048	84.23	80.65	88.35
2049	84.76	81.08	88.99
2050	85.15	81.37	89.5
2051	85.59	81.72	90.05

Table Appendix A11: Predicted life expectancy at birth (e_0) of **Male** with 95% confidence intervals in Bangladesh, for the period 1982–2051(Urban)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
1982	62.06	60.27	63.77
1983	61.12	59.3	62.87
1984	60.42	58.56	62.2
1985	59.9	58.02	61.7
1986	59.54	57.64	61.36
1987	59.69	57.8	61.5
1988	59.81	57.92	61.62
1989	59.43	57.53	61.25
1990	59.69	57.8	61.5
1991	60.48	58.63	62.26
1992	60.7	58.85	62.48
1993	61.2	59.35	62.98
1994	61.96	60.11	63.75
1995	62.83	60.98	64.62
1996	63.71	61.85	65.52
1997	64.44	62.55	66.25
1998	64.9	63.01	66.71
1999	65.07	63.18	66.88
2000	66.15	64.26	67.96
2001	67.26	65.37	69.08
2002	67.82	65.93	69.64
2003	68.18	66.29	70.01
2004	68.74	66.85	70.57
2005	68.87	66.98	70.7
2006	68.64	66.75	70.47
2007	68.56	66.67	70.39
2008	68.88	66.99	70.71
2009	69.07	67.18	70.9
2010	69.58	67.69	71.43
2011	69.72	67.8	71.6
2012	69.95	68.01	71.86
2013	70.24	68.27	72.19
2014	70.49	68.5	72.47
2015	70.93	68.91	72.94
2016	71.17	69.11	73.22
2017	71.41	69.31	73.5
2018	71.96	69.82	74.1
2019	72.69	69.51	74.87
2020	72.92	69.7	75.15
2021	73.26	70	75.56

Table Appendix A11: (Continued)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
2022	73.59	70.28	75.94
2023	73.83	70.47	76.23
2024	74.06	70.65	76.51
2025	74.29	70.85	76.69
2026	74.75	71.26	77.2
2027	75.15	71.61	77.65
2028	75.47	71.87	78.07
2029	75.82	72.17	78.52
2030	76.14	72.44	78.94
2031	76.65	72.9	79.55
2032	76.88	73.08	79.88
2033	77.1	73.25	80.2
2034	77.42	73.52	80.62
2035	77.85	73.9	81.15
2036	78.16	74.16	81.56
2037	78.68	74.63	82.18
2038	78.92	74.82	82.52
2039	79.24	75.09	82.94
2040	79.64	75.44	83.44
2041	79.86	75.57	83.76
2042	80.07	75.73	84.07
2043	80.55	76.16	84.65
2044	80.75	76.31	84.95
2045	81.17	76.68	85.47
2046	81.53	76.99	85.93
2047	81.85	77.26	86.35
2048	82.16	77.52	86.81
2049	82.58	77.89	87.33
2050	82.79	78.05	87.64
2051	83.23	78.44	88.18

Table Appendix A12: Predicted life expectancy at birth (e_0) of **Female** with 95% confidence intervals in Bangladesh, for the period 1982–2051(Urban)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
1982	61.46	58.86	63.88
1983	60.95	58.32	63.41
1984	60.55	57.89	63.04
1985	60.24	57.55	62.74
1986	60.28	57.59	62.78
1987	60.52	57.83	63.02
1988	60.98	58.29	63.48
1989	60.57	57.88	63.07
1990	59.96	57.27	62.46
1991	60.77	58.08	63.27
1992	60.84	58.15	63.34
1993	61.1	58.41	63.6
1994	61.62	58.93	64.12
1995	62.02	59.33	64.52
1996	62.99	60.3	65.49
1997	63.82	61.13	66.32
1998	65.15	62.46	67.65
1999	65.8	63.11	68.3
2000	67.49	64.8	69.99
2001	68.42	65.73	70.92
2002	68.84	66.15	71.34
2003	69.57	66.88	72.07
2004	70.67	67.97	73.19
2005	70.99	68.28	73.53
2006	70.86	68.15	73.4
2007	70.78	68.07	73.32
2008	70.97	68.26	73.51
2009	71.07	68.35	73.63
2010	71.24	68.51	73.82
2011	71.38	68.64	73.98
2012	71.53	68.76	74.16
2013	71.69	68.9	74.35
2014	71.88	69.06	74.58
2015	72.21	69.36	74.95
2016	72.56	69.68	75.34
2017	72.84	69.92	75.67
2018	73.24	70.28	76.12
2019	73.77	70.77	76.72
2020	74.2	71.16	77.21
2021	74.62	71.54	77.68

Table Appendix A12: (Continued)

Year	Life expectancy at birth (e0)	95% confidence intervals	
		Lower limit	Upper limit
2022	74.95	71.83	78.06
2023	75.25	72.09	78.41
2024	75.79	72.59	79
2025	76.18	72.94	79.44
2026	76.59	73.31	79.9
2027	77.01	73.69	80.37
2028	77.39	74.03	80.8
2029	77.78	74.38	81.24
2030	77.97	74.53	81.48
2031	78.43	74.95	81.99
2032	78.95	75.43	82.56
2033	79.36	75.8	83.02
2034	79.66	76.06	83.37
2035	79.98	76.34	83.74
2036	80.27	76.59	84.08
2037	80.93	77.21	84.79
2038	81.35	77.59	85.26
2039	81.65	77.85	85.61
2040	81.93	78.09	85.94
2041	82.36	78.48	86.42
2042	82.76	78.84	86.87
2043	83.15	79.19	87.31
2044	83.59	79.59	87.8
2045	83.99	79.95	88.25
2046	84.3	80.22	88.61
2047	84.76	80.64	89.12
2048	84.98	80.82	89.39
2049	85.46	81.26	89.92
2050	85.93	81.69	90.44
2051	86.35	82.07	90.9

Appendix

Table Appendix A13: Predicted age-specific death rates (ASDRs) for **Male** per 1000 at 5-year age groups in Bangladesh, for the period 2001–2051(National)

Age group	Year								
	2012	2016	2021	2026	2031	2036	2041	2046	2051
0	51.87	47.49	42.54	38.10	34.13	30.57	27.38	24.52	21.96
1-4	3.37	2.77	2.17	1.70	1.34	1.05	0.82	0.64	0.50
5-9	0.98	0.82	0.66	0.54	0.43	0.35	0.28	0.23	0.18
10-14	0.80	0.73	0.65	0.58	0.52	0.46	0.41	0.37	0.33
15-19	0.89	0.82	0.73	0.65	0.58	0.52	0.46	0.41	0.37
20-24	1.25	1.17	1.09	1.00	0.93	0.86	0.79	0.73	0.68
25-29	1.25	1.14	1.02	0.91	0.81	0.72	0.64	0.57	0.51
30-34	1.47	1.32	1.16	1.02	0.90	0.79	0.69	0.61	0.54
35-39	1.89	1.70	1.49	1.30	1.14	1.00	0.87	0.76	0.67
40-44	2.86	2.62	2.35	2.11	1.89	1.70	1.53	1.37	1.23
45-49	4.20	3.77	3.30	2.89	2.53	2.21	1.94	1.69	1.48
50-54	6.69	6.03	5.29	4.63	4.06	3.56	3.13	2.74	2.40
55-59	10.53	9.54	8.44	7.47	6.60	5.84	5.16	4.57	4.04
60-64	17.53	16.00	14.27	12.72	11.35	10.12	9.03	8.05	7.18
65-69	25.02	22.99	20.68	18.60	16.73	15.05	13.54	12.18	10.95
70-74	41.25	38.55	35.41	32.54	29.89	27.46	25.23	23.18	21.30
75+	100.85	95.69	89.61	83.91	78.58	73.58	68.91	64.53	60.43

Table Appendix A14: Predicted age-specific death rates (ASDRs) for **Female** per 1000 at 5-year age groups in Bangladesh, for the period 2001–2051(National)

Age group	Year								
	2012	2016	2021	2026	2031	2036	2041	2046	2051
0	40.44	35.70	31.18	27.25	23.81	20.81	18.18	15.89	13.88
1-4	2.41	1.85	1.38	1.04	0.78	0.58	0.44	0.33	0.25
5-9	0.81	0.67	0.54	0.44	0.36	0.29	0.24	0.19	0.16
10-14	0.60	0.54	0.47	0.41	0.36	0.32	0.28	0.25	0.22
15-19	0.84	0.72	0.61	0.52	0.44	0.38	0.32	0.27	0.23
20-24	0.98	0.84	0.71	0.60	0.51	0.43	0.36	0.31	0.26
25-29	0.98	0.82	0.66	0.54	0.44	0.36	0.29	0.24	0.20
30-34	1.03	0.84	0.67	0.54	0.43	0.35	0.28	0.22	0.18
35-39	1.36	1.11	0.89	0.72	0.58	0.46	0.37	0.30	0.24
40-44	1.92	1.60	1.31	1.07	0.87	0.71	0.58	0.48	0.39
45-49	2.56	2.09	1.68	1.35	1.08	0.87	0.70	0.56	0.45
50-54	4.37	3.72	3.13	2.63	2.21	1.86	1.56	1.31	1.10
55-59	6.51	5.50	4.57	3.81	3.17	2.64	2.20	1.83	1.53
60-64	12.66	11.18	9.76	8.53	7.46	6.51	5.69	4.97	4.35
65-69	18.96	16.88	14.88	13.12	11.57	10.20	8.99	7.93	6.99
70-74	32.45	29.05	25.76	22.85	20.27	17.98	15.95	14.14	12.55
75+	83.95	75.98	68.18	61.21	54.95	49.33	44.29	39.76	35.69

Table Appendix A15: Predicted age-specific death rates (ASDRs) for **Male** per 1000 at 5-year age groups in Bangladesh, for the period 2001–2051(Rural)

Age group	Year								
	2012	2016	2021	2026	2031	2036	2041	2046	2051
0	55.81	51.31	46.19	41.58	37.44	33.70	30.34	27.31	24.59
1-4	3.60	2.97	2.33	1.83	1.44	1.13	0.89	0.70	0.55
5-9	1.00	0.85	0.70	0.57	0.47	0.38	0.31	0.26	0.21
10-14	0.80	0.72	0.63	0.56	0.49	0.43	0.38	0.33	0.29
15-19	0.89	0.79	0.67	0.58	0.49	0.42	0.36	0.31	0.27
20-24	1.29	1.19	1.08	0.98	0.89	0.80	0.73	0.66	0.60
25-29	1.31	1.20	1.07	0.96	0.86	0.77	0.69	0.61	0.55
30-34	1.64	1.50	1.34	1.21	1.08	0.97	0.87	0.78	0.70
35-39	1.95	1.76	1.55	1.36	1.20	1.05	0.93	0.81	0.72
40-44	2.87	2.62	2.34	2.09	1.86	1.66	1.48	1.32	1.18
45-49	4.34	3.89	3.39	2.95	2.57	2.24	1.96	1.71	1.49
50-54	6.68	6.03	5.30	4.66	4.10	3.60	3.17	2.78	2.45
55-59	10.37	9.46	8.42	7.50	6.68	5.95	5.30	4.72	4.20
60-64	17.94	16.58	15.02	13.61	12.33	11.17	10.12	9.17	8.31
65-69	24.92	22.64	20.08	17.80	15.79	14.00	12.42	11.01	9.77
70-74	41.13	38.33	35.10	32.15	29.44	26.96	24.69	22.62	20.71
75+	102.72	97.57	91.49	85.79	80.44	75.43	70.73	66.32	62.19

Table Appendix A16: Predicted age-specific death rates (ASDRs) for **Female** per 1000 at 5-year age groups in Bangladesh, for the period 2001–2051(Rural)

Age group	Year								
	2012	2016	2021	2026	2031	2036	2041	2046	2051
0	44.15	39.92	35.21	31.05	27.38	24.14	21.29	18.78	16.56
1-4	2.66	2.14	1.63	1.25	0.95	0.72	0.55	0.42	0.32
5-9	0.92	0.79	0.66	0.55	0.45	0.38	0.31	0.26	0.22
10-14	0.66	0.59	0.53	0.46	0.41	0.36	0.32	0.28	0.25
15-19	0.93	0.82	0.71	0.60	0.52	0.44	0.38	0.32	0.28
20-24	1.16	1.03	0.89	0.77	0.66	0.57	0.49	0.42	0.37
25-29	1.14	0.99	0.82	0.69	0.57	0.48	0.40	0.33	0.28
30-34	1.19	1.02	0.84	0.70	0.57	0.47	0.39	0.32	0.27
35-39	1.56	1.35	1.12	0.93	0.78	0.65	0.54	0.45	0.37
40-44	2.04	1.73	1.40	1.14	0.93	0.75	0.61	0.50	0.41
45-49	2.59	2.17	1.73	1.38	1.10	0.88	0.70	0.56	0.44
50-54	4.70	4.17	3.58	3.08	2.65	2.28	1.96	1.69	1.45
55-59	6.53	5.67	4.75	3.99	3.34	2.80	2.35	1.97	1.65
60-64	13.54	12.36	11.02	9.83	8.76	7.81	6.97	6.21	5.54
65-69	19.32	17.51	15.49	13.70	12.11	10.71	9.47	8.38	7.41
70-74	32.98	29.96	26.57	23.56	20.89	18.53	16.43	14.57	12.92
75+	86.68	79.62	71.60	64.39	57.91	52.07	46.83	42.11	37.87

Table Appendix A17: Predicted age-specific death rates (ASDRs) for **Male** per 1000 at 5-year age groups in Bangladesh, for the period 2001–2051(Urban)

Age group	Year								
	2012	2016	2021	2026	2031	2036	2041	2046	2051
0	43.29	40.56	37.38	34.46	31.77	29.28	26.99	24.88	22.94
1-4	3.24	2.91	2.55	2.23	1.95	1.71	1.50	1.31	1.15
5-9	0.99	0.88	0.77	0.68	0.59	0.52	0.45	0.40	0.35
10-14	0.80	0.76	0.72	0.67	0.63	0.60	0.56	0.53	0.50
15-19	0.72	0.67	0.60	0.55	0.49	0.45	0.40	0.37	0.33
20-24	1.16	1.11	1.04	0.98	0.92	0.87	0.82	0.77	0.73
25-29	1.15	1.09	1.01	0.94	0.87	0.81	0.75	0.69	0.65
30-34	1.06	0.97	0.88	0.79	0.71	0.64	0.58	0.52	0.47
35-39	1.70	1.61	1.51	1.42	1.33	1.25	1.17	1.10	1.03
40-44	2.67	2.49	2.29	2.10	1.93	1.77	1.62	1.49	1.37
45-49	3.81	3.52	3.18	2.87	2.59	2.34	2.12	1.91	1.73
50-54	6.33	5.90	5.40	4.94	4.52	4.14	3.79	3.47	3.17
55-59	11.06	10.28	9.38	8.56	7.82	7.13	6.51	5.94	5.42
60-64	17.46	16.38	15.12	13.96	12.89	11.90	10.98	10.14	9.36
65-69	26.21	24.53	22.58	20.78	19.13	17.61	16.21	14.92	13.73
70-74	44.32	42.73	40.82	38.99	37.25	35.59	34.00	32.48	31.03
75+	100.59	97.31	93.36	89.57	85.94	82.45	79.11	75.90	72.82

Table Appendix A18: Predicted age-specific death rates (ASDRs) for **Female** per 1000 at 5-year age groups in Bangladesh, for the period 2001–2051(Urban)

Age group	Year								
	2012	2016	2021	2026	2031	2036	2041	2046	2051
0	30.90	27.87	24.49	21.52	18.91	16.62	14.60	12.83	11.27
1-4	1.79	1.48	1.16	0.91	0.71	0.56	0.44	0.35	0.27
5-9	0.54	0.45	0.36	0.29	0.23	0.19	0.15	0.12	0.10
10-14	0.38	0.33	0.28	0.23	0.19	0.16	0.13	0.11	0.09
15-19	0.70	0.62	0.54	0.47	0.40	0.35	0.30	0.26	0.22
20-24	0.52	0.43	0.34	0.27	0.21	0.17	0.13	0.10	0.08
25-29	0.58	0.48	0.37	0.29	0.23	0.18	0.14	0.11	0.09
30-34	0.66	0.54	0.42	0.33	0.26	0.20	0.16	0.12	0.10
35-39	0.91	0.74	0.57	0.44	0.34	0.27	0.21	0.16	0.12
40-44	1.16	0.93	0.70	0.53	0.40	0.31	0.23	0.17	0.13
45-49	1.98	1.63	1.28	1.01	0.79	0.62	0.49	0.38	0.30
50-54	3.06	2.55	2.04	1.63	1.30	1.04	0.83	0.66	0.53
55-59	5.53	4.75	3.92	3.23	2.67	2.20	1.81	1.50	1.24
60-64	9.34	8.13	6.85	5.76	4.85	4.08	3.44	2.89	2.43
65-69	16.59	14.72	12.68	10.93	9.41	8.11	6.98	6.02	5.18
70-74	31.82	29.15	26.13	23.42	21.00	18.82	16.87	15.12	13.56
75+	89.55	86.05	81.88	77.91	74.13	70.53	67.11	63.86	60.76

Appendix- B

Table Appendix B1a: Projected broad age group population (%) of scenario-I (both fertility and mortality is fixed as 2011) for **national,** 2011-2051

Year	Age Group									
	0-14		15-59		60+		15-64		65+	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2011	32.56	31.23	60.23	62.08	7.21	6.68	62.79	64.29	4.65	4.48
2016	27.66	26.96	63.70	64.96	8.64	8.08	66.72	67.69	5.62	5.34
2021	24.44	23.93	65.18	66.01	10.38	10.07	68.80	69.60	6.75	6.47
2026	23.56	23.26	64.24	65.13	12.19	11.62	68.27	68.60	8.17	8.14
2031	22.88	22.46	63.11	63.61	14.01	13.94	67.46	68.10	9.66	9.44
2036	21.73	21.22	62.91	62.54	15.36	16.24	67.12	67.36	11.15	11.42
2041	20.47	19.89	62.89	61.50	16.64	18.61	67.34	66.77	12.19	13.35
2046	19.56	18.92	62.26	59.87	18.18	21.21	67.27	65.74	13.17	15.34
2051	19.09	18.40	61.11	57.70	19.80	23.89	66.49	64.09	14.42	17.51

Table Appendix B1b: Projected broad age group population (%) of scenario-I (both fertility and mortality is fixed as 2011) for **rural,** 2011-2051

Year	Age Group									
	0-14		15-59		60+		15-64		65+	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2011	33.44	32.04	59.03	60.92	7.52	7.03	61.62	63.21	4.94	4.75
2016	28.52	27.89	62.65	63.68	8.83	8.44	65.66	66.51	5.82	5.60
2021	25.47	25.03	64.17	64.63	10.36	10.34	67.69	68.24	6.84	6.73
2026	24.93	24.71	63.15	63.55	11.92	11.74	67.00	66.98	8.08	8.31
2031	24.36	24.03	62.23	62.21	13.40	13.75	66.29	66.49	9.35	9.48
2036	23.27	22.85	62.26	61.41	14.47	15.73	66.17	65.97	10.56	11.18
2041	22.05	21.57	62.51	60.76	15.43	17.67	66.59	65.62	11.36	12.81
2046	21.23	20.69	62.01	59.53	16.75	19.78	66.68	64.89	12.08	14.42
2051	20.85	20.26	60.89	57.72	18.27	22.02	66.00	63.59	13.15	16.15

Table Appendix B1c: Projected broad age group population (%) of scenario-I (both fertility and mortality is fixed as 2011) for **urban,** 2011-2051

Year	Age Group									
	0-14		15-59		60+		15-64		65+	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2011	30.02	29.41	63.67	64.72	6.31	5.87	66.16	66.73	3.82	3.86
2016	25.55	25.06	66.39	67.70	8.05	7.23	69.45	70.20	5.00	4.73
2021	22.35	21.84	67.31	68.78	10.34	9.38	71.23	72.31	6.42	5.85
2026	21.03	20.58	66.14	68.19	12.83	11.24	70.65	71.74	8.32	7.69
2031	20.06	19.49	64.41	66.32	15.53	14.19	69.56	71.26	10.38	9.25
2036	18.80	18.13	63.55	64.67	17.66	17.21	68.57	70.06	12.63	11.82
2041	17.49	16.74	62.73	62.76	19.78	20.50	68.19	68.88	14.32	14.38
2046	16.50	15.67	61.66	60.11	21.85	24.22	67.50	67.12	16.01	17.21
2051	15.91	15.01	60.53	57.11	23.56	27.88	66.42	64.60	17.67	20.39

Table Appendix B2a: Projected broad age group population (%) of scenario-II (fertility fixed as 2011 and mortality forecasted by Lee-Carter model) for **national,** 2011-2051

Year	Age Group									
	0-14		15-59		60+		15-64		65+	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2011	32.56	31.23	60.23	62.08	7.21	6.68	62.79	64.29	4.65	4.48
2016	27.66	26.96	63.70	64.96	8.64	8.08	66.72	67.69	5.62	5.34
2021	24.22	23.87	65.18	65.89	10.60	10.24	68.87	69.52	6.90	6.61
2026	23.19	23.16	64.04	64.77	12.77	12.07	68.19	68.30	8.61	8.54
2031	22.47	22.35	62.49	62.89	15.03	14.76	67.01	67.45	10.52	10.21
2036	21.36	21.07	61.74	61.37	16.91	17.56	66.12	66.26	12.53	12.68
2041	20.09	19.65	61.16	59.83	18.76	20.52	65.77	65.13	14.14	15.21
2046	19.15	18.58	59.94	57.61	20.90	23.81	65.11	63.48	15.74	17.94
2051	18.63	17.93	58.23	54.82	23.14	27.25	63.72	61.11	17.64	20.96

Table Appendix B2b: Projected broad age group population (%) of scenario-II (fertility fixed as 2011 and mortality forecasted by Lee-Carter model) for **rural,** 2011-2051

Year	Age Group									
	0-14		15-59		60+		15-64		65+	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2011	33.44	32.04	59.03	60.92	7.52	7.03	61.62	63.21	4.94	4.75
2016	28.52	27.89	62.65	63.68	8.83	8.44	65.66	66.51	5.82	5.60
2021	25.27	24.97	64.17	64.56	10.56	10.47	67.75	68.21	6.98	6.82
2026	24.60	24.61	62.97	63.28	12.43	12.11	66.92	66.76	8.48	8.63
2031	24.01	23.92	61.67	61.61	14.32	14.47	65.86	65.96	10.12	10.12
2036	22.96	22.72	61.20	60.39	15.84	16.88	65.25	65.02	11.79	12.26
2041	21.74	21.38	60.96	59.28	17.30	19.34	65.17	64.19	13.09	14.43
2046	20.89	20.41	59.97	57.54	19.14	22.05	64.77	62.91	14.34	16.68
2051	20.47	19.86	58.36	55.18	21.17	24.96	63.57	60.99	15.96	19.14

Table Appendix B2c: Projected broad age group population (%) of scenario-II (fertility fixed as 2011 and mortality forecasted by Lee-Carter model) for **urban,** 2011-2051

Year	Age Group									
	0-14		15-59		60+		15-64		65+	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2011	30.02	29.41	63.67	64.72	6.31	5.87	66.16	66.73	3.82	3.86
2016	25.55	25.06	66.39	67.70	8.05	7.23	69.45	70.20	5.00	4.73
2021	22.09	21.79	67.36	68.65	10.55	9.56	71.38	72.22	6.53	5.99
2026	20.57	20.50	66.04	67.80	13.39	11.70	70.73	71.41	8.70	8.08
2031	19.53	19.38	63.92	65.59	16.55	15.03	69.31	70.61	11.16	10.00
2036	18.30	17.96	62.51	63.52	19.19	18.52	67.78	69.01	13.92	13.04
2041	17.01	16.59	61.11	61.49	21.88	21.93	66.81	67.18	16.18	16.24
2046	16.02	15.34	59.43	57.97	24.55	26.70	65.51	65.01	18.47	19.65
2051	15.42	14.59	57.71	54.41	26.87	31.00	63.80	61.85	20.78	23.56

Appendix

Table Appendix B3a: Different characteristics of the projected population for different mortality assumptions in Bangladesh (**National**), 2011-2051

Indicator	Year								
	2011	2016	2021	2026	2031	2036	2041	2046	2051
Scenario-I (Both fertility and mortality fixed as 2011)									
TDR*	63.57	55.48	52.48	54.62	57.84	59.43	60.76	63.75	68.30
TDR**	57.43	48.82	44.52	46.13	47.54	48.72	49.13	50.36	53.15
YDR*	52.20	42.47	36.89	36.20	35.78	34.24	32.44	31.51	31.55
YDR**	50.24	40.65	34.96	34.21	33.45	31.94	30.09	28.93	28.71
ODR*	11.37	13.00	15.59	18.42	22.05	25.19	28.32	32.24	36.75
ODR**	7.19	8.16	9.56	11.92	14.09	16.78	19.04	21.42	24.44
Median Age									
Male	23.93	25.90	27.98	30.02	32.32	34.53	36.48	37.88	38.72
Female	24.60	27.11	29.35	31.18	33.28	35.53	37.58	39.31	40.17
Total	24.28	26.54	28.61	30.55	32.77	35.01	37.01	38.56	39.43
Scenario-II (Fertility fixed as 2011 and mortality forecasted by Lee-Carter model)									
TDR*	63.57	55.48	52.61	55.28	59.51	62.45	65.30	70.13	76.93
TDR**	57.43	48.82	44.53	46.53	48.75	51.09	52.78	55.53	60.23
YDR*	52.20	42.47	36.70	35.99	35.75	34.46	32.85	32.10	32.34
YDR**	50.24	40.65	34.76	33.96	33.33	32.05	30.36	29.34	29.29
ODR*	11.37	13.00	15.91	19.29	23.77	27.99	32.45	38.03	44.59
ODR**	7.19	8.16	9.77	12.57	15.41	19.04	22.42	26.19	30.94
Median Age									
Male	23.93	25.90	28.12	30.33	32.76	35.22	37.41	39.34	40.58
Female	24.60	27.11	29.43	31.38	33.58	36.04	38.34	40.66	41.98
Total	24.28	26.54	28.72	30.81	33.15	35.61	37.86	39.98	41.27

Note: TDR* = Total dependency ratio (obtain from the people between 0-14 years of age and 60+ years of age divided by people 15-59 years of age); TDR** = Total dependency ratio (obtain from the people between 0-14 years of age and 64+ years of age divided by people 15-64 years of age); CDR* = Child dependency ratio (obtain from people 0-14 years of age divided by people 15-59 years of age); CDR** = Child dependency ratio (obtain from people 0-14 years of age divided by people 15-64 years of age); ODR* = Older dependency ratio (obtain from people 60+ years of age divided by people 15-59 years of age); and ODR** = Older dependency ratio (obtain from people 64+ years of age divided by people 15-64 years of age).

All dependency ratios and sex ratio is considered as percentage and median age years.

Table Appendix B3b: Different characteristics of the projected population for different mortality assumptions in Bangladesh (**Rural**), 2011-2051

Indicator	Year								
	2011	2016	2021	2026	2031	2036	2041	2046	2051
Scenario-I (Both fertility and mortality fixed as 2011)									
TDR*	66.79	58.35	55.29	57.86	60.72	61.70	62.23	64.53	68.60
TDR**	60.27	51.35	47.14	49.28	50.63	51.35	51.27	51.99	54.32
YDR*	54.64	44.67	39.22	39.18	38.89	37.29	35.39	34.50	34.66
YDR**	52.51	42.69	37.16	37.05	36.45	34.91	33.00	31.87	31.73
ODR*	12.15	13.68	16.07	18.68	21.82	24.41	26.84	30.03	33.94
ODR**	7.77	8.65	9.98	12.23	14.18	16.45	18.27	20.13	22.60
Median Age									
Male	23.26	25.09	27.20	29.12	31.40	33.41	35.20	36.04	36.65
Female	24.35	26.65	28.56	30.10	32.19	34.22	36.05	37.10	37.75
Total	23.83	25.90	27.81	29.56	31.77	33.80	35.61	36.55	37.19
Scenario-II (Fertility fixed as 2011 and mortality forecasted by Lee-Carter model)									
TDR*	66.79	58.35	55.36	58.42	62.23	64.47	66.32	70.18	76.14
TDR**	60.27	51.35	47.12	49.60	51.72	53.53	54.60	56.63	60.55
YDR*	54.64	44.67	39.03	38.98	38.88	37.57	35.86	35.15	35.52
YDR**	52.51	42.69	36.96	36.81	36.37	35.07	33.33	32.35	32.38
ODR*	12.15	13.68	16.33	19.44	23.34	26.90	30.46	35.03	40.62
ODR**	7.77	8.65	10.16	12.79	15.36	18.46	21.26	24.28	28.18
Median Age									
Male	23.26	25.09	27.33	29.38	31.77	33.99	35.97	37.27	38.14
Female	24.35	26.65	28.63	30.27	32.44	34.64	36.68	38.23	39.21
Total	23.83	25.90	27.91	29.78	32.09	34.30	36.32	37.73	38.67

Note: TDR* = Total dependency ratio (obtain from the people between 0-14 years of age and 60+ years of age divided by people 15-59 years of age); TDR** = Total dependency ratio (obtain from the people between 0-14 years of age and 64+ years of age divided by people 15-64 years of age); CDR* = Child dependency ratio (obtain from people 0-14 years of age divided by people 15-59 years of age); CDR** = Child dependency ratio (obtain from people 0-14 years of age divided by people 15-64 years of age); ODR* = Older dependency ratio (obtain from people 60+ years of age divided by people 15-59 years of age); and ODR** = Older dependency ratio (obtain from people 64+ years of age divided by people 15-64 years of age).

All dependency ratios and sex ratio is considered as percentage and median age years.

Table Appendix B3c: Different characteristics of the projected population for different mortality assumptions in Bangladesh (**Urban**), 2011-2051

Indicator	Year								
	2011	2016	2021	2026	2031	2036	2041	2046	2051
Scenario-I (Both fertility and mortality fixed as 2011)									
TDR*	55.81	49.18	46.99	48.93	53.02	56.00	59.37	64.24	70.02
TDR**	50.52	43.23	39.36	40.48	42.05	44.28	45.92	48.57	52.66
YDR*	46.31	37.76	32.49	30.99	30.27	28.81	27.28	26.41	26.29
YDR**	44.74	36.26	30.80	29.23	28.10	26.64	24.98	23.89	23.60
ODR*	9.50	11.41	14.50	17.94	22.75	27.20	32.09	37.82	43.73
ODR**	5.78	6.97	8.56	11.25	13.95	17.64	20.94	24.68	29.05
Median Age									
Male	25.88	28.09	30.09	32.31	34.50	36.98	39.10	41.28	42.59
Female	25.08	27.98	30.87	33.24	35.52	38.23	40.61	43.45	44.95
Total	25.44	28.03	30.46	32.76	34.99	37.59	39.83	42.32	43.74
Scenario-II (Fertility fixed as 2011 and mortality forecasted by Lee-Carter model)									
TDR*	55.81	49.18	47.07	49.46	54.45	58.69	63.13	70.39	78.47
TDR**	50.52	43.23	39.29	40.71	42.94	46.22	49.26	53.24	59.22
YDR*	46.31	37.76	32.27	30.70	30.05	28.77	27.40	26.71	26.77
YDR**	44.74	36.26	30.56	28.90	27.82	26.51	25.07	24.02	23.88
ODR*	9.50	11.41	14.80	18.76	24.39	29.92	35.73	43.68	51.70
ODR**	5.78	6.97	8.73	11.81	15.13	19.71	24.19	29.22	35.33
Median Age									
Male	25.88	28.09	30.27	32.69	35.06	37.83	40.22	42.97	44.81
Female	25.08	27.98	30.96	33.46	35.88	38.84	41.47	44.91	46.91
Total	25.44	28.03	30.60	33.07	35.46	38.32	40.83	43.91	45.85

Note: TDR* = Total dependency ratio (obtain from the people between 0-14 years of age and 60+ years of age divided by people 15-59 years of age); TDR** = Total dependency ratio (obtain from the people between 0-14 years of age and 64+ years of age divided by people 15-64 years of age); CDR* = Child dependency ratio (obtain from people 0-14 years of age divided by people 15-59 years of age); CDR** = Child dependency ratio (obtain from people 0-14 years of age divided by people 15-64 years of age); ODR* = Older dependency ratio (obtain from people 60+ years of age divided by people 15-59 years of age); and ODR** = Older dependency ratio (obtain from people 64+ years of age divided by people 15-64 years of age).

All dependency ratios and sex ratio is considered as percentage and median age years.