Analyzing Geographical Variation in Cause-of-Death Mortality for China

Evidence from 2004 to 2019

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Aging and Retirement

Analyzing Geographical Variation in Cause-of-Death Mortality for China

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Executive Summary

This report models and forecasts future mortality improvements in China, by geographical regions, as well as by causes of death. We collect the most up-to-date deaths and population exposures data from "China's Causes of Death Monitoring Dataset" published by the Chinese Center for Disease Control and Prevention over the period 2004–2019. Using the cutting-edge forecast reconciliation method, we conduct stochastic modeling and projection of region-area-cause-specific mortality rates for 2020–2029. We also conduct mortality prediction under several cause-elimination scenarios and quantify the impact of these scenarios on future mortality levels.

Section 1: Introduction

With one of the fastest-growing economies, China has experienced rapid improvements in life expectancy in recent decades. According to the World Bank, in 2018, the life expectancy in China was just two years less than in the United States (76.3 versus 78.7 years). Despite this overall improvement, there remain significant inequalities in mortality rates between different geographical regions and socioeconomic groups. In recent studies, substantial regional disparities were found, with healthy life expectancy varying by up to 10 years across Chinese provinces for both men and women (see, e.g., Li et al., 2021). This motivates the need to better identify and assess geographical variations in mortality rates in China, and more importantly, to project how these trends will look in the future.

Mortality by cause of death also provides important insights into how future mortality levels will evolve. There are a number of medical and epidemiological studies that analyze cross-sectional and longitudinal trends in cause-specific mortality in China. For example, a recent study published by Zhou et al. (2019) in the Lancet conducted a systematic analysis of mortality, morbidity, and risk factors at a Chinese provincial level over the period 1990–2017. Their results show significant changes in the causes of death over time. In 1990, the five leading causes of death were 1. Lower respiratory infection, 2. Neonatal disorders, 3. Stroke, 4. Chronic obstructive pulmonary disease, and 5. Road injuries. In 2017, the five leading causes of death became 1. Stroke, 2. Ischemic heart disease, 3. Lung cancer, 4. Chronic obstructive pulmonary disease, and 5. Liver cancer. The authors also report substantial regional variations in the province-level mortality experience in 2017. They conclude that urban, coastal, and wealthier provinces and cities in eastern China generally have better health outcomes than those in the west, although mortality by cause varied substantially between provinces. Several other studies focus on mortality modeling by a single cause of death. However, to the best of our knowledge, the literature is yet to conduct a modeling exercise to forecast trends in cause-specific mortality at the national and regional levels for China.

Mortality by geographical regions and socioeconomic groups and mortality by cause-of-death are twin issues that should be dealt with in an integrated manner. They are of particular interest to actuaries working in fields such as product design, underwriting, and valuing portfolios of life insurance contracts. As mortality forecasts are key inputs into the decision-making processes of insurance companies, this project focuses on providing forecasts on mortality improvement for China, across age groups, gender, three geographical regions as well as by leading causes of death. In this research, we aim to address the following questions:

- Where are the gaps in mortality experience across China?
- Have these gaps closed or widened over time? Which causes of death are driving these gaps?
- What can be said about the future? How to forecast regional-area-cause specific mortality?

Drawing on the successful SOA initiatives on mortality modeling for the U.S., we propose a consistent framework tailored designed for the mortality experience in China. In this project, we conduct mortality prediction under several cause-elimination scenarios and evaluate the impact on the overall mortality improvement and regional-level mortality improvement. These scenario-based forecasts will be implemented via the cutting-edge forecast reconciliation method (Li et al., 2019).

It should be noted that our dataset covers the period 2004–2019, before the onset of the COVID-19 pandemic. The reported number of deaths caused by COVID-19 in China is relatively low[1], so we do not expect our model estimates and scenario-based analysis to change substantially if more recent data becomes available for China.

[1] The reported number of COVID-19 deaths in China since the start of the pandemic was 14,964 on Sep 7, 2022 (John Hopkins University, Coronavirus Resource Center, https://coronavirus.jhu.edu/region/china, accessed Sep 7, 2022).

The remainder of this report is structured as follows. In Section 2, we conduct a literature review on cause-of-death mortality in China and summarize some key findings. In Section 3, we describe the data used and visualize mortality rate by genders, regions, urban vs. rural areas, as well as across leading causes of death. In Section 4, we introduce the mortality model and forecast reconciliation method. We also present the reconciled mortality forecasts during 2020–2029 for all levels. We present results on scenario-based mortality forecasts in Section 5. Section 6 concludes the project and discusses its potential limitations.

Section 2: Literature review

2.1 CAUSE-OF-DEATH MORTALITY IN CHINA

In the following, we summarize recent medical and epidemiological studies that analyze cross-sectional and longitudinal trends in cause-specific mortality in China. We begin with studies that compare several causes of death and then summarize the research for specific causes of death. For each study, we comment on the data used and key results in terms of time trends and regional variations. Our review focuses on studies that cover all of China and does not include studies that focus on a single province. We summarize the literature review in Section 2.3.

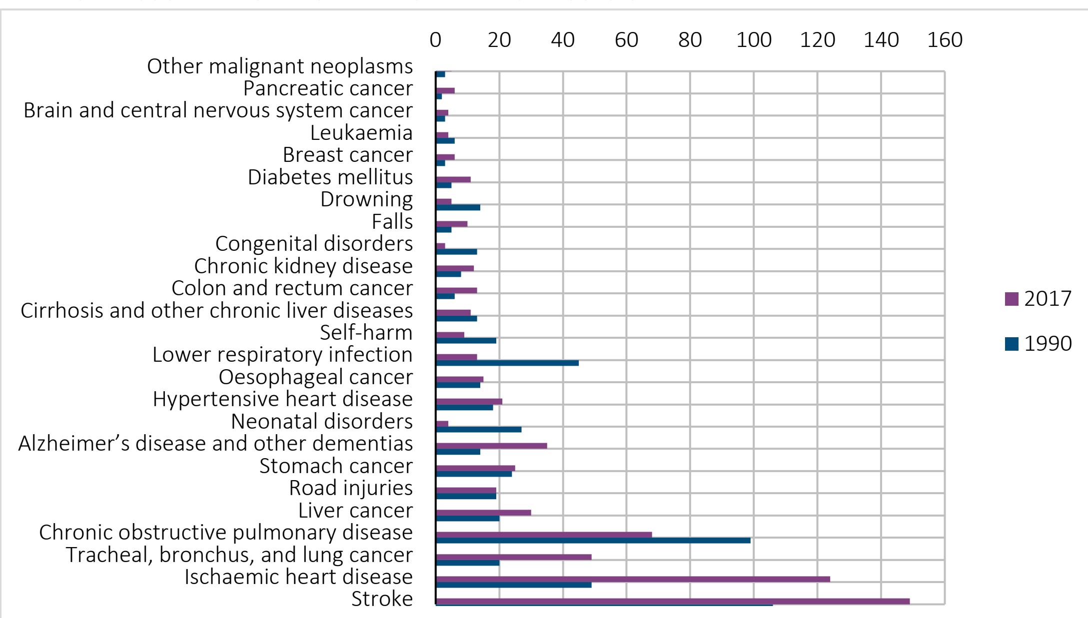
We note that we only found studies that analyze levels and trends in cause-specific mortality in China. There seems to be no prior research that develops statistical models that can be used to forecast cause-specific mortality rates. Existing actuarial models to forecast cause-specific mortality models have only been applied to developed countries (e.g., Li et al., 2019; Arnold and Glushko, 2021; Lyu et al., 2021).

ALL CAUSES OF DEATH

An important study published by Zhou et al. (2019) in the Lancet conducted a systematic analysis of mortality, morbidity, and risk factors in China using provincial-level data from 1990–2017 from the Global Burden of Diseases (GBD) 2017 study. Their results show significant changes in the causes of death over time. In 1990, the five leading causes of death were lower respiratory infection, neonatal disorders, stroke, chronic obstructive pulmonary disease, and road injuries. In 2017, the five leading causes of death were stroke, ischemic heart disease, lung cancer, chronic obstructive pulmonary disease, and liver cancer (see Figure 1 below). The authors reported substantial regional variations in province-level mortality in 2017. They conclude that urban, coastal, and wealthier provinces and cities in eastern China generally have better health outcomes than those in the west, although mortality by cause varied substantially between provinces. An earlier, similar study by Zhou et al. (2016) used GBD 2013 data for the period 1990-2013.

Figure 1

DEATHS IN 1990 AND 2017 FOR THE 25 LEADING CAUSES OF DEATH IN CHINA



Notes: Deaths per 100,000 population. Source of data: Zhou et al. (2019).

CARDIOVASCULAR DISEASE MORTALITY

Two types of cardiovascular disease mortality were the leading causes of death in China in 2017 (stroke and ischemic heart disease, also called coronary heart disease). A third type, hypertensive heart disease, was the 10th leading cause of death (see Figure 1):

Wang et al. (2013) analyzed the long-term trends of stroke mortality in China between 1994 and 2013 using stroke mortality data from the GBD 2013 data. Using an age-period-cohort framework, the authors estimated the age pattern of stroke mortality for males and females and documented significant negative trends in stroke mortality for both males and females.

Li et al. (2017) conducted an age-period-cohort analysis of stroke mortality data from urban and rural regions in China between 1988 and 2013. They used stroke mortality data from the Chinese Health Statistics Annual Report (1987–2001) and Chinese Health Statistics Yearbooks (2003–2014) and population data from population censuses (i.e., 1982, 1990, 2000, and 2010). The authors found a modest period effect, accompanied by substantial age and cohort effects over the years 1987 to 2013. The decline in stroke mortality was slower for the rural population than the urban population (which had a higher initial stroke mortality rate in 1987).

CANCER MORTALITY

Three types of cancer were among the top 10 causes of death in China in 2017 (see Figure 1): tracheal, bronchus, and lung cancer (#3); liver cancer (#5), and stomach cancer (#7).

Jiang et al. (2021) studied trends in cancer mortality in China from 2004 to 2018 and compared rural and urban residents in three geographic regions. Their study was based on raw data from the national mortality surveillance system of China to assess the mortalities of all cancer and site-specific cancers. The authors found that cancer was the second leading cause of death in the whole population and the first leading cause of death in those <65 years during 2014-2018. In terms of time trends, Jiang et al. (2021) found that crude mortality rate (CMR) of all cancer continually increased while their age-standardized mortality rates (ASMR) decreased, which indicates that aging contributed greatly to the increased cancer death. Furthermore, Jiang et al. (2021) found that the CMR of all cancer was higher in rural residents than in urban residents in the population <65 years; however, the situation was inversed for the ≥65 years population. Lung/bronchus cancer, colorectal cancer, and pancreas cancer increased in rural residents.

A second study by Cao et al. (2021) summarized the most recent changing profiles of cancer burden worldwide and in China and compared the cancer data of China with those of other regions. The authors used GLOBOCAN 2018 and GLOBOCAN 2020 data[2], as well as cancer incidence and mortality from the 2015 National Cancer Registry Report in China. The authors found that both China's age-standardized incidence rate (204.8 per 100,000) and the age-standardized mortality rate (129.4 per 100,000) were above the global average. They classified the mortality rate of cancer in China as high. Furthermore, the authors reported that worldwide, in 2020, lung, liver, stomach, breast, and colon cancers were the top five leading causes of cancer-related death, while in China, the top five causes were lung, liver, stomach, esophagus and colon cancer. China is undergoing a cancer transition with an increasing burden of lung cancer, gastrointestinal cancer, and breast cancers.

[2] GLOBOCAN 2020 is an online database providing global cancer statistics and estimates of incidence and mortality in 185 countries for 36 types of cancer, and for all cancer sites combined.

LUNG DISEASES

Chronic obstructive pulmonary disease (COPD), a type of lung disease, was the 4th most prevalent cause of death in China in 2017 (see Figure 1). There are few recent studies that analyze COPD mortality across all of China.

An older study by Yin et al. (2016b) analyzed spatiotemporal variations in COPD in China based on data from the nationally representative China Mortality Surveillance System for the period 2006–2012. The authors found that COPD mortality rate decreased markedly from 105.1 to 73.7 per 100,000 during 2006 to 2012 and varied over two-fold across China. Yin et al. found that COPPD mortality rates were higher in west China compared with east China, and higher in rural areas than in urban areas. They noted that adjustment for age, gender, urban/rural, region, smoking prevalence, indoor air pollution, mean body mass index and socioeconomic circumstances accounted for 67% of the geographical variation. Interestingly, Yin et al. reported that urban/rural differences in COPD mortality narrowed over time, but the magnitude of the east-west inequality persisted without change.

Fang et al. (2018) estimated the nationwide prevalence of COPD using data from a cross-sectional survey of a nationally representative sample of individuals from mainland China aged 40+ years conducted in 2014–2015. They found that prevalence of COPD differed by geographic region, with the highest prevalence in southwest China and the lowest in central China. This study did not analyze COPD mortality.

ROAD INJURIES

Road injuries were the 6th most prevalent cause of death in China in 2017 (see Figure 1).

Wang et al. (2019) analyzed mortality rates from road traffic injury in China from 2006 to 2016 using data from China's national mortality surveillance system. The authors found that overall age-adjusted road traffic mortality increased from 2006 to 2011 and then decreased to 2016. They reported that males, older adults, and rural areas consistently had higher road traffic mortality rates than did females, younger people, and urban areas. Wang et al. found that mortality changes varied across urban and rural areas and by sex, age group, and province between 2006 and 2016.

DEMENTIA

Alzheimer's disease and other dementias was the 8th most common cause of death in China in 2017 (see Figure 1).

Yin et al. (2016a) analyzed temporal trends and geographic variations in dementia mortality in China. They used annual dementia mortality counts for the period 2006 to 2012 from the nationally representative China Mortality Surveillance System. The authors found substantial regional and spatiotemporal variations in dementia mortality. Mortality rates were significantly higher in the east compared with the north. The authors report a declining trend in 2 (east and northwest) of the 7 regions. Importantly, the authors found that dementia mortality decreased by 15% in urban areas but increased by 24% in rural areas.

Bo et al. (2019) conducted a similar study as Yin et al. (2016a), using more recent data from the Mortality Surveillance System for the period 2009–2015. They found that the crude mortality from Alzheimer's disease and other forms of dementia increased from 2009 to 2015, but the age-standardized mortality decreased. Furthermore, Bo et al. (2019) found that age-standardized mortality in the east was higher than those in the west and middle regions, and the age-standardized mortality in rural areas was higher than that in urban areas.

2.2 SUMMARY

We have summarized recent medical and epidemiological studies that analyze cross-sectional and longitudinal trends in cause-specific mortality in China. The literature review has shown that there are substantial regional differences in the levels and trends in cause-specific mortality rates. Furthermore, there are also differences between rural and urban populations within provinces. Therefore, on top of the national level total mortality, we also look into the mortality differences across regions, urban and rural areas, and causes of death. In short, instead of the "big picture", we focus on the detailed picture at granular levels.

The existing literature has focused on documenting levels and trends in cause-specific mortality in China. There seems to be no prior research that develops statistical models that can be used to forecast region-area-cause-specific mortality rates. Our study aims to fill this gap.

Section 3: Data

3.1 DESCRIPTION

This project considers "China's Causes of Death Monitoring Dataset" published by the Chinese Center for Disease Control and Prevention (hereafter abbreviated as China CDC), and the investigation period is from 2004 to 2019. The data is collected via the National Disease Surveillance System (NDSS), which has been responsible for monitoring the mortality level and disease pattern changes of the Chinese population since 1978. In 2004, NDSS expanded to 161 surveillance sites across China and began to provide annual cause-of-death information. In 2013, there was a further expansion of the surveillance sites to 605 monitoring points.

The Cause of Death Monitoring Dataset (CDMD) summarizes the population and death data reported by each surveillance site and groups the 31 provinces, autonomous regions, and municipalities into three broad regions, namely East, Central, and West.[3] Table 1 notes regions in China showing this grouping method. The cause of death classification follows the ICD-10 codification. We collected the most completed and up-to-date region-cause-specific mortality data from the CDMD over 2004–2019. See below for some detailed descriptions of the dataset and available cause-of-death information.

- Annual death and population exposure data: disaggregated into males/females, 5-year age groups (1–4, 5–9, . . ., 85+)[4], East/Central/West, and Urban/Rural. The definitions of the three broad regions are shown in Table 1.

Table 1
DEFINITION OF THREE BROAD REGIONS IN CHINA

Region	Province
East	Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan
Central	Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan
West	Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Tibet, Gansu, Qinghai, Ningxia, Xinjiang

- Specific causes of death reported with corresponding ICD-10, CDMD, and GBD codifications as presented in Table 2.

[3] Note that this grouping method follows the classification of regions by the National Bureau of Statistics of China.
[4] In this research, we decide to exclude data for age 0 (i.e., infant mortality) to avoid potential under-reporting issues, particularly in rural areas.

Table 2
CODIFICATION OF 9 MAJOR CAUSES OF DEATH

Cause of death	CDMD code	ICD-10 code	GBD code
Infectious	C003, C031	A00-B99, G00, G03-G04, H65-H66, J00-J06, J10-J18, J20-J22, N70-N73	U002, U038
Cancer	C054	C00-C97	U060
Diabetes	C074	E10-E14	U079
Mental	C076	F01-F99, G06-G98	U081
Circulatory	C084	I00-I99	U104
Respiratory	C093	J30-J98	U111
Digestive	C098	K20-K92	U115
Congenital	C112	Q00-Q99	U131
External	C115	V01-Y89	U148

3.2 SUMMARY STATISTICS AND VISUALIZATION

Figure 2 plots the total mortality rates for 2004–2019 by age on a log scale. We use darker colors to plot earlier years and lighter colors to show the mortality rates in more recent years. The log mortality rates in any given year follow the typical age pattern observed in many countries, with a U-shape at younger ages followed by an almost linear increase in mortality rates to ages 85+. Furthermore, Figure 2 shows that mortality rates in China have generally improved during 2004–2019.

Figure 2
TOTAL MORTALITY 2004-2019 (MALES AND FEMALES COMBINED)

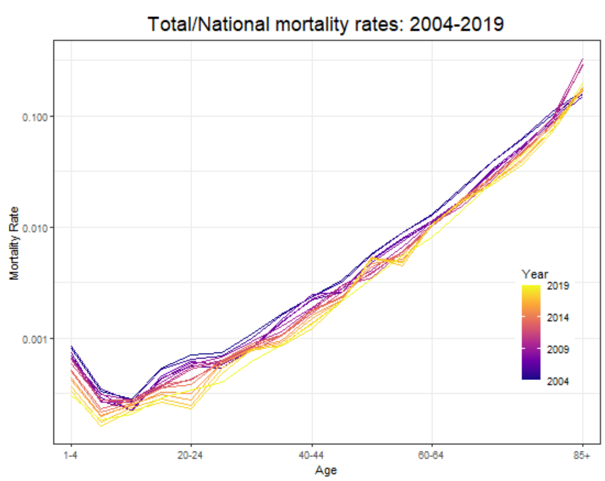


Table 3 confirms that all ages except the age group 85+ experienced improvements in the mortality rates over the period 2004–2019. The average mortality improvement rates during 2004–2019 are all positive except for ages 85+. The improvements were generally larger at younger ages and middle ages than at higher ages.

As shown in Table 3, the average mortality improvement rate during 2004–2019 is estimated to be around 3.2%, and this is across all age groups except for age 0. When we look at the geographical differences in the improvement rates, we find that East China has the highest average improvement rate, which is about 3.4%, while West China has the lowest average improvement rate, which is about 2.9%. On the other hand, it is a bit surprising to see that urban and rural areas had similar improvement rates during this time. However, for urban areas, the improvement rate is generally higher for older age groups, whereas for rural areas, the improvement rate is higher for younger age groups.

Table 3
AVERAGE MORTALITY IMPROVEMENT RATES DURING 2004–2019 (MALES AND FEMALES COMBINED)

	National	East	Central	West	Urban	Rural
1-4	0.064	0.058	0.048	0.070	0.044	0.070
5-9	0.039	0.039	0.028	0.042	0.037	0.040
10-14	0.022	0.026	0.012	0.027	0.025	0.020
15-19	0.040	0.046	0.031	0.046	0.025	0.046
20-24	0.048	0.055	0.053	0.038	0.043	0.049
25-29	0.040	0.045	0.035	0.034	0.048	0.036
30-34	0.037	0.040	0.033	0.034	0.046	0.032
35-39	0.042	0.038	0.044	0.042	0.042	0.041
40-44	0.037	0.036	0.043	0.036	0.041	0.036
45-49	0.029	0.033	0.032	0.023	0.030	0.029
50-54	0.034	0.039	0.035	0.025	0.037	0.033
55-59	0.031	0.031	0.032	0.029	0.024	0.035
60-64	0.031	0.024	0.034	0.035	0.024	0.035
65-69	0.030	0.029	0.031	0.031	0.028	0.032
70-74	0.029	0.026	0.032	0.030	0.034	0.027
75-79	0.022	0.029	0.024	0.009	0.028	0.019
80-84	0.022	0.028	0.028	0.003	0.028	0.019
85+	-0.016	-0.012	-0.006	-0.033	-0.011	-0.018
Average	0.032	0.034	0.032	0.029	0.032	0.032

3.3 MORTALITY BY GENDER

Figure 3 shows the log mortality rates by age separately for males and females for all years 2004–2019. The mortality rates for males and females show similar age patterns and similar time trends. However, the female mortality rates are generally lower than male mortality rates. Furthermore, the reductions in mortality rates seem to be larger for females than for males, given that the curves for different years are farther apart than the curves for males.

Figure 3
MALE AND FEMALE MORTALITY 2004–2019

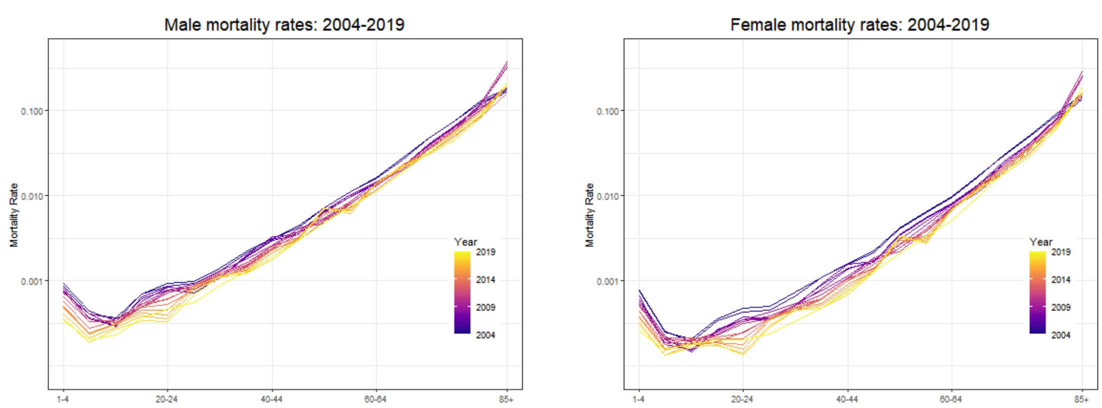


Figure 4 compares the log mortality rates by age for males and females in the years 2004, 2009, 2014, and 2019. The figure shows that the gap between male and female mortality rates has widened over time for young adults and middle-aged adults. For children and older ages, this mortality gap has become smaller.

Figure 4

MALE AND FEMALE MORTALITY IN 2004, 2009, 2014 AND 2019

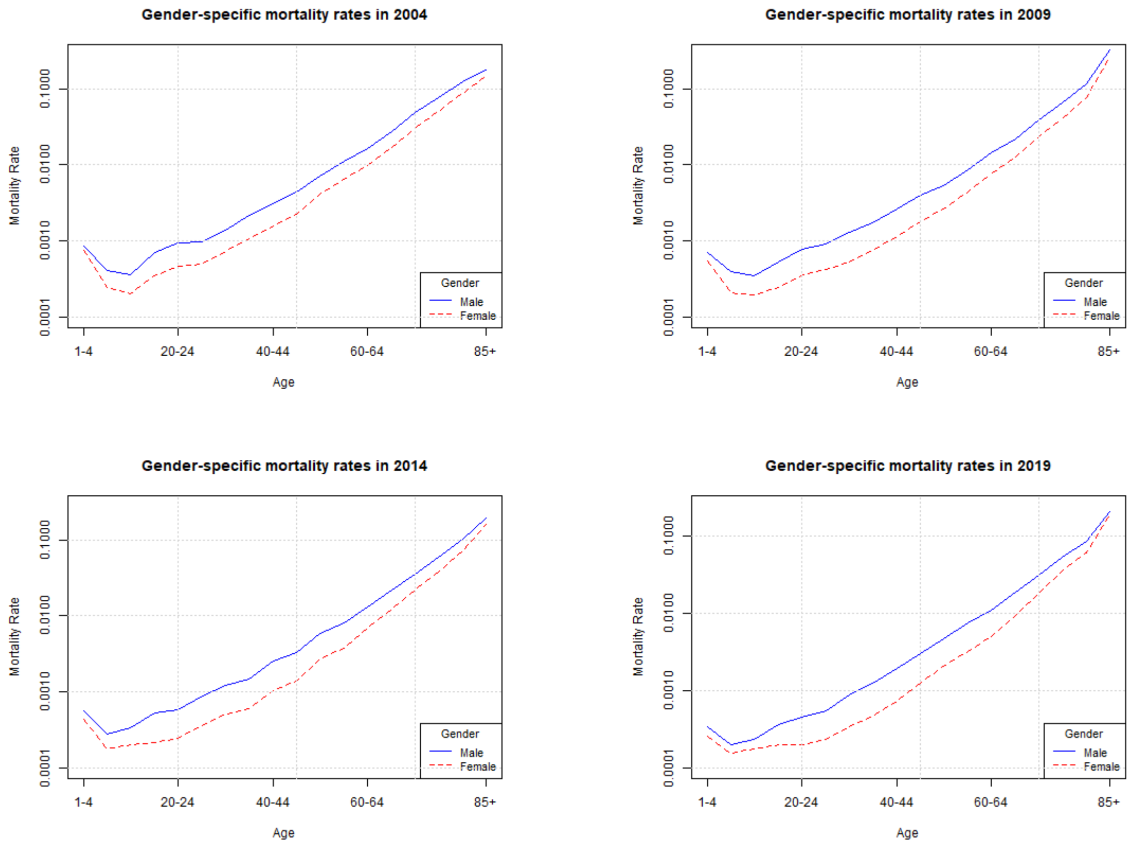


Table 4 and Table 5 compare the average annual improvement rates for males and females over the period 2004–2019. We focus here on the national level rates. Mortality rates for both males and females decreased for all age groups, except for ages 85+. The reductions in mortality rates were larger for females than for males for the age groups 1–4 and all age groups between 20–24 and 70–74. The remaining age groups (5–9, 10–14, 15–19, 80–84, 85+) saw larger reductions in male mortality rates than in female mortality rates.

Table 4

AVERAGE MORTALITY IMPROVEMENT RATE DURING 2004–2019, MALES

	National	East	Central	West	Urban	Rural
1-4	0.060	0.058	0.047	0.062	0.040	0.066
5-9	0.045	0.047	0.037	0.045	0.049	0.044
10-14	0.029	0.035	0.021	0.033	0.030	0.029
15-19	0.043	0.053	0.033	0.046	0.029	0.048
20-24	0.046	0.056	0.052	0.033	0.041	0.048
25-29	0.037	0.043	0.033	0.031	0.046	0.032
30-34	0.030	0.035	0.025	0.027	0.042	0.024
35-39	0.036	0.034	0.037	0.035	0.037	0.035
40-44	0.031	0.033	0.036	0.026	0.037	0.029
45-49	0.025	0.031	0.027	0.018	0.028	0.024
50-54	0.027	0.035	0.028	0.015	0.032	0.025
55-59	0.025	0.025	0.025	0.021	0.016	0.028
60-64	0.025	0.019	0.028	0.029	0.016	0.029
65-69	0.025	0.023	0.026	0.025	0.021	0.027

70-74	0.027	0.022	0.031	0.029	0.030	0.026
75-79	0.022	0.027	0.025	0.009	0.026	0.020
80-84	0.023	0.026	0.030	0.008	0.031	0.018
85+	-0.013	-0.007	-0.002	-0.034	-0.006	-0.016
Average	0.030	0.033	0.030	0.025	0.030	0.030

Table 5

AVERAGE MORTALITY IMPROVEMENT RATE DURING 2004–2019, FEMALES

	National	East	Central	West	Urban	Rural
1-4	0.069	0.056	0.048	0.079	0.049	0.075
5-9	0.029	0.026	0.014	0.038	0.019	0.033
10-14	0.010	0.011	-0.001	0.020	0.020	0.006
15-19	0.037	0.035	0.030	0.048	0.022	0.043
20-24	0.053	0.055	0.057	0.049	0.049	0.055
25-29	0.047	0.052	0.041	0.044	0.053	0.044
30-34	0.049	0.048	0.046	0.051	0.053	0.047
35-39	0.053	0.047	0.056	0.058	0.052	0.055
40-44	0.051	0.041	0.056	0.057	0.051	0.051
45-49	0.036	0.036	0.040	0.035	0.034	0.039
50-54	0.046	0.047	0.045	0.043	0.047	0.046
55-59	0.044	0.042	0.044	0.045	0.039	0.047
60-64	0.042	0.035	0.044	0.047	0.039	0.044
65-69	0.039	0.037	0.039	0.039	0.039	0.039
70-74	0.031	0.032	0.032	0.031	0.040	0.028
75-79	0.022	0.032	0.023	0.008	0.030	0.019
80-84	0.022	0.031	0.027	-0.002	0.026	0.020
85+	-0.017	-0.015	-0.008	-0.031	-0.013	-0.019
Average	0.037	0.036	0.035	0.037	0.036	0.037

3.4 MORTALITY BY REGION

Figure 5 shows the log mortality rates by age separately for the three regions of China for all years 2004–2019. The corresponding average mortality improvement rates are shown in Table 3 (for males and females combined) and in Table 4 and Table 5 (by gender). In all three regions, mortality rates have decreased over the period 2004–2019 for all age groups except the age group 85+. The reductions in mortality rates were largest on average in East China, followed by Central China and West China.

Figure 5

MORTALITY BY REGION, 2004–2019

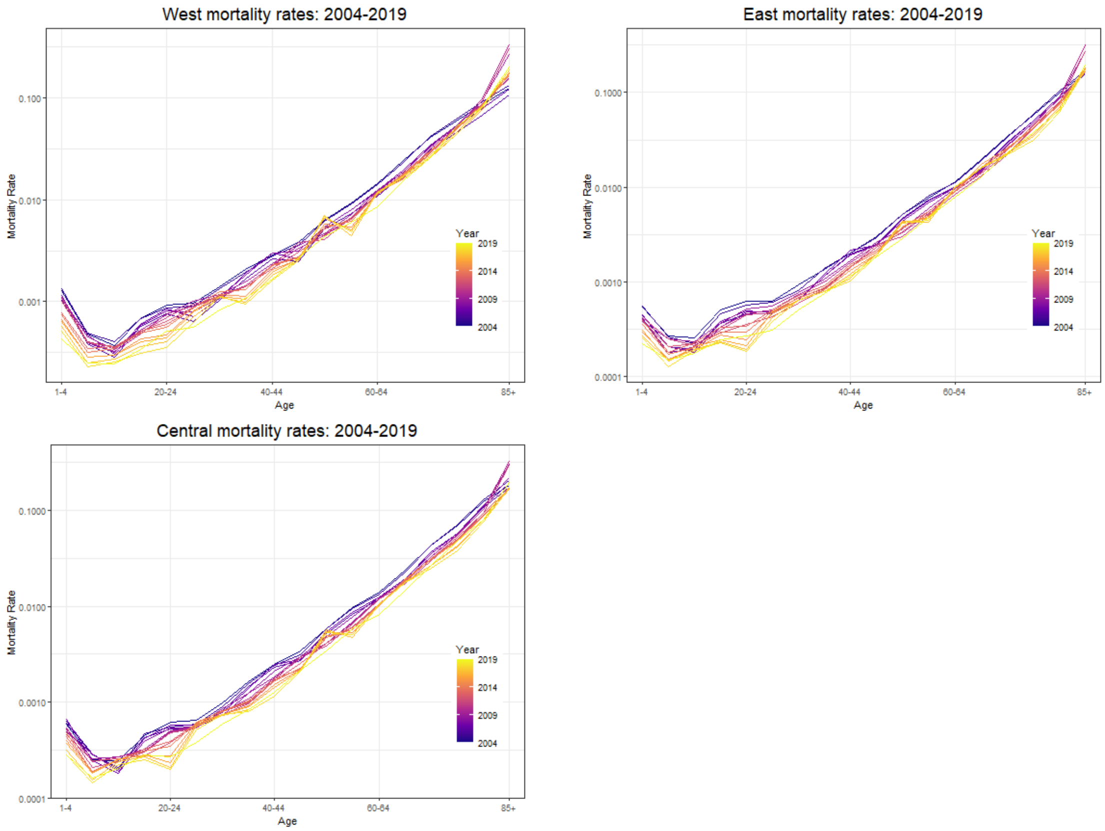
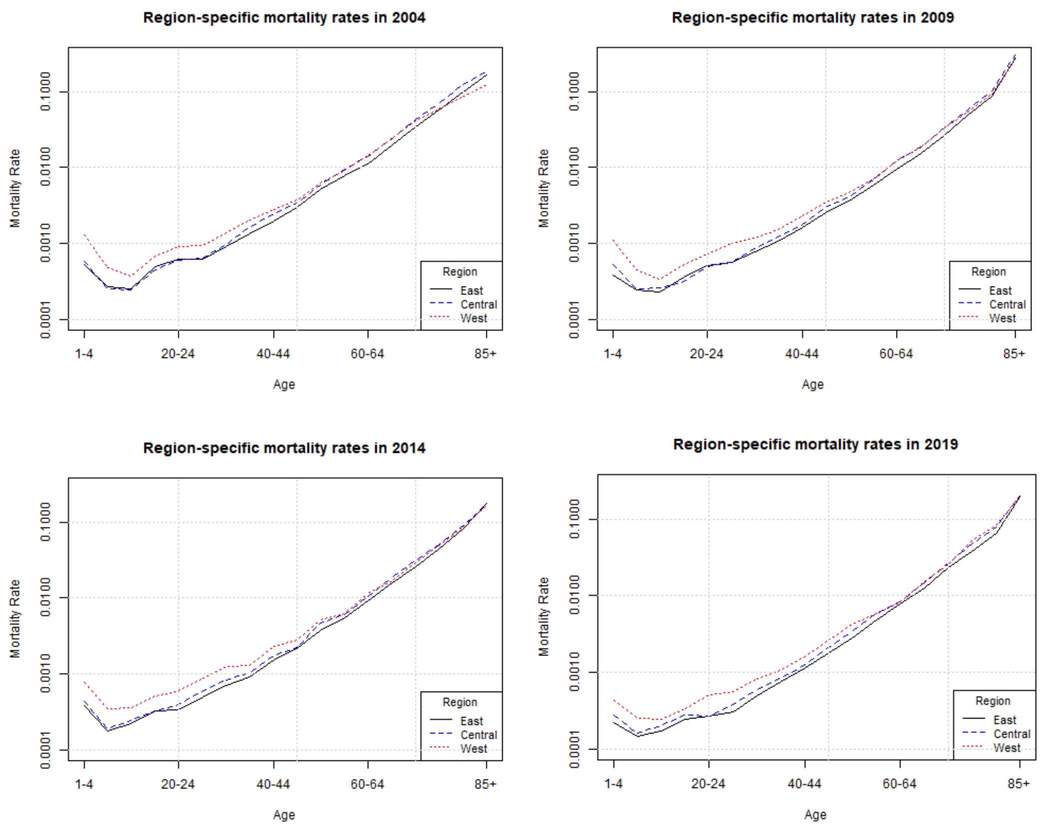


Figure 6 compares the log mortality rates by age in the three regions for the years 2004, 2009, 2014, and 2019. The graph shows that there are persistent regional differences between mortality rates. Mortality rates in West China are higher than mortality rates in Central and East China, especially at younger ages.

Figure 6
MORTALITY BY REGION, 2004, 2009, 2014 AND 2019



3.5 URBAN VS RURAL MORTALITY

Figure 7 shows the log mortality rates by age separately for urban and rural areas for all years 2004–2019. In 2004, mortality rates were lower in urban areas than in rural areas. The corresponding average mortality improvement rates are shown in Table 3 (for males and females combined) and in Table 4 and Table 5 (by gender). Over the period 2004–2019, urban and rural areas experienced similar average mortality improvement rates. As a result, there is a persistent gap between urban and rural mortality.

Figure 7
URBAN VS RURAL MORTALITY, 2004–2019

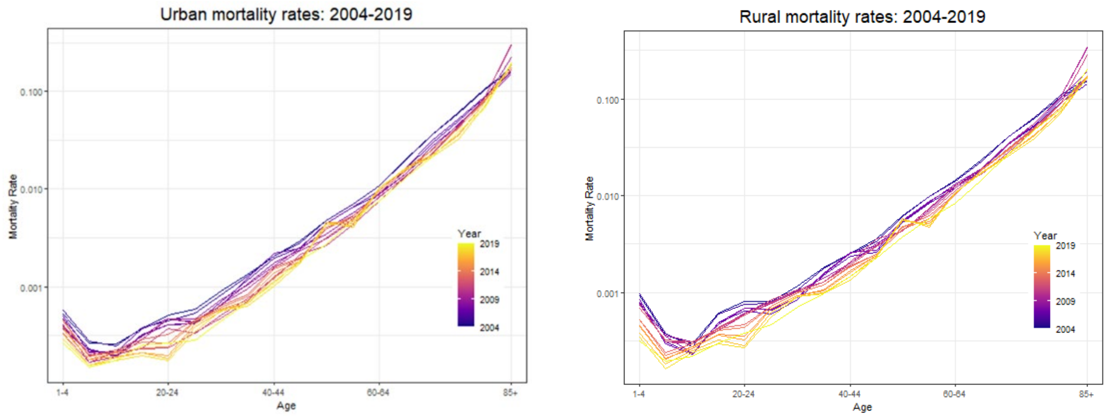
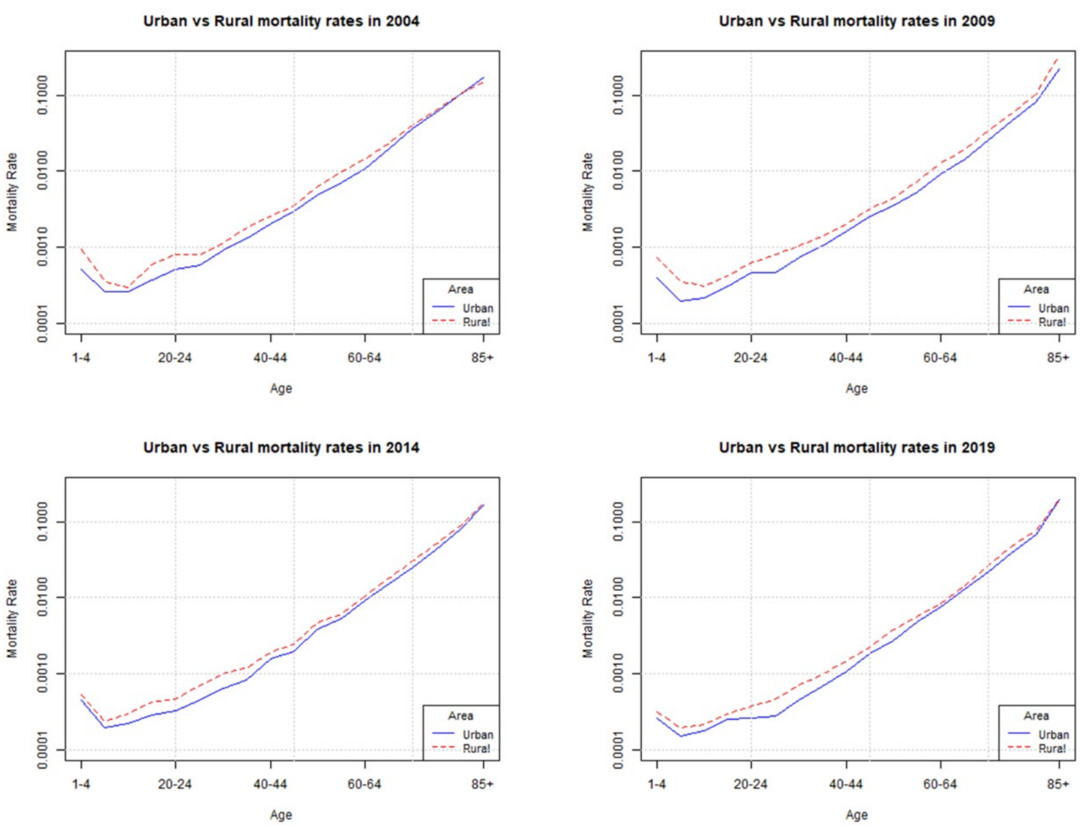


Figure 8 compares the log mortality rates by age in urban and rural areas in 2004, 2009, 2014, and 2019. The graphs confirm that there are persistent urban-rural differences in mortality rates. Mortality rates in rural China are higher than in urban China, especially at younger ages.

Figure 8
URBAN VS RURAL MORTALITY, 2004, 2009, 2014 AND 2019



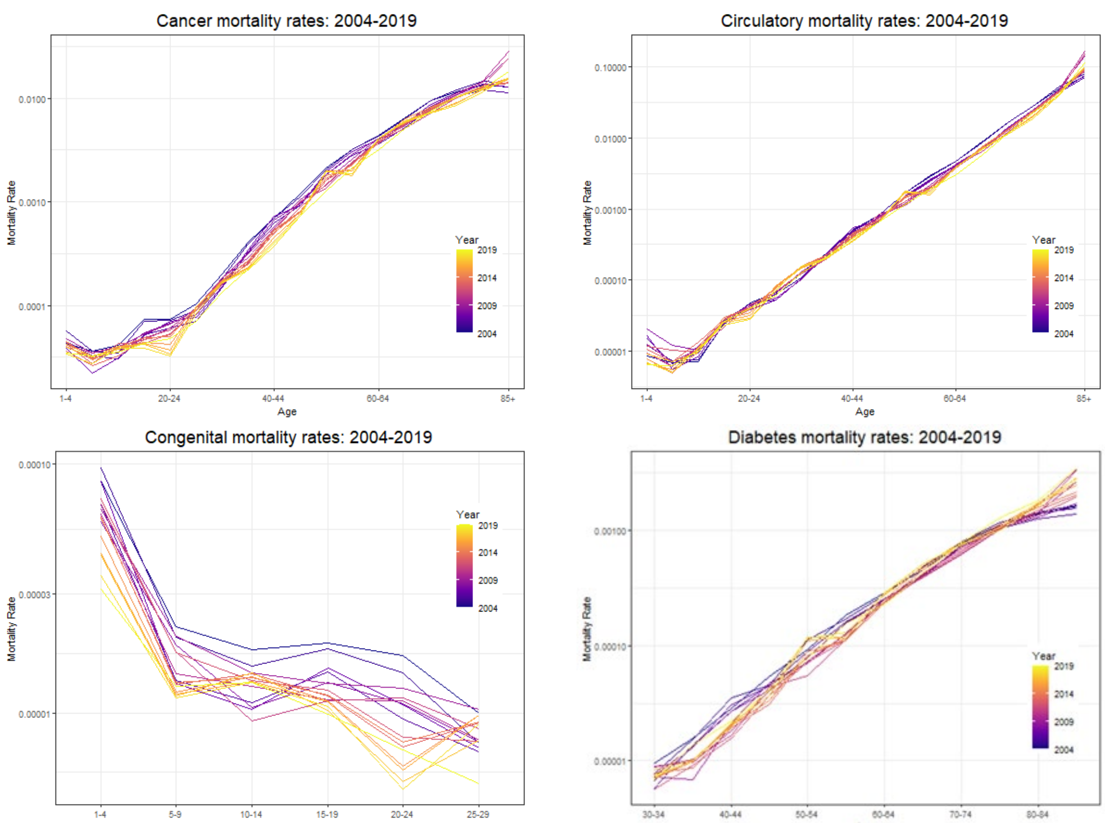
3.6 MORTALITY BY CAUSE OF DEATH

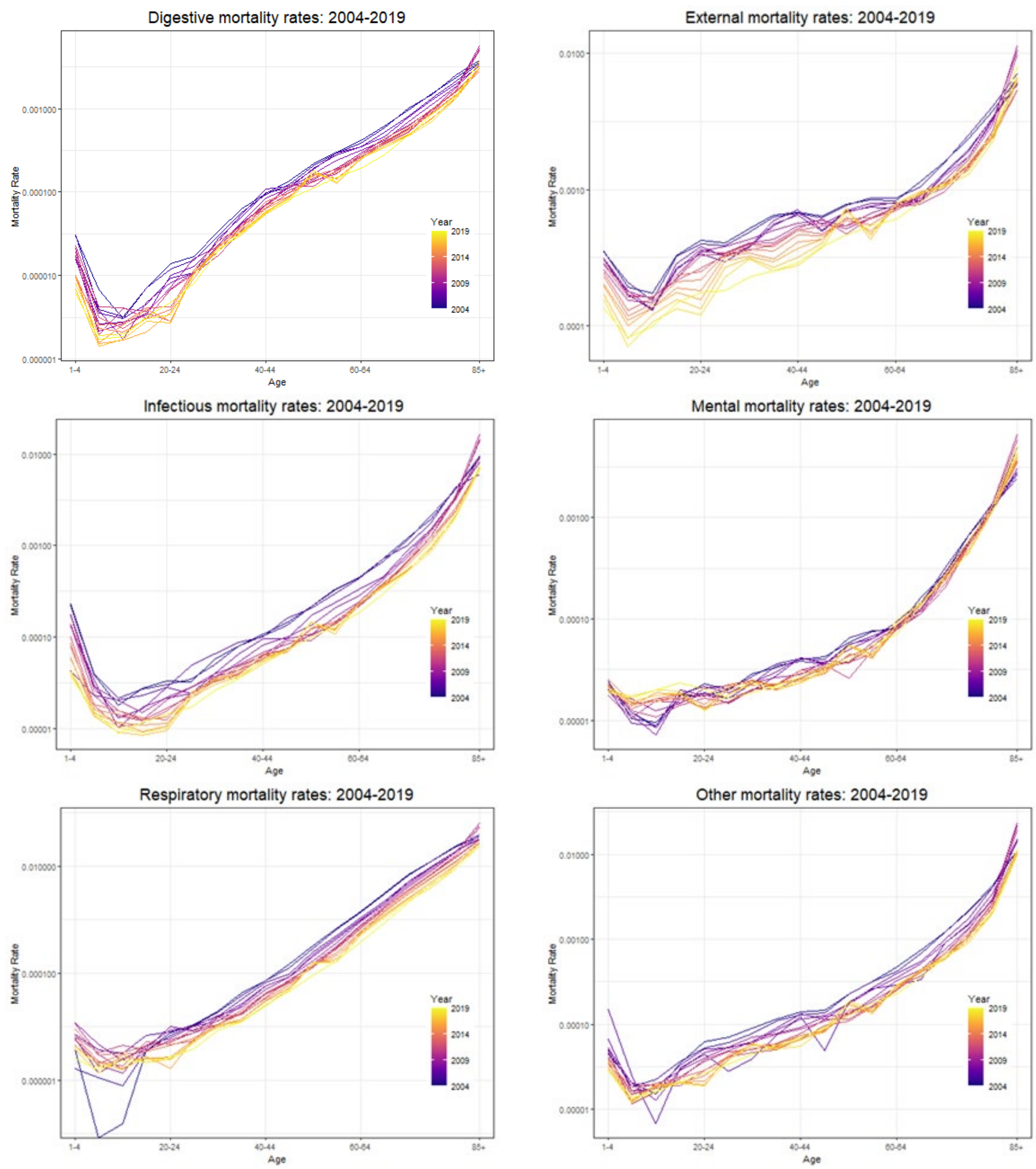
Finally, Figure 9 shows the log mortality by cause of death all years 2004–2019. The graphs show very different age patterns of different causes of death and different time trends. All mortality rates except congenital mortality increase by age. Nearly all causes of death have reduced over time. The reductions are especially large for congenital mortality, external mortality, and infectious mortality. Circulatory and diabetes mortality do not show clear improvements over time.

In terms of leading causes of death, circulatory is the #1 cause of death for people over age 65, and external deaths, which include accident, homicide, and suicide, is the #1 cause of death for people below age 35 (excluding age 0). Note that for congenital mortality, we only consider ages below 30, and for mortality due to diabetes, we only consider ages above 30. This is because congenital deaths generally happen before age 30, and deaths due to diabetes are rare for youngers ages below 30, particularly at the granular levels.

Figure 9

MORTALITY BY CAUSE OF DEATH, 2004–2019





Section 4: Mortality modeling and projection

In this section, we introduce the model used for mortality projection, as well as the forecast reconciliation method adopted to ensure consistency and coherence of forecasts across different series.

4.1 HYNDMAN AND ULLAH MODEL (2007)

The Lee-Carter model proposed in the early 1990s is undoubtedly one of the most influential mortality models in the new era of stochastic mortality modeling. It incorporates both age and time factors in a single model of the form:

$$\log(m_{x,t}) = a_x + b_x\kappa_t,$$

where $m_{x,t}$ is the central mortality rate at age *x* and time *t*, calculated by the ratio of death counts to population exposure. a_x and b_x represent age-related effects, and κ_t represents time-related effect.

Hyndman and Ullah (2007) proposed a generalized version of the Lee-Carter model to allow for smoothness in the age dimension via nonparametric techniques. More importantly, the model is defined as follows:

$$\log(m_{x,t}) = \mu_x + \sum_{k=1}^{K} \beta_{t,k}\, \phi_k(x),$$

where μ_x measures the location of log mortality rates. $\phi_k(x)$ is a set of orthonormal basis functions and $\beta_{t,k}$ are the corresponding coefficients for *k*=1, 2, … , *K*. To project future mortality levels, $\beta_{t,k}$ needs to be projected first via ARIMA time series models.

The general form of ARIMA models can be expressed as follows:

$$(1 - \eta_1 B - \cdots - \eta_p B^p)y_t = c + (1 + \theta_1 B + \cdots + \theta_q B^q)\varepsilon_t,$$

where *B* is the backward operator such that $(1 - B)y_t = y_t - y_{t-1}$. *p*, *d*, and *q* denote the order of the AR model, the order of differencing, and the order of the MA model, respectively. ε_t is the error term, and η and θ are coefficients to be estimated.

In this project, optimal ARIMA models are selected based on the Akaike information criterion (AIC). We set the number of orthonormal basis functions to be 2 (*i.e.,* the value of *K*). The mortality projection is implemented via the R package '*demography*'.

4.2 FORECAST RECONCILIATION

Once predictions on mortality rates are generated via the Hyndman and Ullah model (2007) described in Section 4.1, we adopt a forecast reconciliation approach to ensure consistency and coherence of forecasts across different mortality series[5].

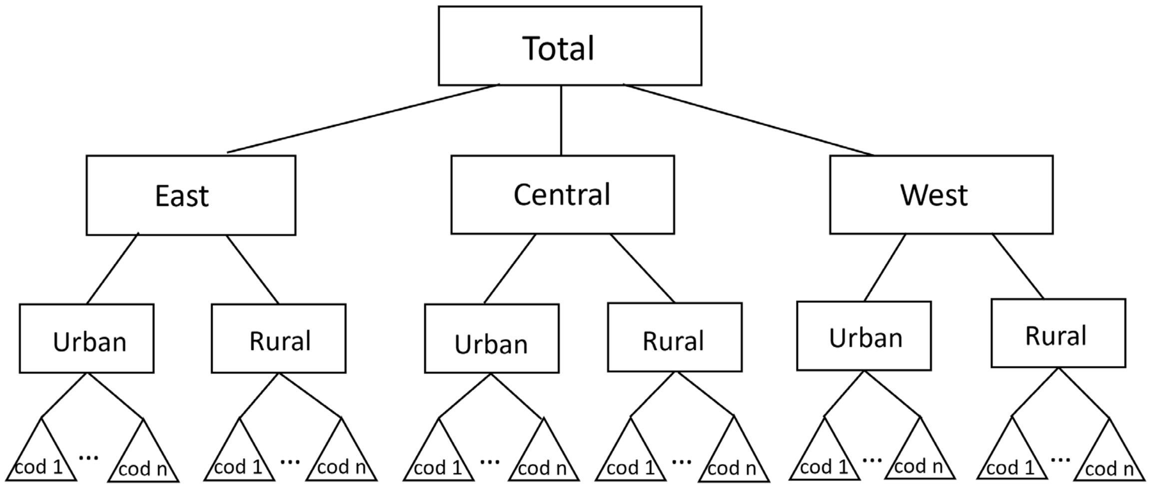
Naturally, region-area-cause-specific mortality rates follow a hierarchical setting, as illustrated in Figure 10. At the top level, we have the total mortality rate. Then we divide the population into three broader regions, namely, East, Central, and West, to form region-specific mortality rates. In the next level down, we further divide the population into urban and rural areas. Finally, at the bottom level, cause-of-death information is considered, and we have the most granular-level data on region-area-cause-specific mortality rates. For each time series in the hierarchy, we model and forecast the mortality rates using separate models. Therefore, it is very unlikely for these forecasts to add up (as a weighted average) in the same way as specified in the underlying hierarchy structure. We need to reconcile these forecasts so that they fulfill certain aggregation constraints.

Forecast reconciliation is a cutting-edge methodology that eliminates the discrepancy resulting from conflicting forecasts. By incorporating information from all levels, reconciliation methods also improve overall forecast accuracy. It is a useful tool that has been applied in various fields, including mortality forecasting.

[5] For more details of this approach, please refer to Li and Tang (2019), Li et al. (2019), and Li and Hyndman (2021).

Figure 10

HIERARCHICAL TREE FOR MORTALITY RATE



Based on the hierarchical structure illustrated in Figure 10, at any given time *t* and age *x*, we have the following aggregation constraints

$$\frac{E_{\text{East}}}{E_{\text{Total}}} \times m^{\text{East}} + \frac{E_{\text{Central}}}{E_{\text{Total}}} \times m^{\text{Central}} + \frac{E_{\text{West}}}{E_{\text{Total}}} \times m^{\text{West}} = m^{\text{Total}},$$

$$\frac{E_{\text{region,urban}}}{E_{\text{region}}} \times m^{\text{region,urban}} + \frac{E_{\text{region,rural}}}{E_{\text{rural}}} \times m^{\text{region,rural}} = m^{\text{region}}, \text{for region} = \text{East, Central, West}$$

$$\sum_{i=1}^{n} m_{\text{cod } i}^{\text{region,area}} = m^{\text{region,area}}, \text{for region} = \text{East, Central, West and area} = \text{urban, rural}$$

In this project, we employ the approach proposed by Li and Hyndman (2021) and Wickramasuriya et al. (2019). For simplicity, we illustrate the methodology based on only two causes of death at the bottom level. We define the following notation

- Let $y = (m^{\text{Total}}, m^{\text{East}}, m^{\text{Central}}, m^{\text{West}}, m^{\text{East,urban}}, m^{\text{East,rural}}, m^{\text{Central,urban}}, m^{\text{Central,rural}}, m^{\text{West,urban}}, m^{\text{West,rural}}, m_{\text{cod 1}}^{\text{East,urban}}, m_{\text{cod 2}}^{\text{East,urban}}, m_{\text{cod 1}}^{\text{East,rural}}, m_{\text{cod 2}}^{\text{East,rural}}, m_{\text{cod 1}}^{\text{Central,urban}}, m_{\text{cod 2}}^{\text{Central,urban}}, m_{\text{cod 1}}^{\text{Central,rural}}, m_{\text{cod 2}}^{\text{Central,rural}}, m_{\text{cod 1}}^{\text{West,urban}}, m_{\text{cod 2}}^{\text{West,urban}}, m_{\text{cod 1}}^{\text{West,rural}}, m_{\text{cod 2}}^{\text{West,rural}})$ be a vector that contains observations of all series in the hierarchy.
- Let $x = (m_{\text{cod 1}}^{\text{East,urban}}, m_{\text{cod 2}}^{\text{East,urban}}, m_{\text{cod 1}}^{\text{East,rural}}, m_{\text{cod 2}}^{\text{East,rural}}, m_{\text{cod 1}}^{\text{Central,urban}}, m_{\text{cod 2}}^{\text{Central,urban}}, m_{\text{cod 1}}^{\text{Central,rural}}, m_{\text{cod 2}}^{\text{Central,rural}}, m_{\text{cod 1}}^{\text{West,urban}}, m_{\text{cod 2}}^{\text{West,urban}}, m_{\text{cod 1}}^{\text{West,rural}}, m_{\text{cod 2}}^{\text{West,rural}})$ be a vector that contains observations at the bottom level only.

We can then link these two vectors by the equation

$$y = Sx,$$

where S is a summing matrix of dimension 22×20, which aggregates region-area-cause-specific mortality rates to the total level. As the aggregation rules of mortality rates involve weighted summation, as shown previously, we adopt the method by Li and Hyndman (2021) and use the 2015–2019 average weights to construct S matrix for forecast reconciliation.

Let $\hat{y}_h$ be a vector of independently obtained h-step-ahead forecasts of all series in the hierarchy, and $\hat{b}_h$ be a vector of independently obtained h-step-ahead forecasts of bottom-level series only. According to Wickramasuriya et al. (2019), the trace minimization (MinT) reconciliation methods can be expressed as

$$\tilde{y}_h = SP\hat{y}_h,$$

where $\tilde{y}_h$ is the reconciled forecasts, and P is a matrix of dimension 20×22, and it is given by

$$P = (S'W_h^{-1}S)^{-1}S'W_h^{-1},$$

where W_h is a variance-covariance matrix of the h-step-ahead in-sample forecast errors.

As proved by Wickramasuriya et al. (2019) and the references therein, MinT reconciliation produces unbiased forecasts and leads to improved overall forecast accuracy. Particularly in our research, at the granular level, region-area-cause-specific mortality rates can be very volatile and therefore challenging to forecast[6]. The MinT reconciliation method tackles this problem by "borrowing" information from higher-level forecasts.

4.3 MORTALITY PROJECTIONS: 2020–2029

In this section, we present and visualize mortality projections for 2020–2029 based on the data described in Section 3 and methodologies introduced in Sections 4.1 and 4.2 for both males and females. We produce mortality forecasts across regions, urban and rural areas, and causes of deaths.

MALE MORTALITY PROJECTIONS

As shown in Table 6, we find that the average improvement rate for males is expected to decrease by approximately 0.7% over the next 10 years. We also find that the geographical gap in mortality rate between East and West China is likely to continue. On the other hand, we predict that the rural and urban mortality gap will become narrower over time.

For male mortality rates, we plot the total and regional-level forecasts in Figure 11 and region-area specific forecasts in Figure 12. We also plot the region-area-cause-specific mortality forecasts in Figure 13.

Table 6
FORECASTED AVERAGE MORTALITY IMPROVEMENT RATES, MALES, 2020–2029

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	0.038	0.018	0.038	0.032	0.025	0.032	0.030	0.022	0.063	0.052
5-9	0.025	0.026	0.029	0.029	0.024	0.015	0.017	0.018	0.036	0.031
10-14	0.028	0.030	0.040	0.038	0.029	0.020	0.022	0.019	0.030	0.027
15-19	0.034	0.045	0.053	0.051	0.040	0.024	0.027	0.021	0.035	0.031
20-24	0.035	0.047	0.053	0.051	0.044	0.023	0.027	0.016	0.035	0.030
25-29	0.029	0.036	0.039	0.038	0.034	0.021	0.024	0.015	0.030	0.026
30-34	0.024	0.029	0.027	0.028	0.028	0.020	0.022	0.016	0.027	0.024
35-39	0.023	0.035	0.025	0.028	0.029	0.020	0.022	0.018	0.023	0.021
40-44	0.023	0.053	0.026	0.032	0.028	0.020	0.022	0.015	0.018	0.017
45-49	0.020	0.046	0.024	0.030	0.029	0.019	0.022	0.006	0.012	0.010
50-54	0.015	0.030	0.016	0.020	0.015	0.015	0.015	0.005	0.009	0.008

[6] A large proportion of the unreconciled forecasts at the bottom level shows no mortality improvement over 2020-2029. However, at the top level or middle level, mortality improvement is excepted based on the Hyndman and Ullah model.

55-59	0.012	0.011	0.010	0.010	0.009	0.017	0.015	0.008	0.011	0.010
60-64	0.013	0.003	0.011	0.008	0.007	0.022	0.018	0.008	0.015	0.013
65-69	0.017	0.012	0.015	0.014	0.014	0.025	0.022	0.009	0.016	0.013
70-74	0.020	0.025	0.020	0.021	0.024	0.027	0.026	0.008	0.014	0.012
75-79	0.021	0.026	0.024	0.024	0.026	0.025	0.025	0.006	0.014	0.011
80-84	0.019	0.014	0.025	0.021	0.014	0.028	0.025	0.000	0.010	0.006
85+	0.014	0.001	0.021	0.013	0.007	0.031	0.024	-0.005	0.003	0.000
Average	0.023	0.027	0.027	0.027	0.024	0.022	0.022	0.011	0.022	0.019

Figure 11

TOTAL AND REGIONAL MORTALITY FORECASTS, MALES, 2020–2029

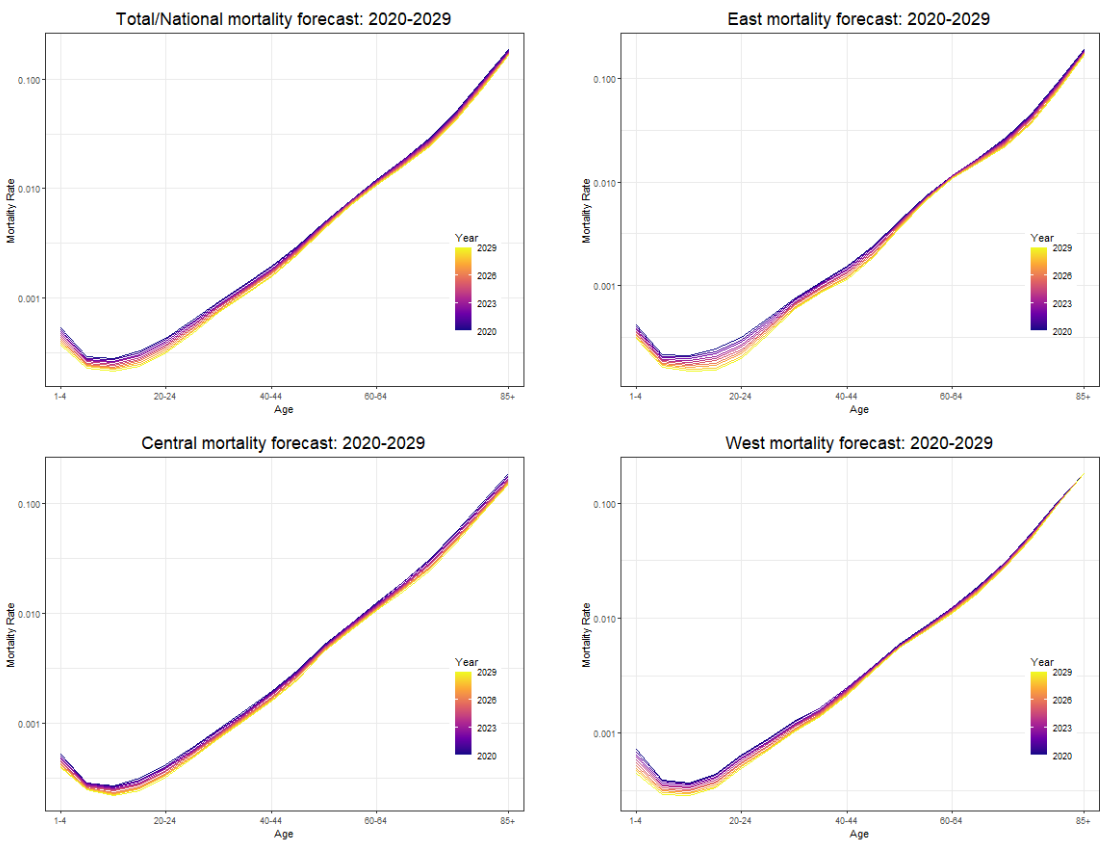


Figure 12

REGION-AREA SPECIFIC MORTALITY FORECASTS, MALES, 2020–2029

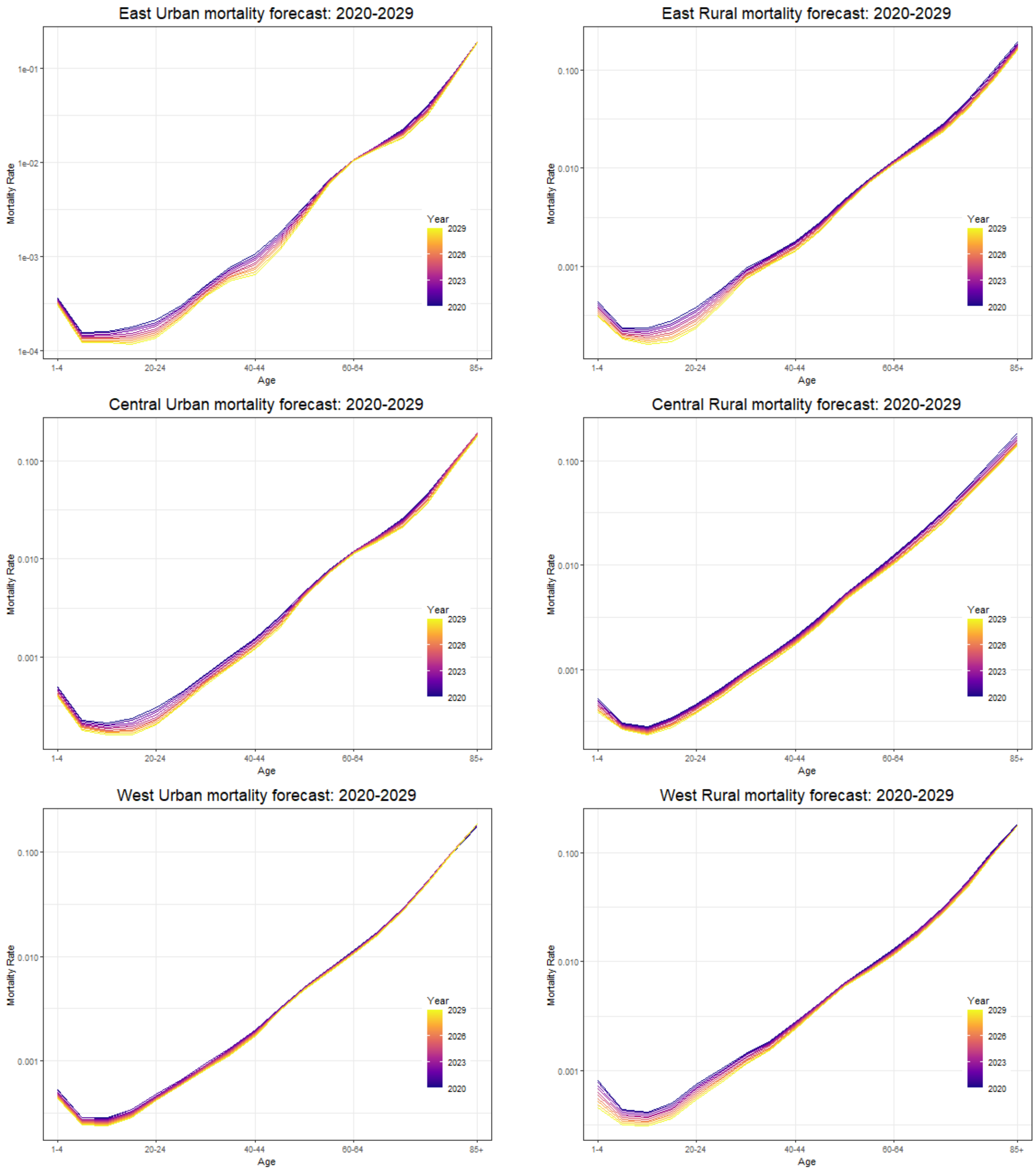
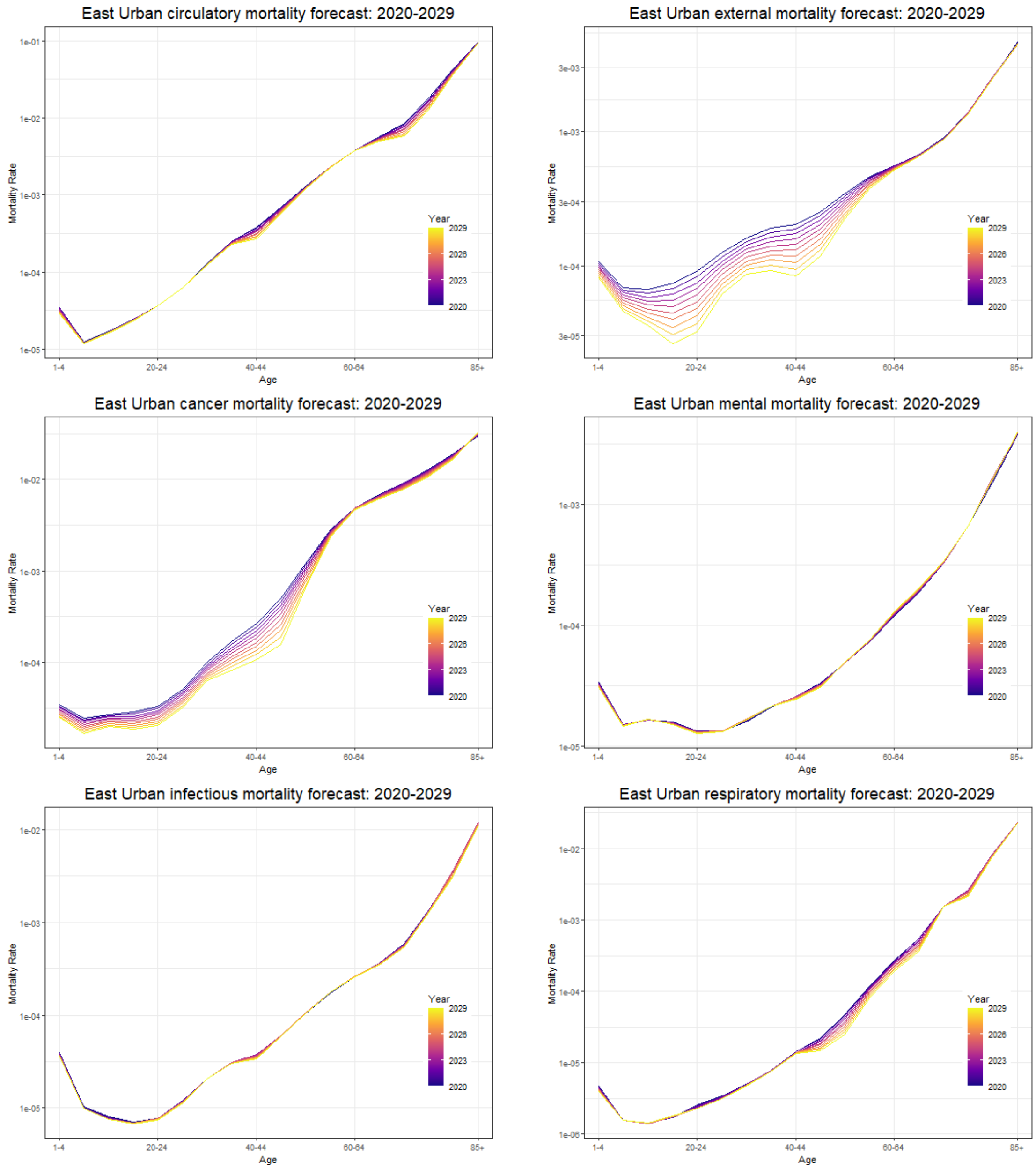
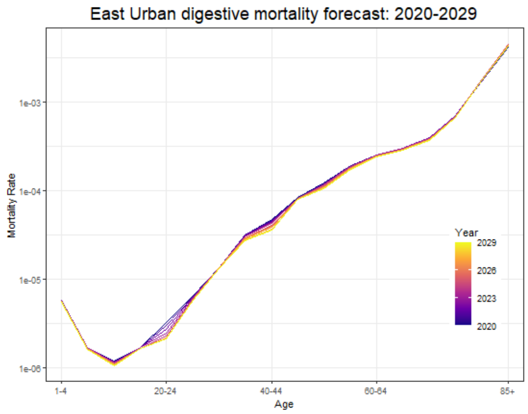
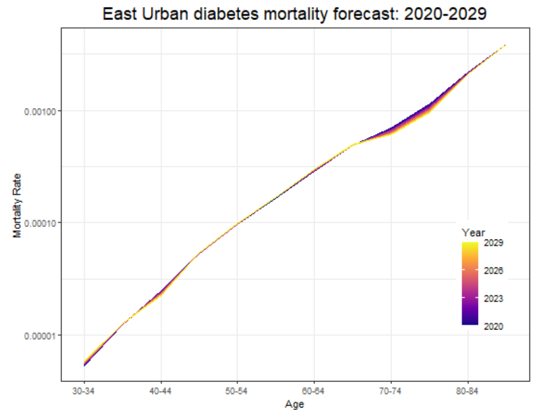


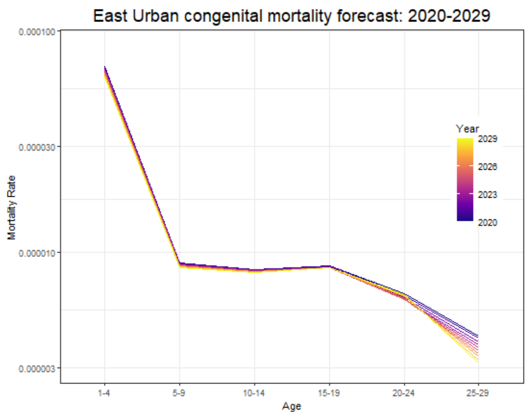
Figure 13

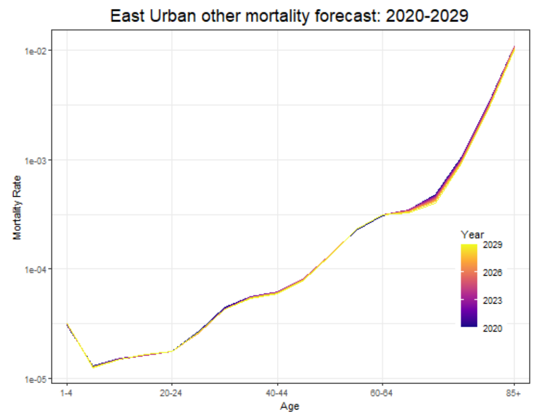
REGION-AREA-CAUSE-SPECIFIC MORTALITY FORECASTS, MALES, 2020–2029

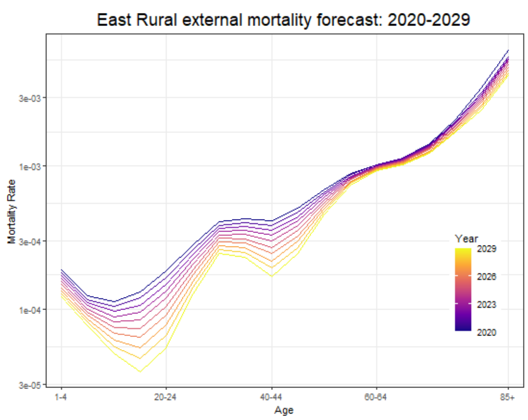


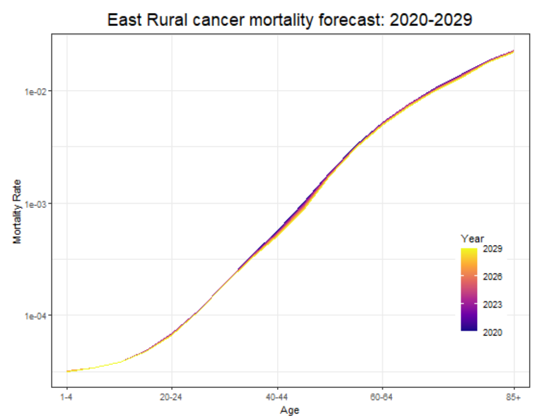

East Urban digestive mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

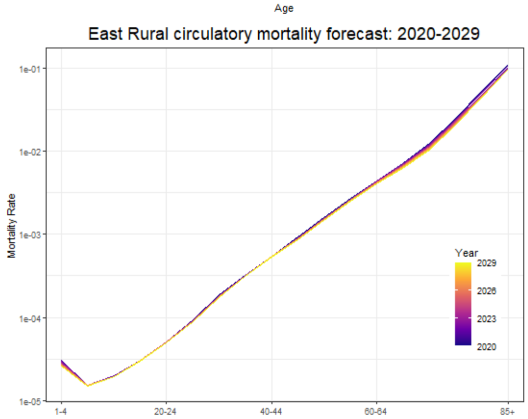

East Urban diabetes mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

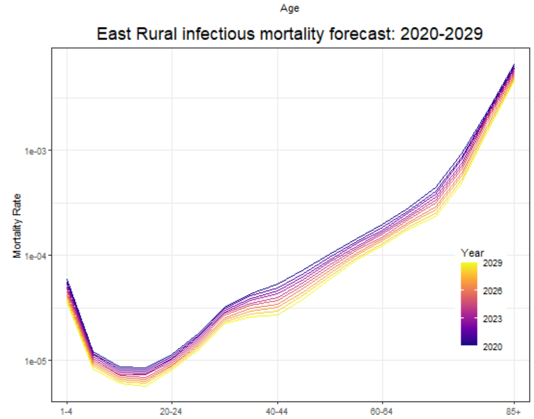

East Urban congenital mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Urban other mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

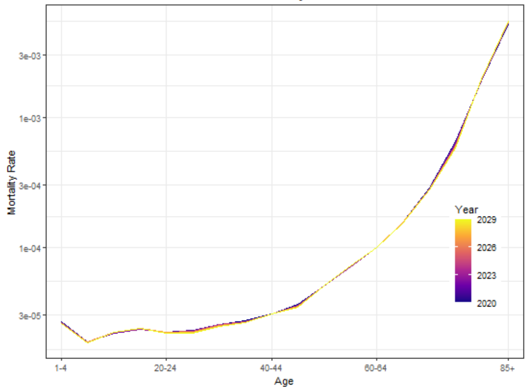

East Rural external mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Rural cancer mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

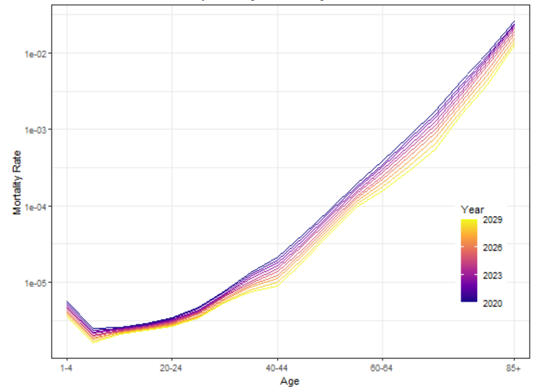

East Rural circulatory mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Rural infectious mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

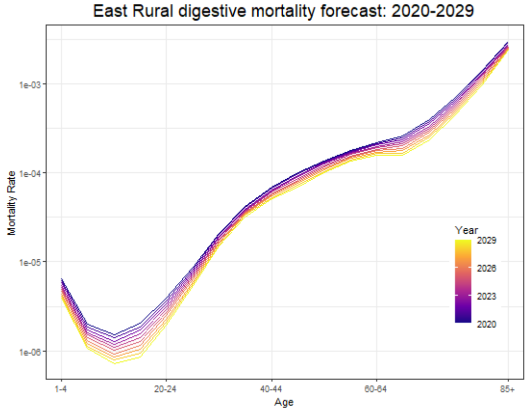
East Rural mental mortality forecast: 2020-2029



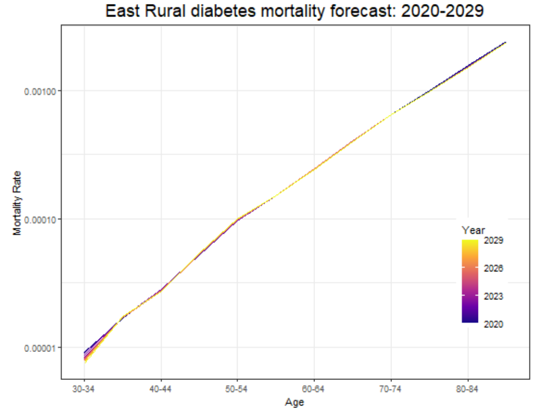
East Rural respiratory mortality forecast: 2020-2029



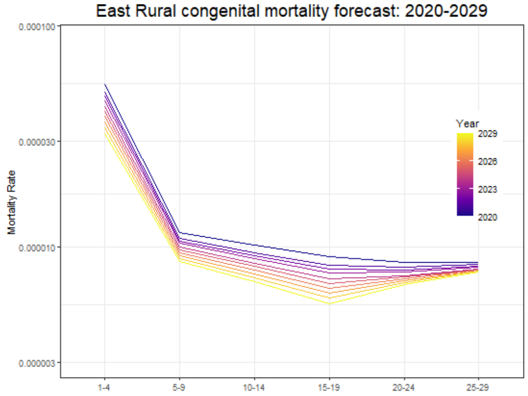
East Rural digestive mortality forecast: 2020-2029



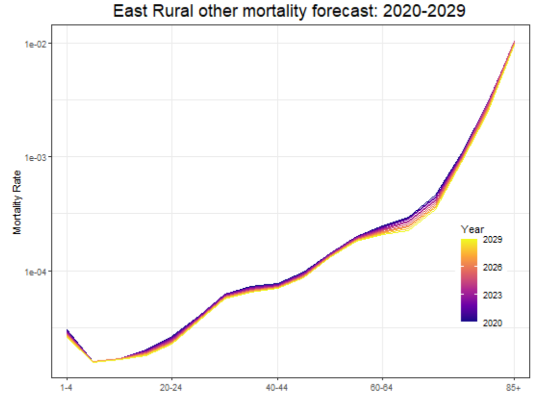
East Rural diabetes mortality forecast: 2020-2029



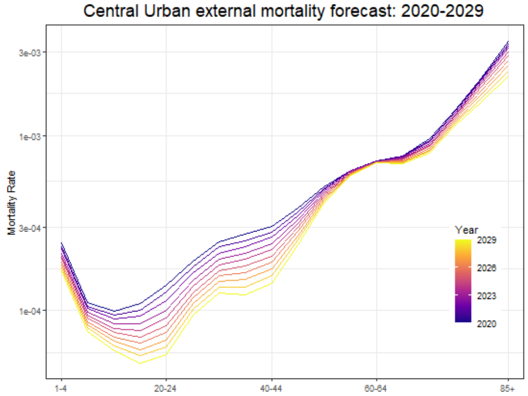
East Rural congenital mortality forecast: 2020-2029



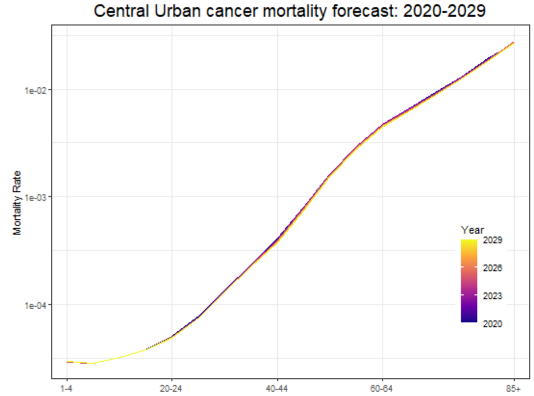
East Rural other mortality forecast: 2020-2029



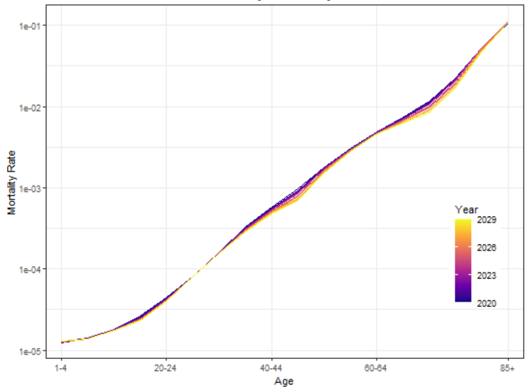
Central Urban external mortality forecast: 2020-2029



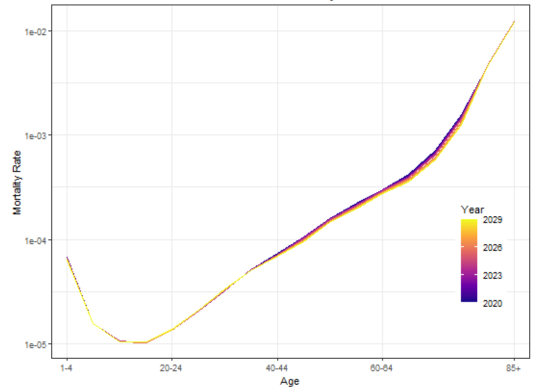
Central Urban cancer mortality forecast: 2020-2029



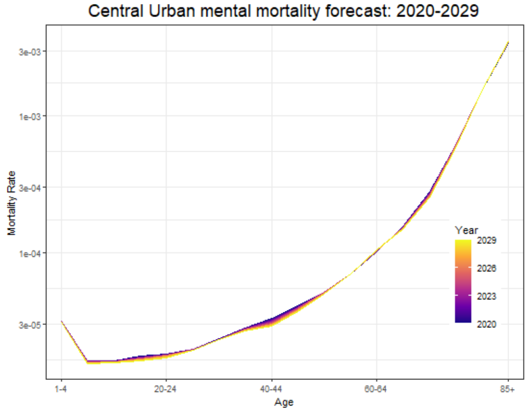
Central Urban circulatory mortality forecast: 2020-2029



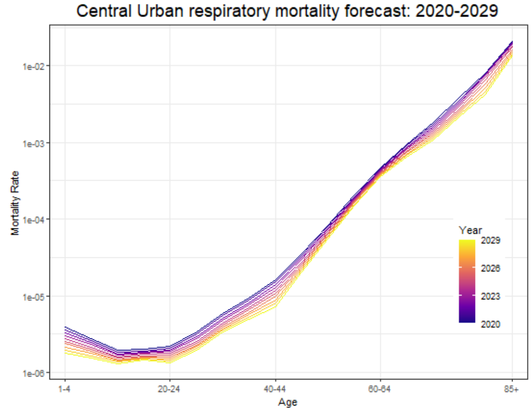
Central Urban infectious mortality forecast: 2020-2029



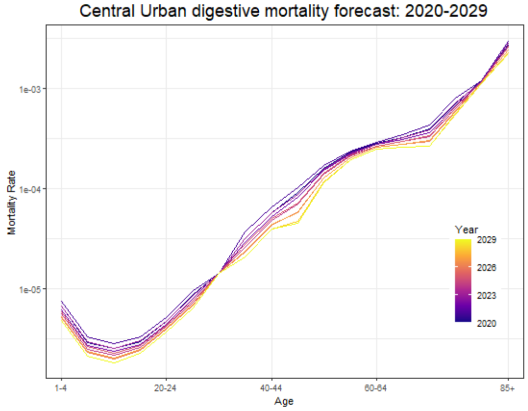
Central Urban mental mortality forecast: 2020-2029



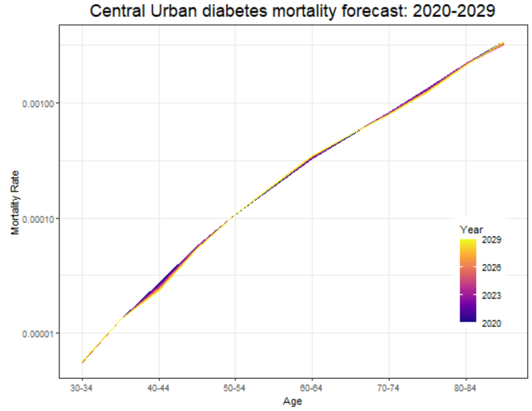
Central Urban respiratory mortality forecast: 2020-2029



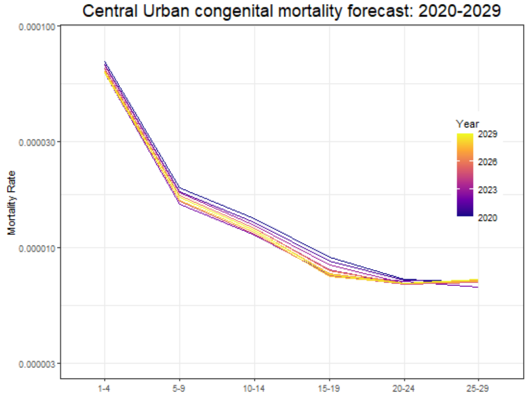
Central Urban digestive mortality forecast: 2020-2029



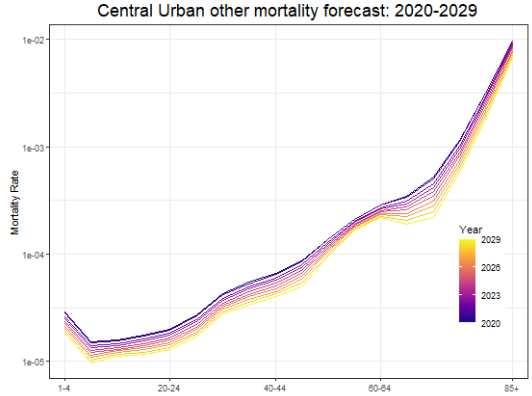
Central Urban diabetes mortality forecast: 2020-2029



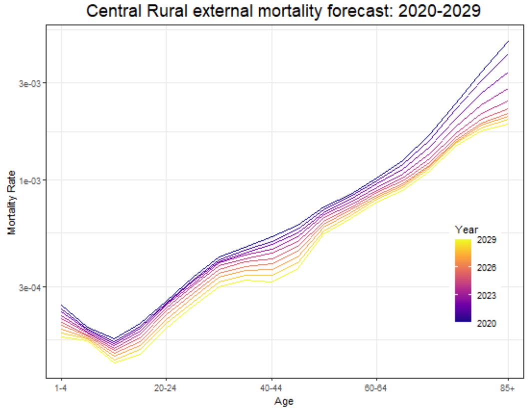
Central Urban congenital mortality forecast: 2020-2029



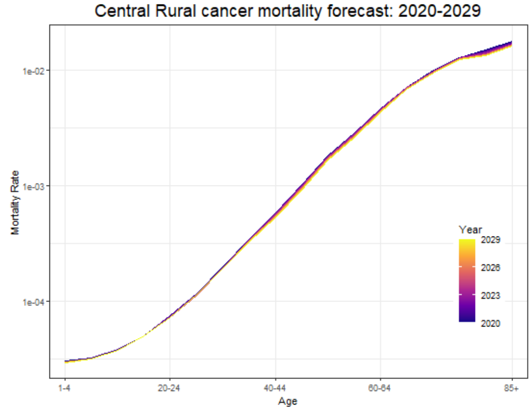
Central Urban other mortality forecast: 2020-2029



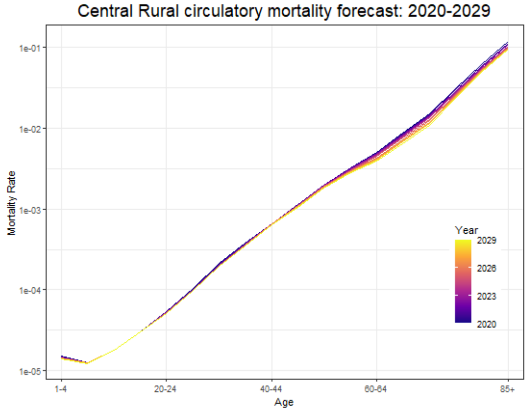
Central Rural external mortality forecast: 2020-2029



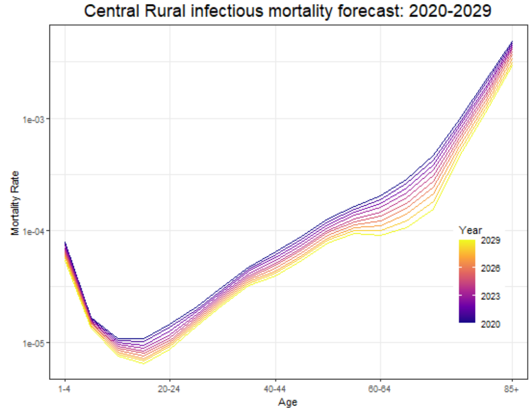
Central Rural cancer mortality forecast: 2020-2029



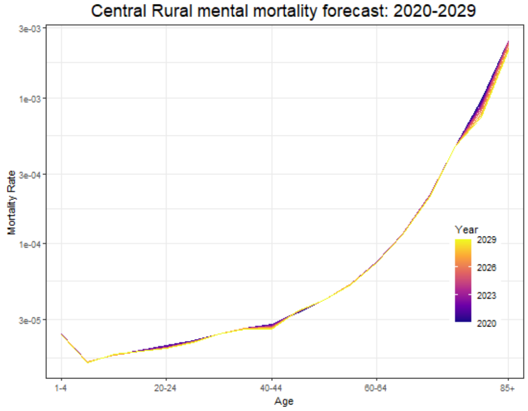
Central Rural circulatory mortality forecast: 2020-2029



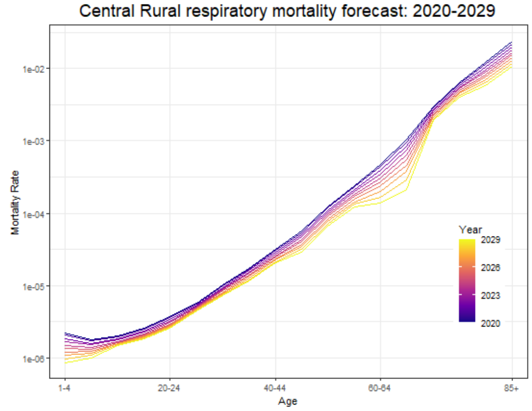
Central Rural infectious mortality forecast: 2020-2029



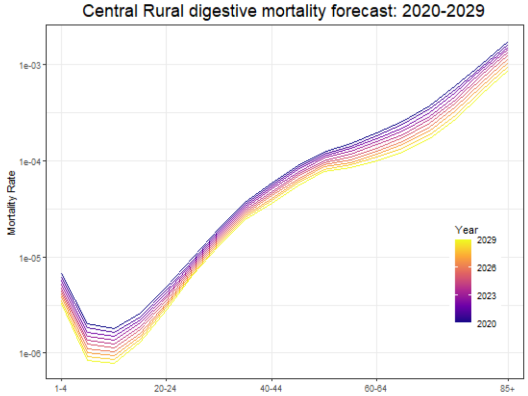
Central Rural mental mortality forecast: 2020-2029



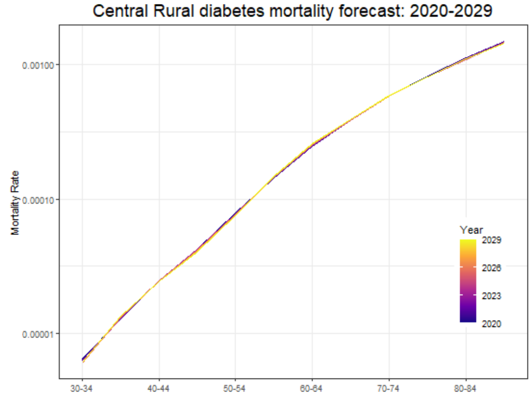
Central Rural respiratory mortality forecast: 2020-2029

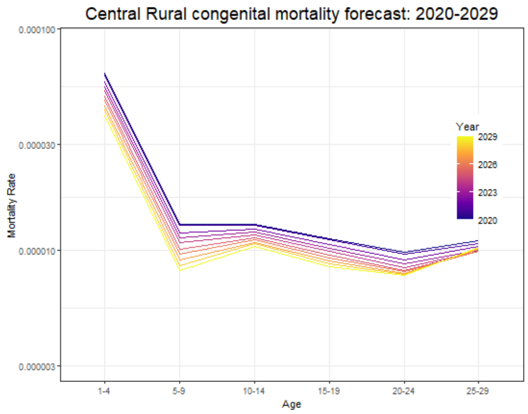


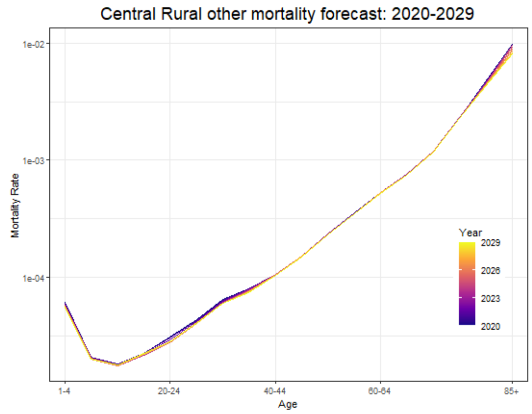
Central Rural digestive mortality forecast: 2020-2029

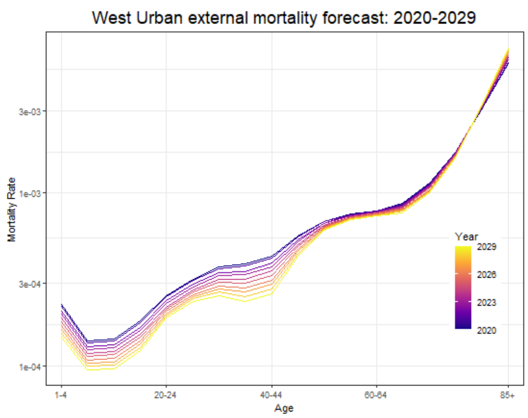


Central Rural diabetes mortality forecast: 2020-2029




Central Rural congenital mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


Central Rural other mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Urban external mortality forecast: 2020-2029
Mortality Rate
Age
Year
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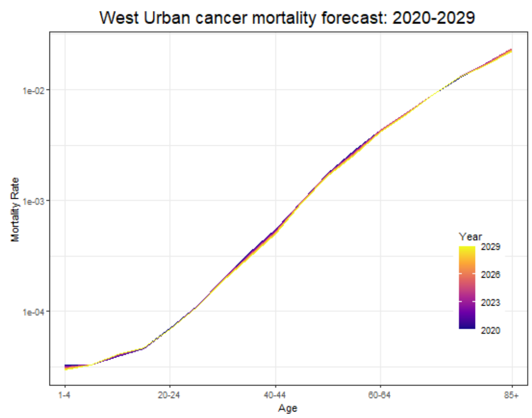
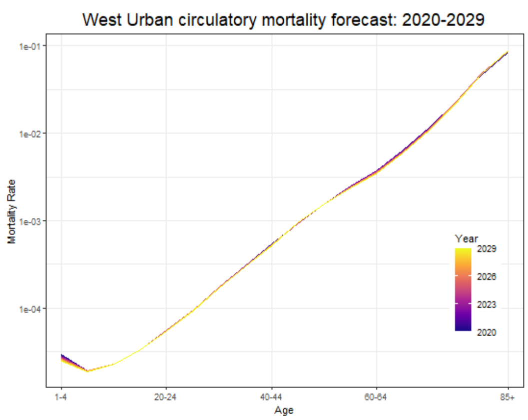
2026
2023
2020


West Urban cancer mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Urban circulatory mortality forecast: 2020-2029
Mortality Rate
Age
Year
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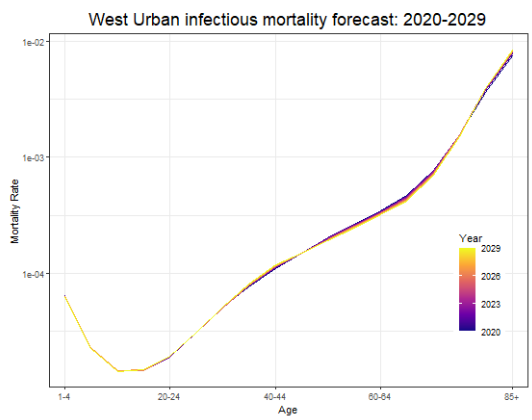
2026
2023
2020


West Urban infectious mortality forecast: 2020-2029
Mortality Rate
Age
Year
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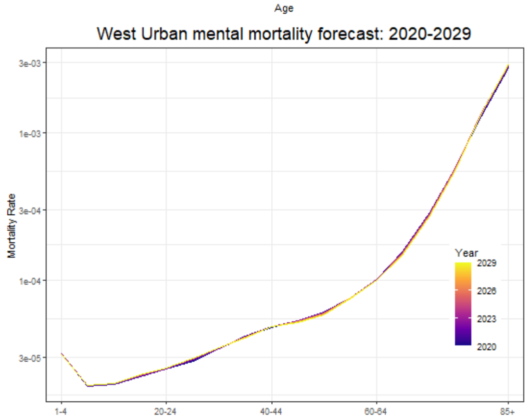
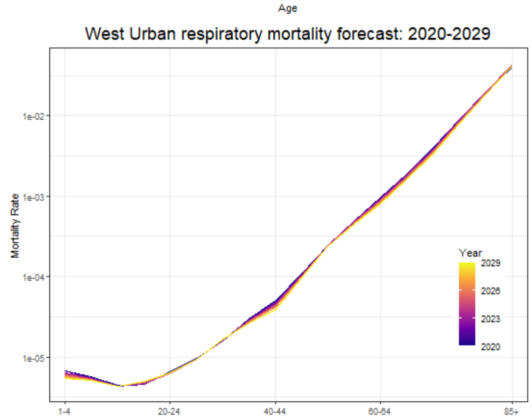
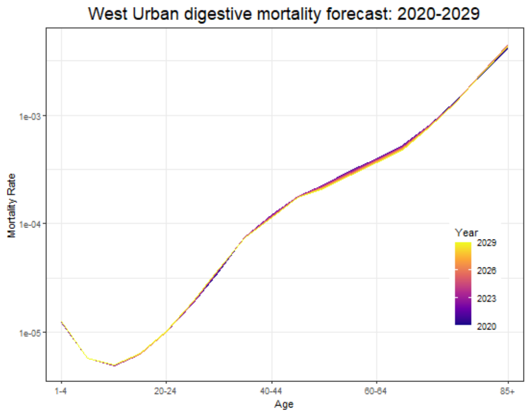
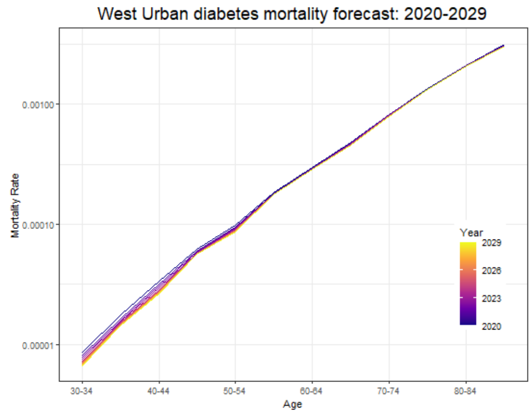
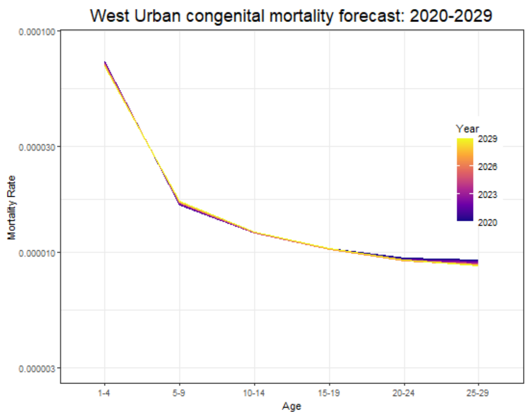
2026
2023
2020


West Urban mental mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Urban respiratory mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Urban digestive mortality forecast: 2020-2029
Mortality Rate
1e-03
1e-04
1e-05
Age
1-4
20-24
40-44
60-64
85+
Year
2029
2026
2023
2020


West Urban diabetes mortality forecast: 2020-2029
Mortality Rate
0.00100
0.00010
0.00001
Age
30-34
40-44
50-54
60-64
70-74
80-84
Year
2029
2026
2023
2020


West Urban congenital mortality forecast: 2020-2029
Mortality Rate
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0.000030
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0.000003
Age
1-4
5-9
10-14
15-19
20-24
25-29
Year
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2026
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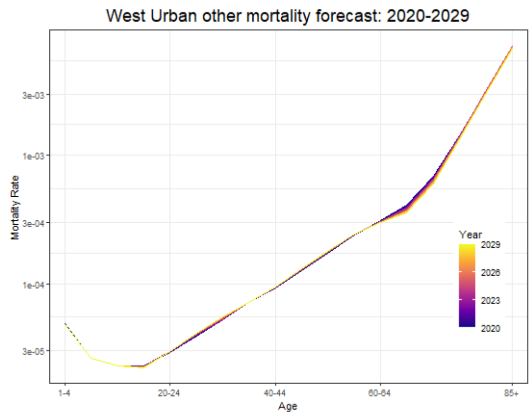
2020


West Urban other mortality forecast: 2020-2029
Mortality Rate
3e-03
1e-03
3e-04
1e-04
3e-05
Age
1-4
20-24
40-44
60-64
85+
Year
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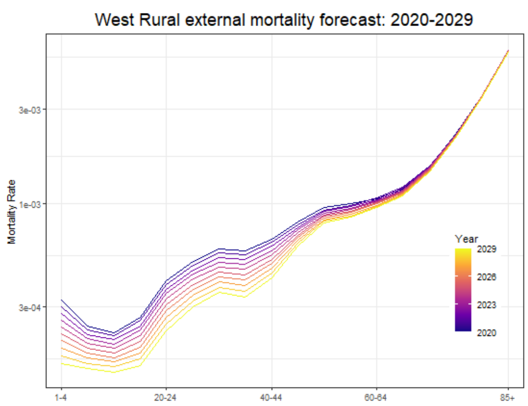
2026
2023
2020


West Rural external mortality forecast: 2020-2029
Mortality Rate
3e-03
1e-03
3e-04
Age
1-4
20-24
40-44
60-64
85+
Year
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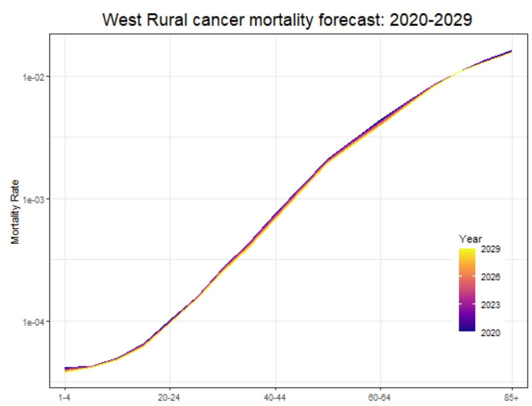
2026
2023
2020


West Rural cancer mortality forecast: 2020-2029
Mortality Rate
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1e-03
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Age
1-4
20-24
40-44
60-64
85+
Year
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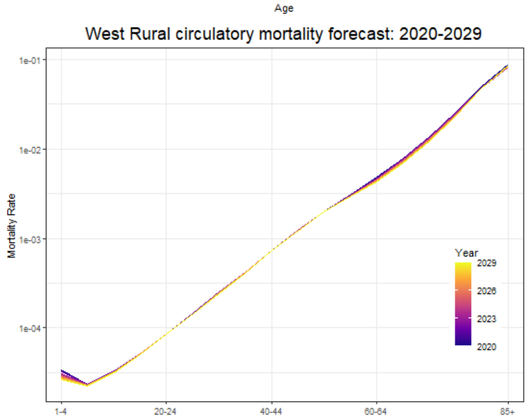
2026
2023
2020


West Rural circulatory mortality forecast: 2020-2029
Mortality Rate
1e-01
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1e-03
1e-04
Age
1-4
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40-44
60-64
85+
Year
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2023
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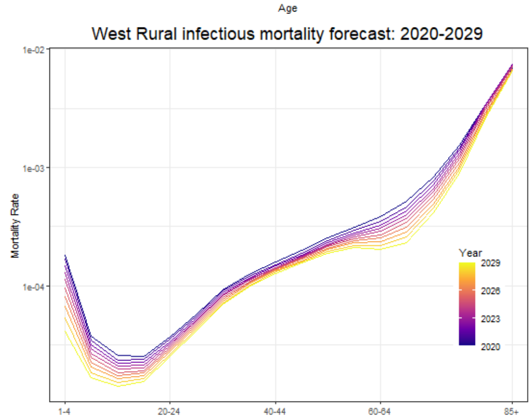
West Rural infectious mortality forecast: 2020-2029
Mortality Rate
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Age
1-4
20-24
40-44
60-64
85+
Year
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2026
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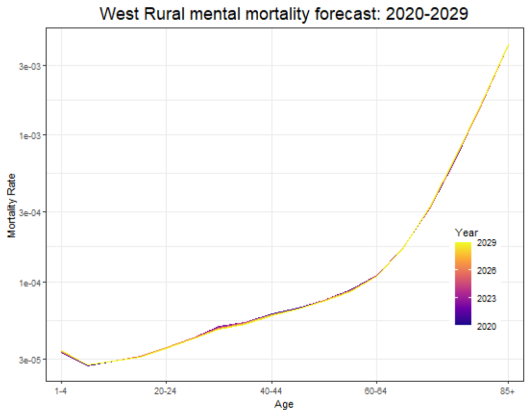
2020


West Rural mental mortality forecast: 2020-2029
Mortality Rate
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1e-03
3e-04
1e-04
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1-4
20-24
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60-64
85+
Age
Year
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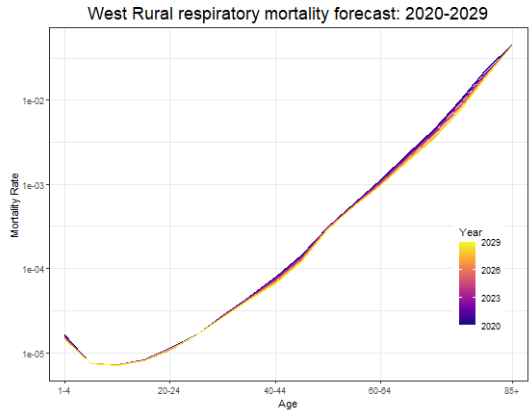
2020


West Rural respiratory mortality forecast: 2020-2029
Mortality Rate
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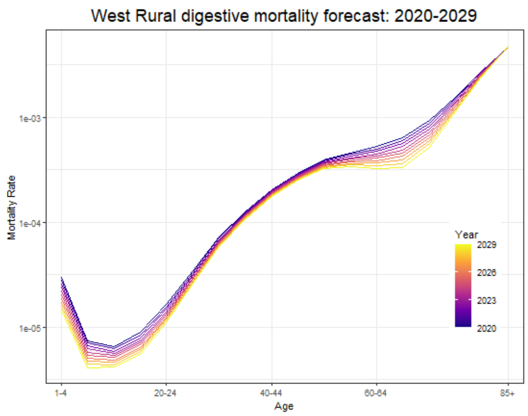
1e-03
1e-04
1e-05
1-4
20-24
40-44
60-64
85+
Age
Year
2029
2026
2023
2020


West Rural digestive mortality forecast: 2020-2029
Mortality Rate
1e-03
1e-04
1e-05
1-4
20-24
40-44
60-64
85+
Age
Year
2029
2026
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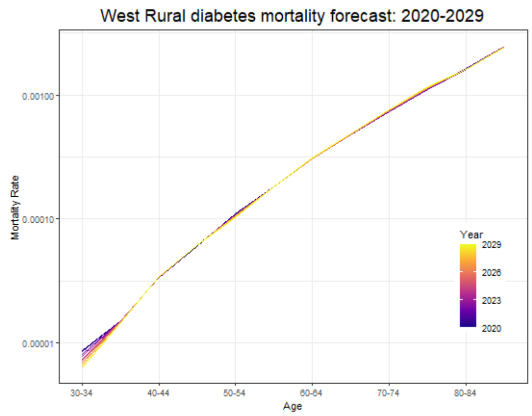
2020


West Rural diabetes mortality forecast: 2020-2029
Mortality Rate
0.00100
0.00010
0.00001
30-34
40-44
50-54
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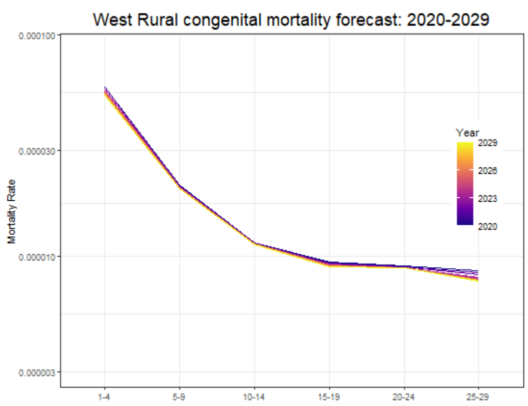
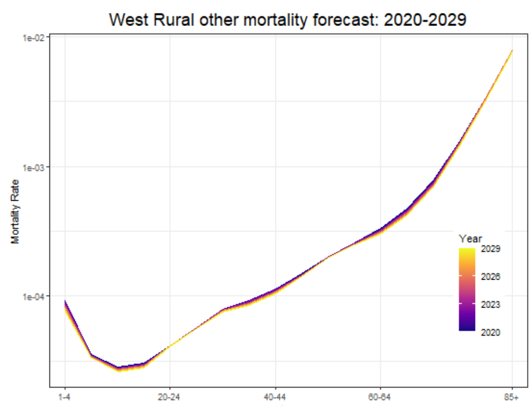
70-74
80-84
Age
Year
2029
2026
2023
2020


West Rural congenital mortality forecast: 2020-2029
Mortality Rate
0.000100
0.000030
0.000010
0.000003
1-4
5-9
10-14
15-19
20-24
25-29
Age
Year
2029
2026
2023
2020


West Rural other mortality forecast: 2020-2029
Mortality Rate
1e-02
1e-03
1e-04
1-4
20-24
40-44
60-64
85+
Age
Year
2029
2026
2023
2020

FEMALE MORTALITY PROJECTIONS

As shown in Table 7, we find that the average improvement rate for females is expected to decrease by approximately 1.5% over the next 10 years. This indicates that mortality improvement for females will slow down more than for males. We also find that the geographical gap in mortality rate between East, Central and West China is likely to continue to exist. Similar to males, we predict that the rural and urban mortality gap will become narrower over time.

For female mortality rates, we plot the total and regional-level forecasts in Figure 14 and region-area specific forecasts in Figure 15. We also plot the region-area-cause-specific mortality forecasts in Figure 16.

Table 7

FORECASTED AVERAGE MORTALITY IMPROVEMENT RATES, FEMALES, 2020–2029

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	0.030	0.013	0.029	0.025	0.017	0.025	0.023	0.012	0.049	0.039
5-9	0.015	0.018	0.017	0.018	0.014	0.004	0.006	0.011	0.026	0.022
10-14	0.018	0.021	0.019	0.020	0.020	0.008	0.011	0.016	0.026	0.023
15-19	0.024	0.031	0.026	0.027	0.030	0.018	0.021	0.016	0.028	0.024
20-24	0.026	0.039	0.023	0.027	0.033	0.023	0.026	0.019	0.026	0.024
25-29	0.025	0.035	0.023	0.026	0.031	0.025	0.027	0.015	0.025	0.022
30-34	0.020	0.023	0.020	0.021	0.022	0.023	0.022	0.009	0.021	0.018
35-39	0.018	0.017	0.022	0.021	0.016	0.021	0.019	0.010	0.019	0.016
40-44	0.024	0.022	0.031	0.028	0.021	0.023	0.023	0.019	0.022	0.021
45-49	0.025	0.031	0.031	0.031	0.018	0.024	0.023	0.024	0.022	0.023
50-54	0.029	0.033	0.034	0.034	0.020	0.029	0.026	0.029	0.022	0.024
55-59	0.026	0.016	0.028	0.024	0.013	0.033	0.027	0.026	0.028	0.027
60-64	0.025	0.016	0.024	0.021	0.016	0.031	0.027	0.026	0.029	0.028
65-69	0.026	0.030	0.029	0.030	0.023	0.024	0.024	0.029	0.023	0.025
70-74	0.025	0.029	0.040	0.036	0.018	0.022	0.021	0.020	0.019	0.019
75-79	0.021	0.021	0.037	0.031	0.012	0.020	0.018	0.008	0.015	0.013
80-84	0.014	0.014	0.020	0.018	0.011	0.017	0.016	0.001	0.007	0.005
85+	0.005	-0.013	0.015	0.004	0.005	0.016	0.012	-0.003	-0.005	-0.004
Average	0.022	0.022	0.026	0.025	0.019	0.021	0.021	0.016	0.022	0.021

Figure 14

TOTAL AND REGIONAL MORTALITY FORECASTS, FEMALES, 2020–2029

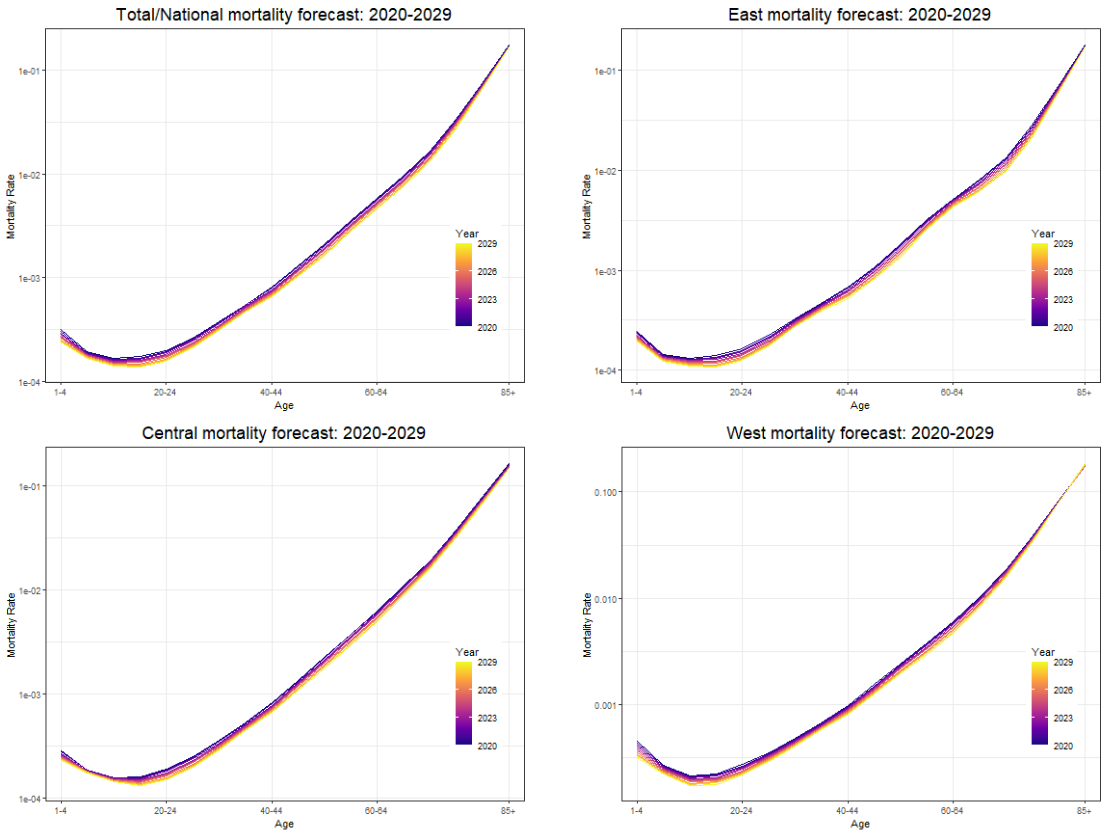


Figure 15

TOTAL AND REGIONAL MORTALITY FORECASTS, FEMALES, 2020–2029

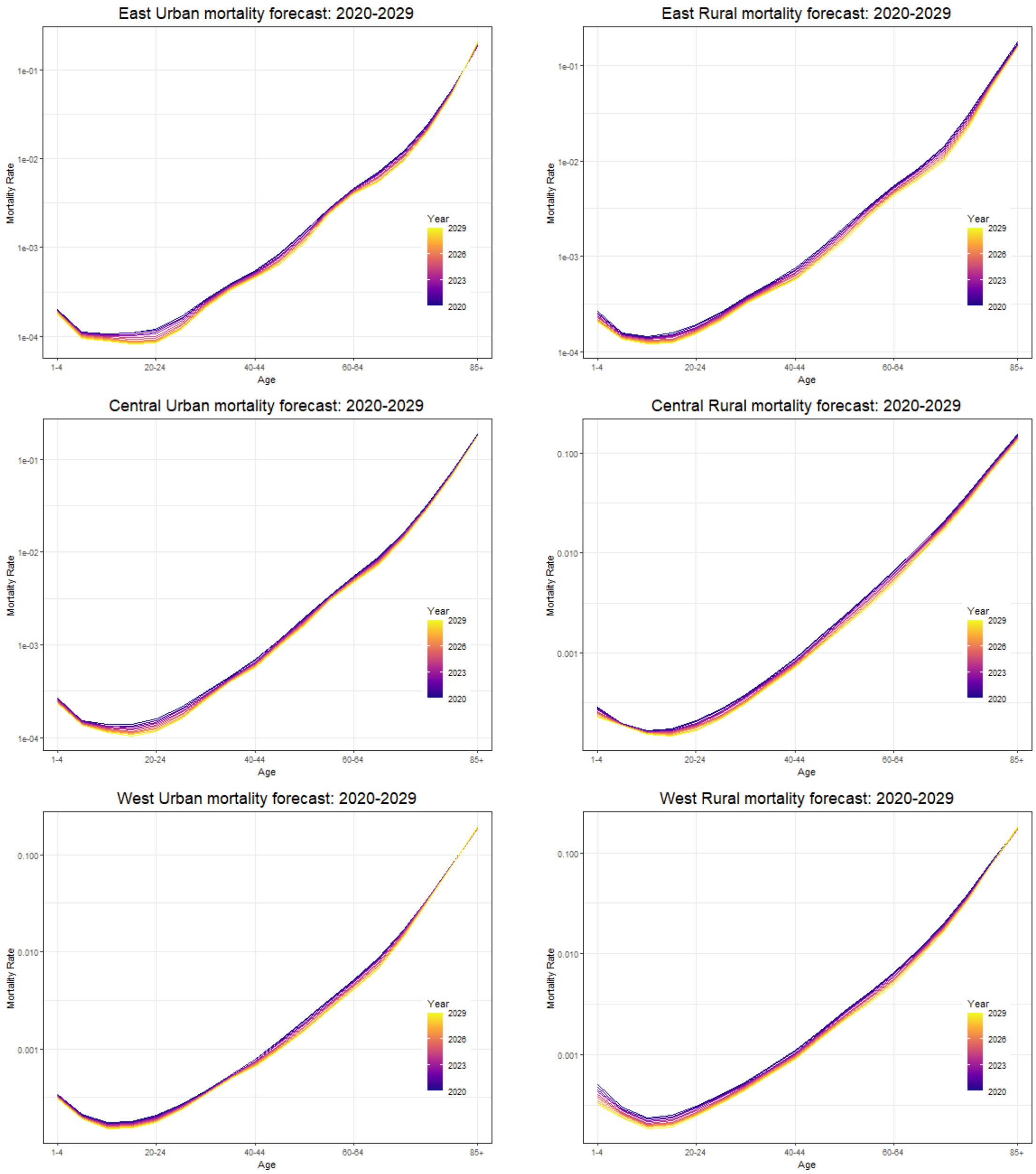
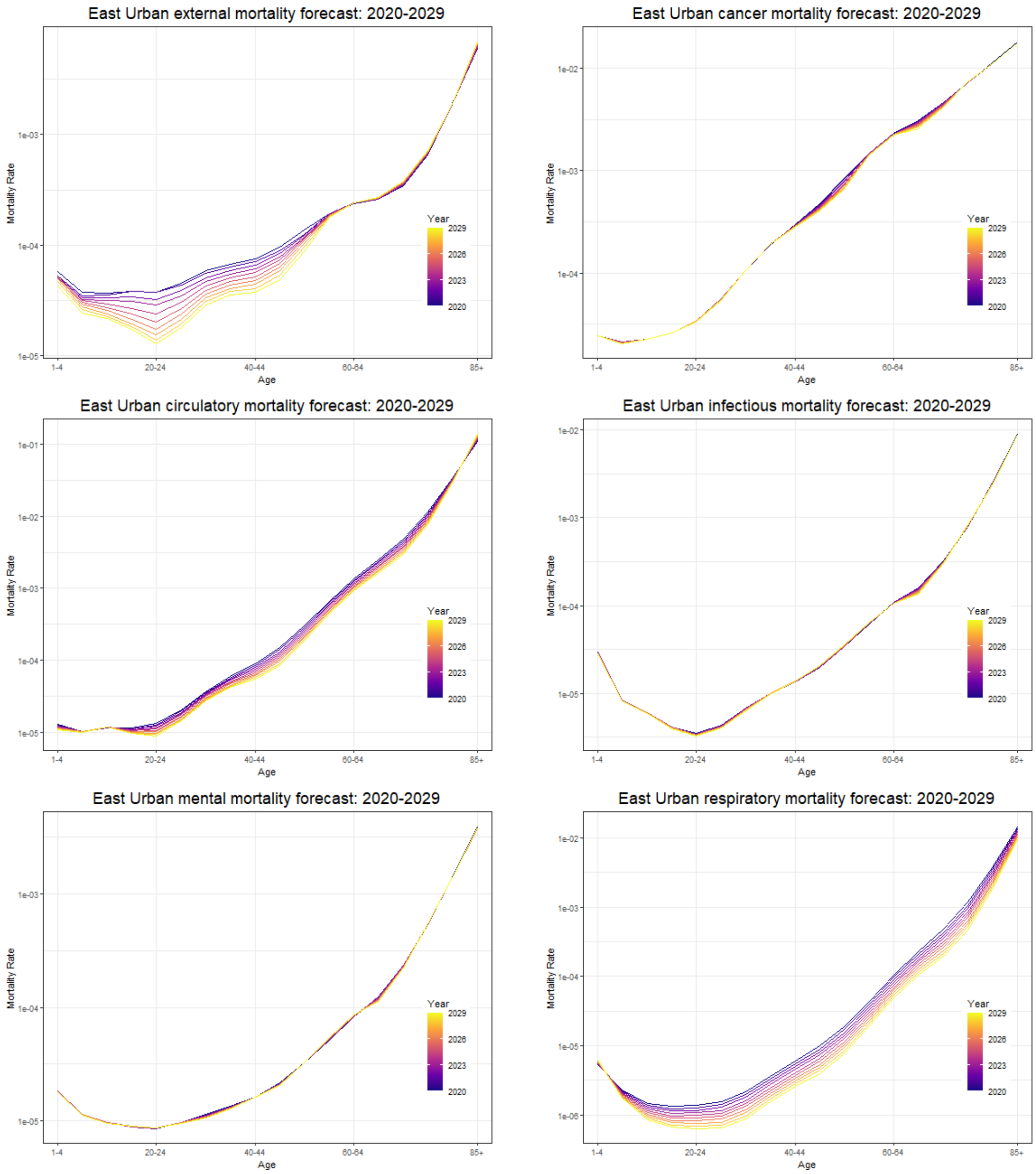
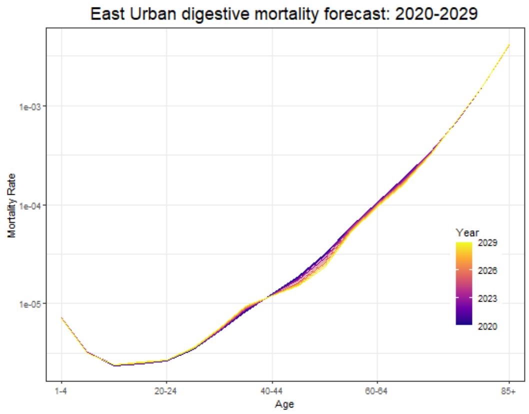
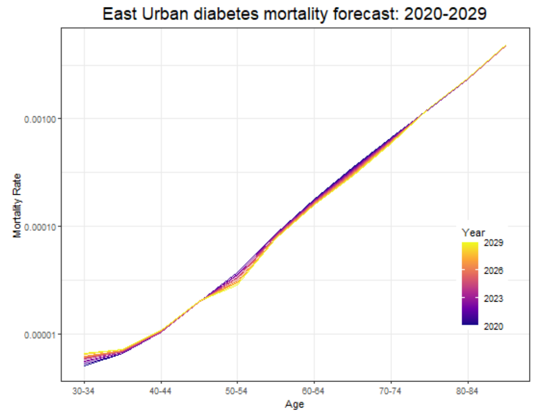


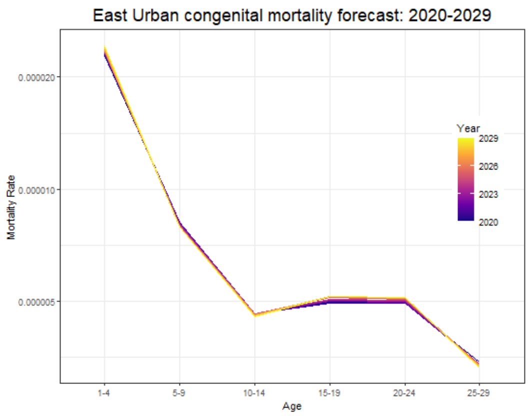
Figure 16

REGION-AREA-CAUSE-SPECIFIC MORTALITY FORECASTS, FEMALES, 2020–2029




East Urban digestive mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Urban diabetes mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Urban congenital mortality forecast: 2020-2029
Mortality Rate
Age
Year
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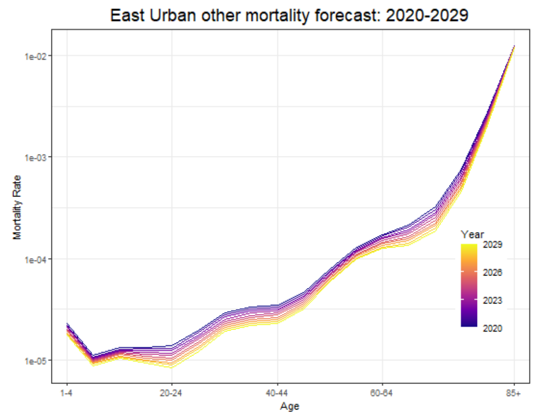
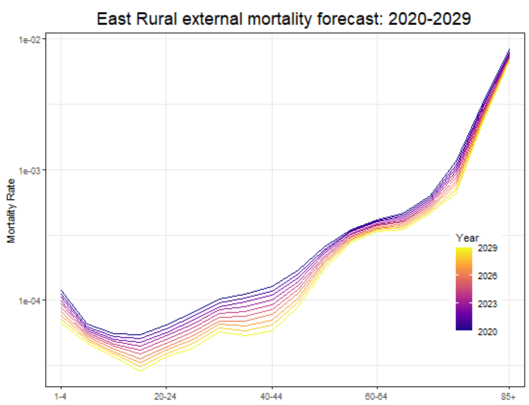
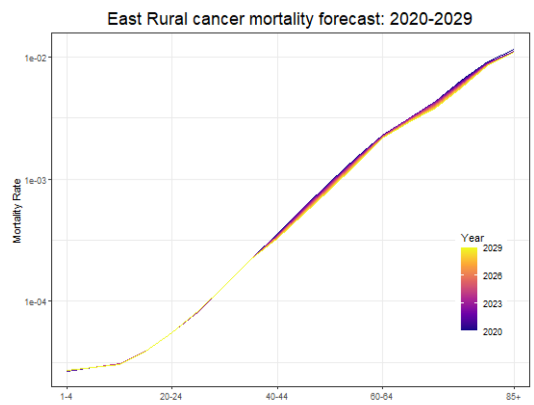
2026
2023
2020


East Urban other mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Rural external mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Rural cancer mortality forecast: 2020-2029
Mortality Rate
Age
Year
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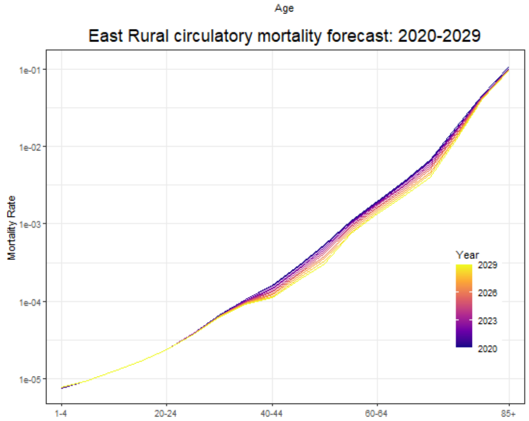
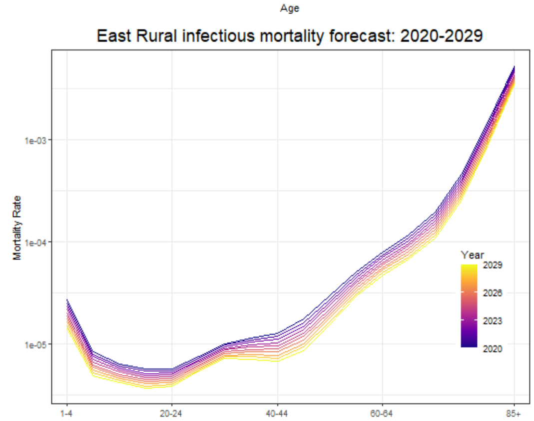
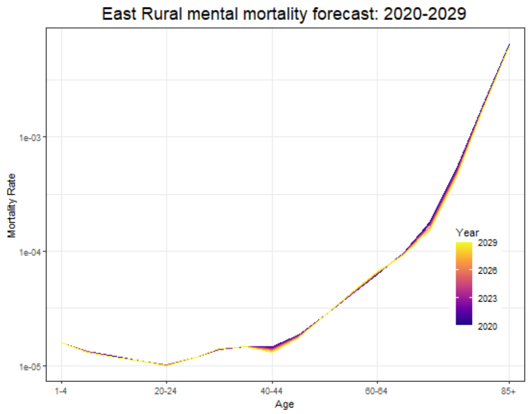
2023
2020


East Rural circulatory mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Rural infectious mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Rural mental mortality forecast: 2020-2029
Mortality Rate
Age
Year
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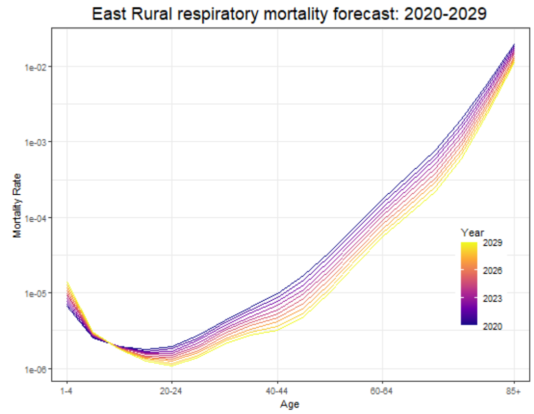
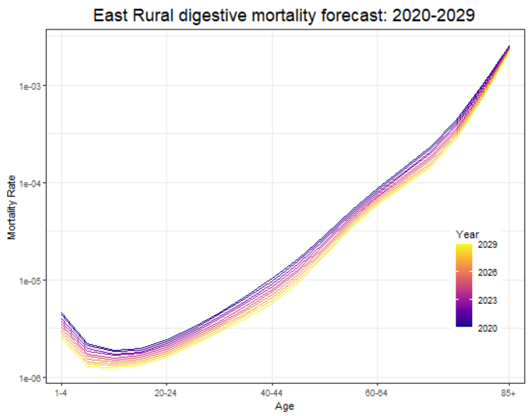
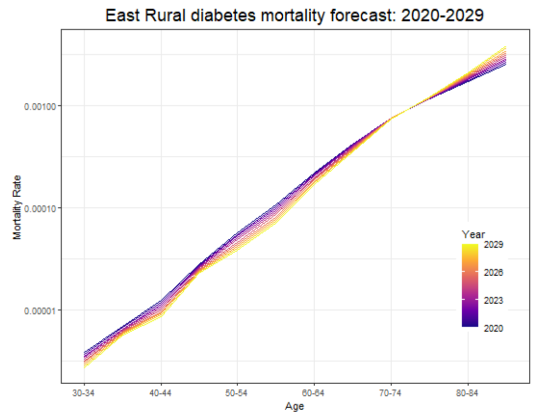
2026
2023
2020


East Rural respiratory mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


East Rural digestive mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020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Mortality Rate
Age
Year
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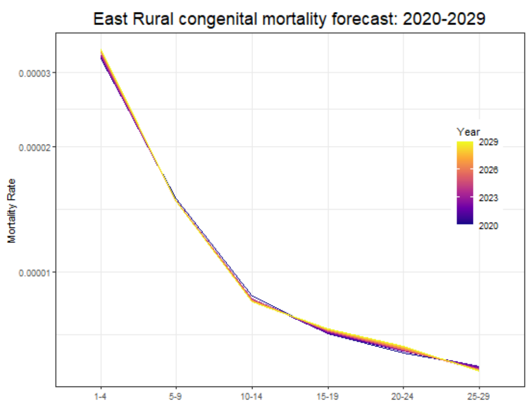
2026
2023
2020


East Rural congenital mortality forecast: 2020-2029
Mortality Rate
Age
Year
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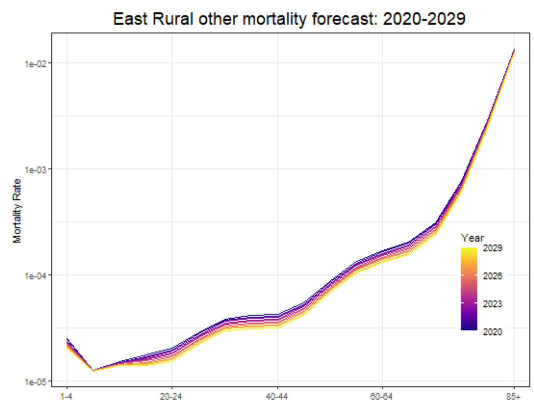
2026
2023
2020


East Rural other mortality forecast: 2020-2029
Mortality Rate
Age
Year
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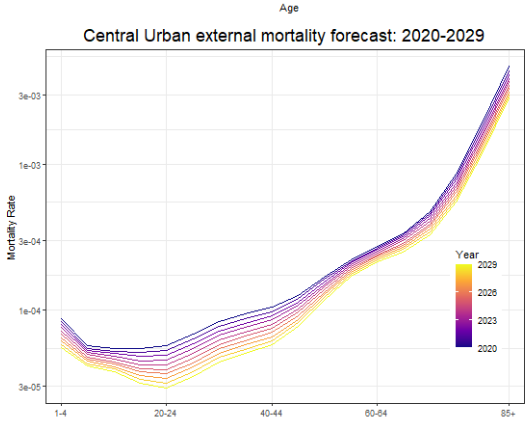
2023
2020


Central Urban external mortality forecast: 2020-2029
Mortality Rate
Age
Year
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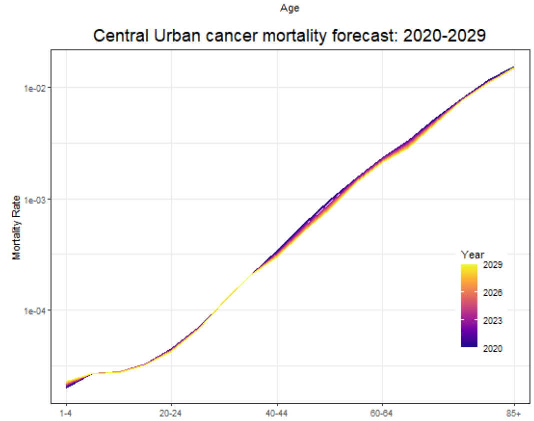
2026
2023
2020


Central Urban cancer mortality forecast: 2020-2029
Mortality Rate
Age
Year
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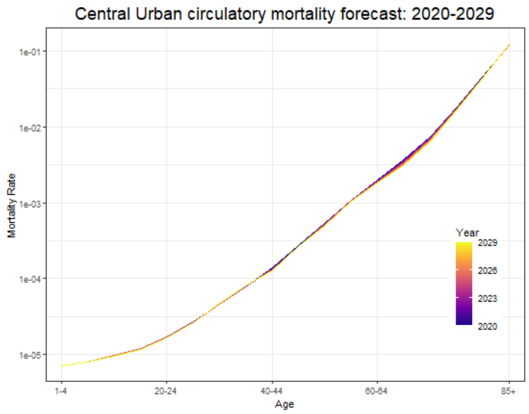
2023
2020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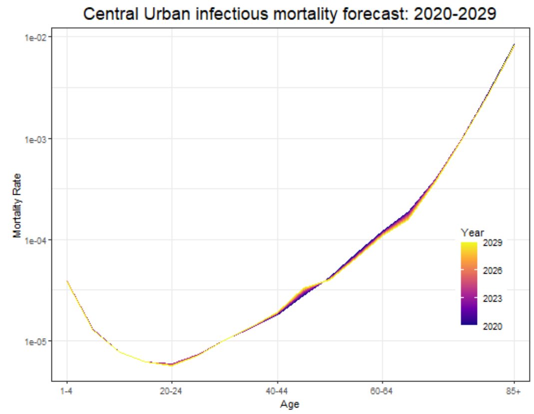
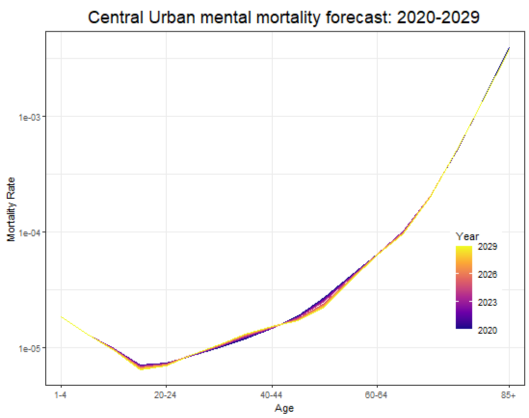
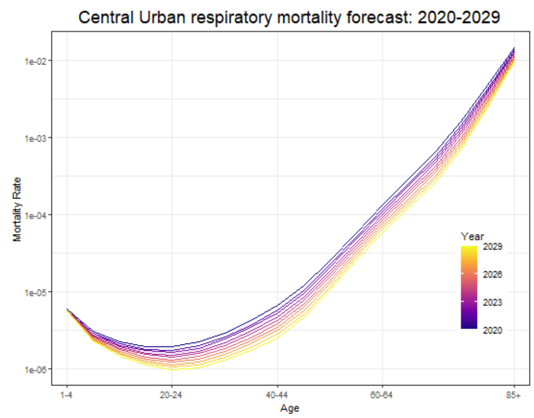
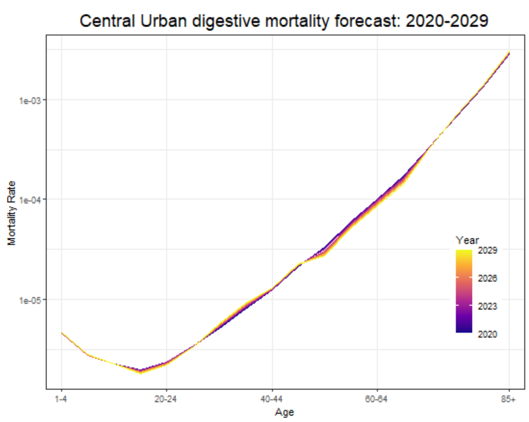
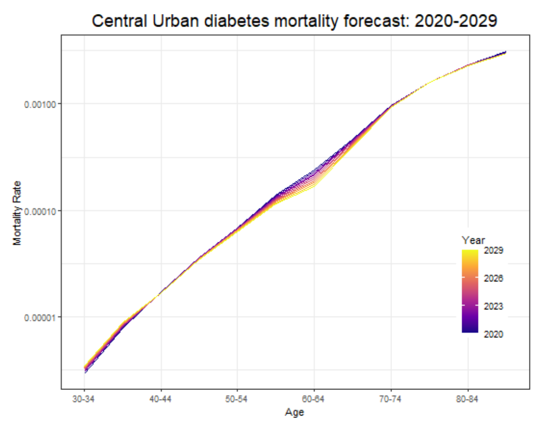
Mortality Rate
Age
Year

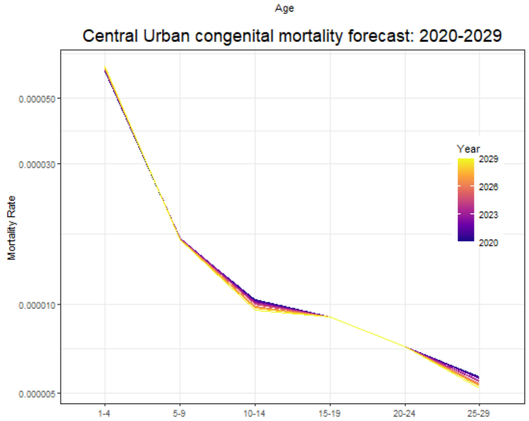

Central Urban infectious mortality forecast: 2020-2029
Mortality Rate
Age
Year

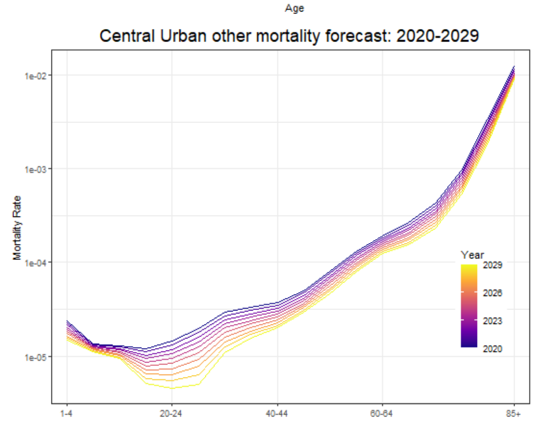

Central Urban mental mortality forecast: 2020-2029
Mortality Rate
Age
Year

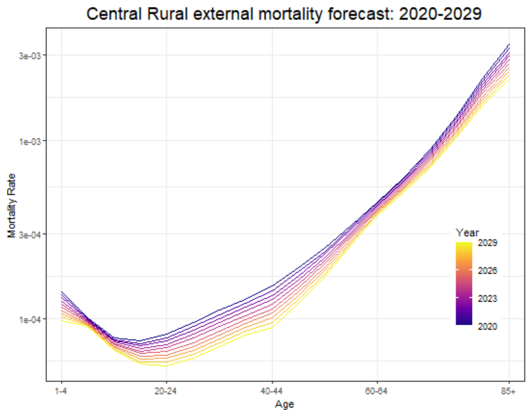

Central Urban respiratory mortality forecast: 2020-2029
Mortality Rate
Age
Year

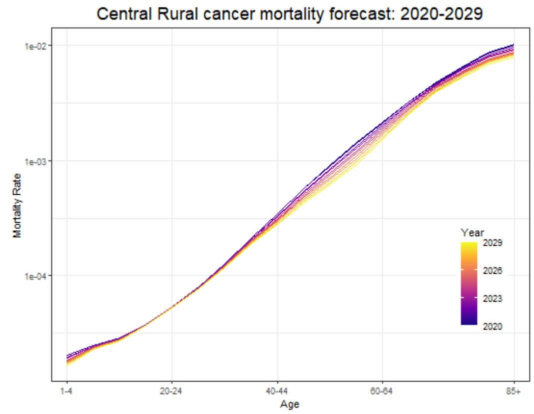

Central Urban digestive mortality forecast: 2020-2029
Mortality Rate
Age
Year

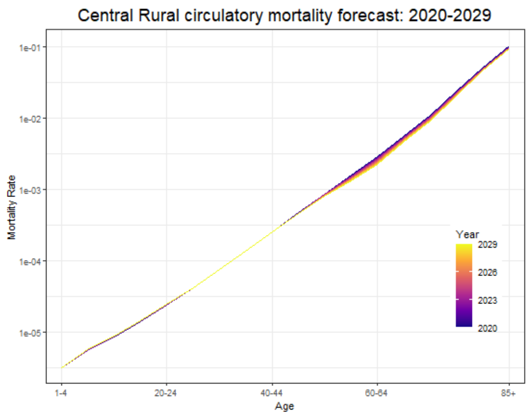

Central Urban diabetes mortality forecast: 2020-2029
Mortality Rate
Age
Year

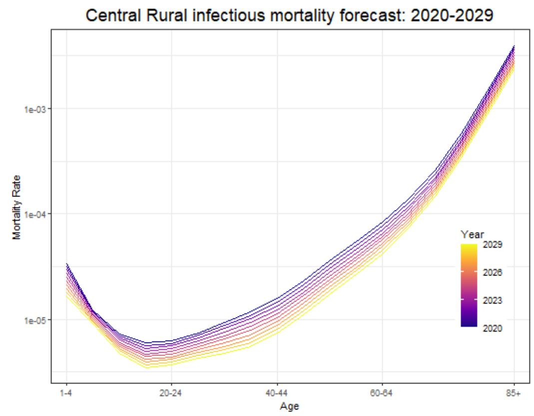

Central Urban congenital mortality forecast: 2020-2029
Mortality Rate
Age
Year

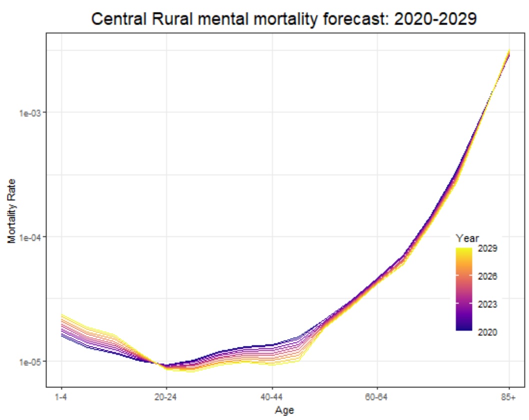

Central Urban other mortality forecast: 2020-2029
Mortality Rate
Age
Year

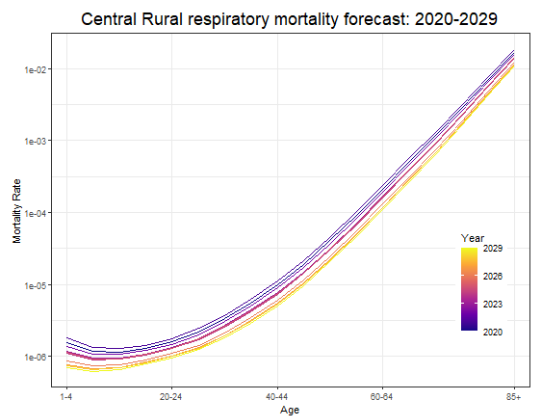

Central Rural external mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

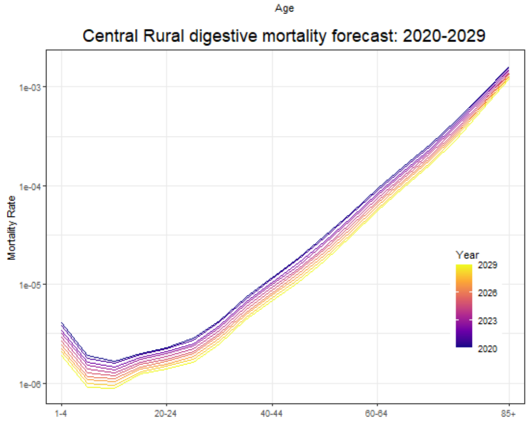

Central Rural cancer mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

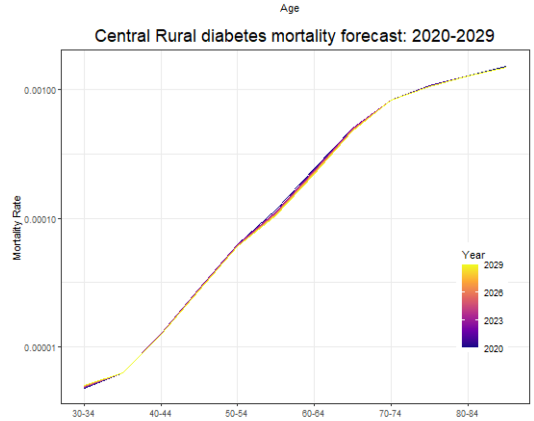

Central Rural circulatory mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

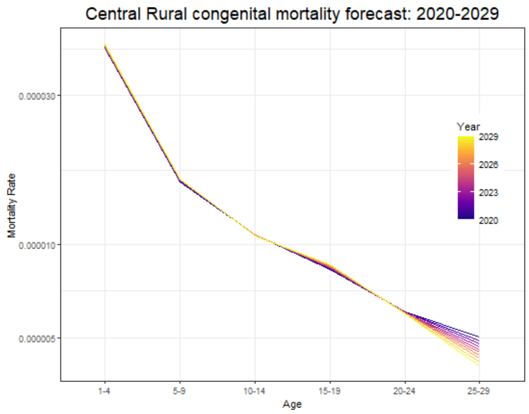

Central Rural infectious mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

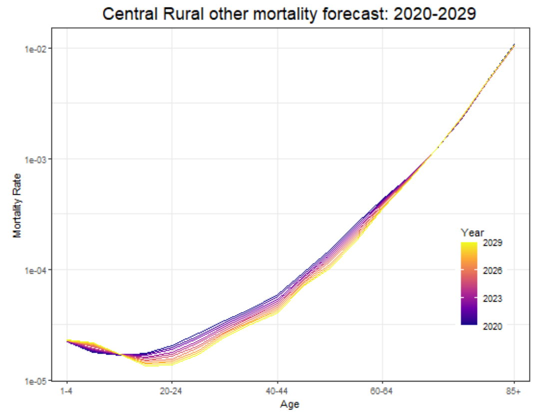

Central Rural mental mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

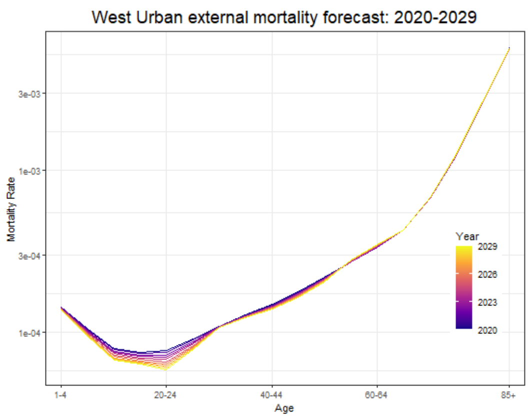

Central Rural respiratory mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

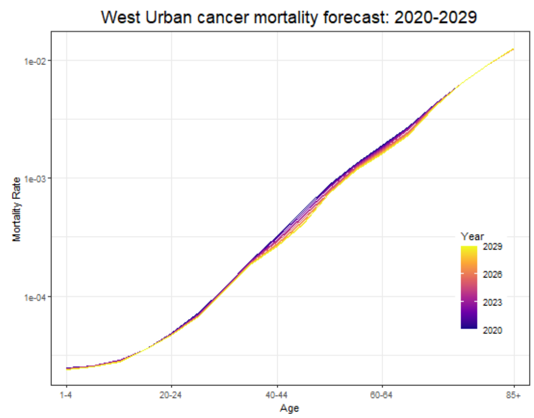

Central Rural digestive mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

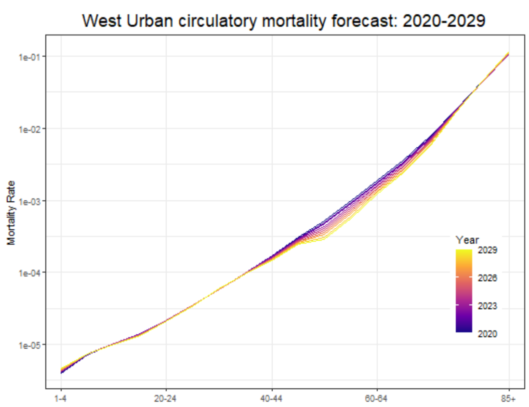

Central Rural diabetes mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

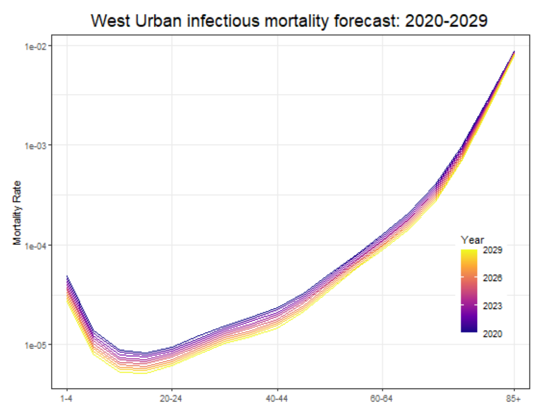

Central Rural congenital mortality forecast: 2020-2029
Mortality Rate
0.000030
0.000010
0.000005
Age
1-4
5-9
10-14
15-19
20-24
25-29
Year
2029
2026
2023
2020

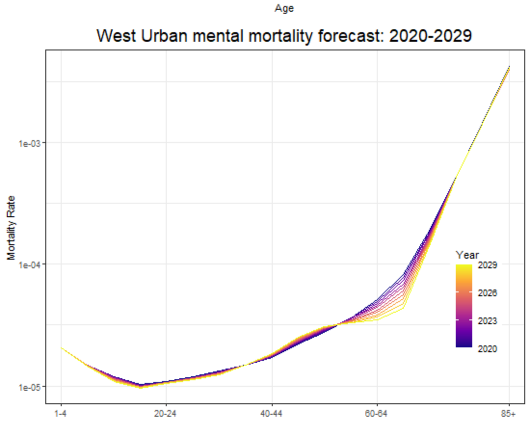

Central Rural other mortality forecast: 2020-2029
Mortality Rate
1e-02
1e-03
1e-04
1e-05
Age
1-4
20-24
40-44
60-64
85+
Year
2029
2026
2023
2020

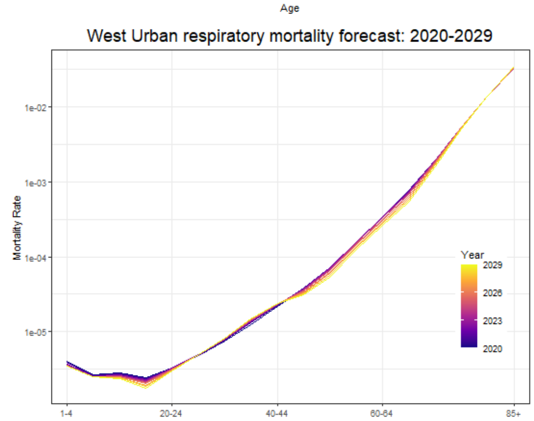

West Urban external mortality forecast: 2020-2029
Mortality Rate
3e-03
1e-03
3e-04
1e-04
Age
1-4
20-24
40-44
60-64
85+
Year
2029
2026
2023
2020


West Urban cancer mortality forecast: 2020-2029
Mortality Rate
1e-02
1e-03
1e-04
Age
1-4
20-24
40-44
60-64
85+
Year
2029
2026
2023
2020

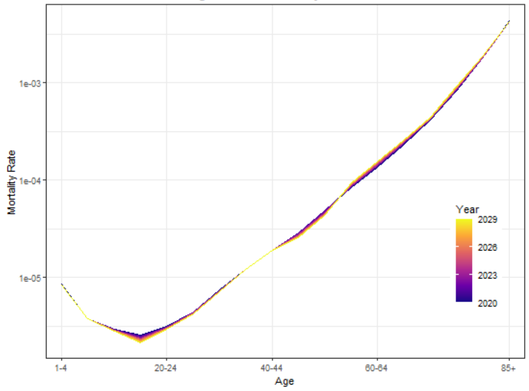

West Urban circulatory mortality forecast: 2020-2029
Mortality Rate
1e-01
1e-02
1e-03
1e-04
1e-05
Age
1-4
20-24
40-44
60-64
85+
Year
2029
2026
2023
2020


West Urban infectious mortality forecast: 2020-2029
Mortality Rate
1e-02
1e-03
1e-04
1e-05
Age
1-4
20-24
40-44
60-64
85+
Year
2029
2026
2023
2020

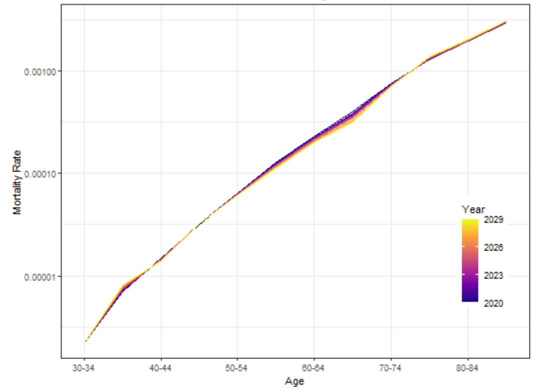

West Urban mental mortality forecast: 2020-2029
Mortality Rate
1e-03
1e-04
1e-05
Age
1-4
20-24
40-44
60-64
85+
Year
2029
2026
2023
2020


West Urban respiratory mortality forecast: 2020-2029
Mortality Rate
1e-02
1e-03
1e-04
1e-05
Age
1-4
20-24
40-44
60-64
85+
Year
2029
2026
2023
2020

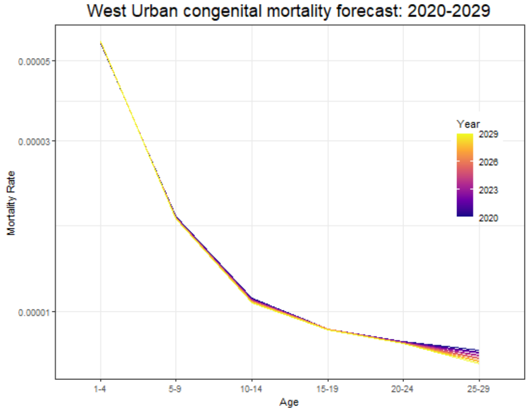
West Urban digestive mortality forecast: 2020-2029



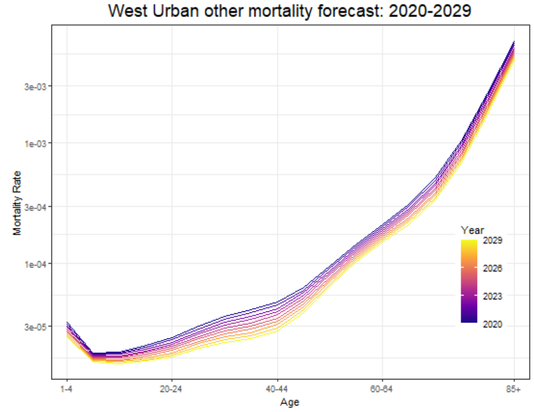
West Urban diabetes mortality forecast: 2020-2029



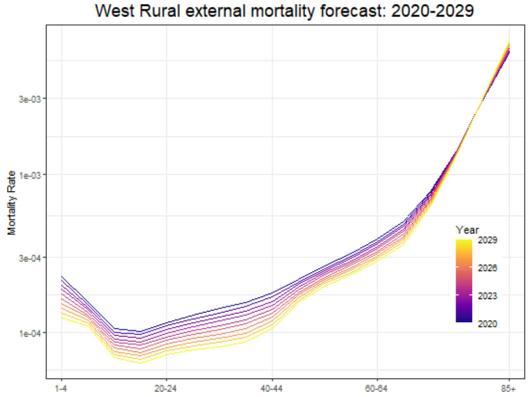
West Urban congenital mortality forecast: 2020-2029



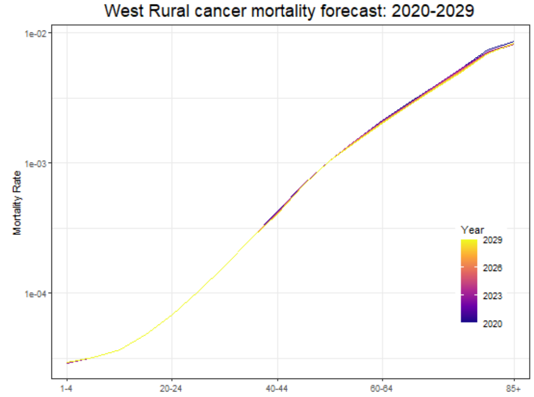
West Urban other mortality forecast: 2020-2029



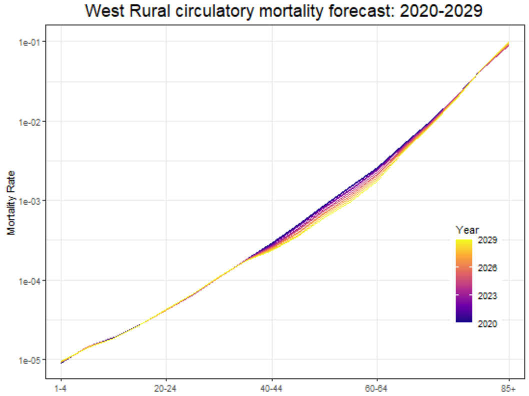
West Rural external mortality forecast: 2020-2029



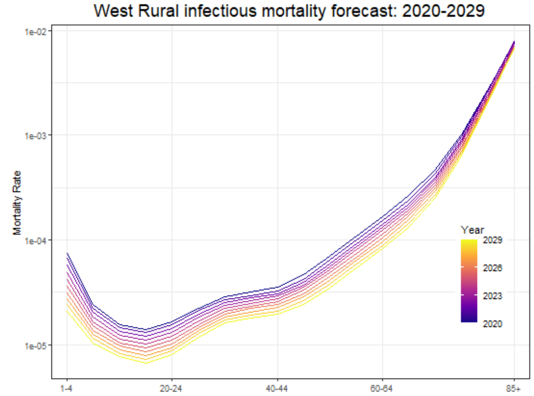
West Rural cancer mortality forecast: 2020-2029

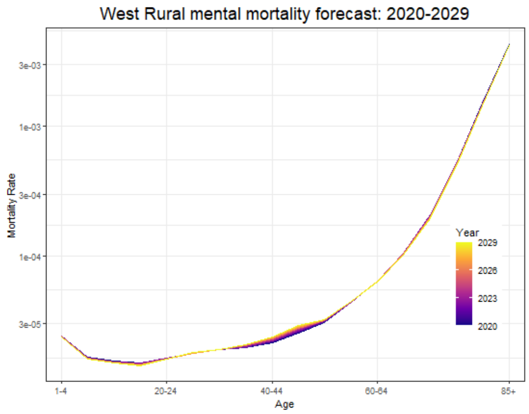


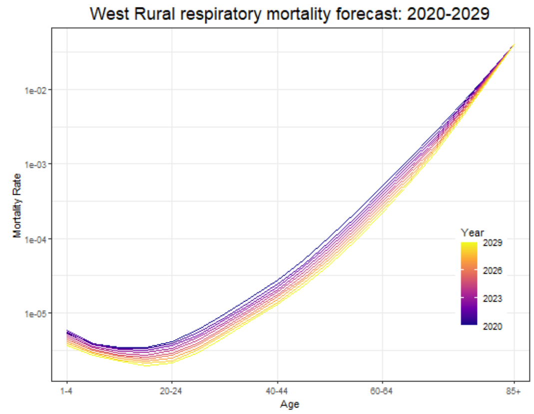
West Rural circulatory mortality forecast: 2020-2029

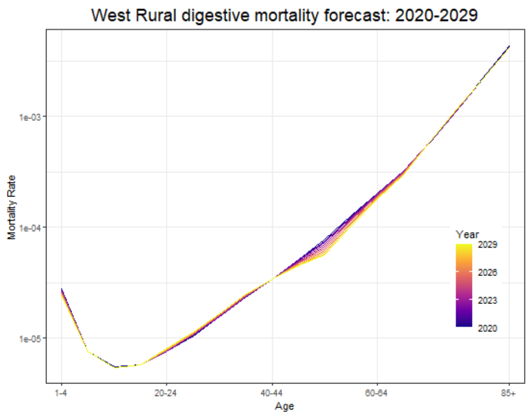


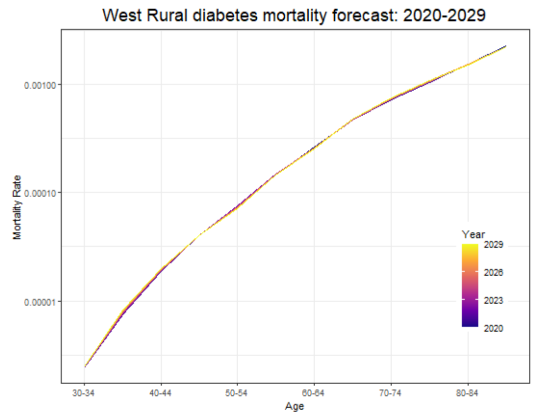
West Rural infectious mortality forecast: 2020-2029

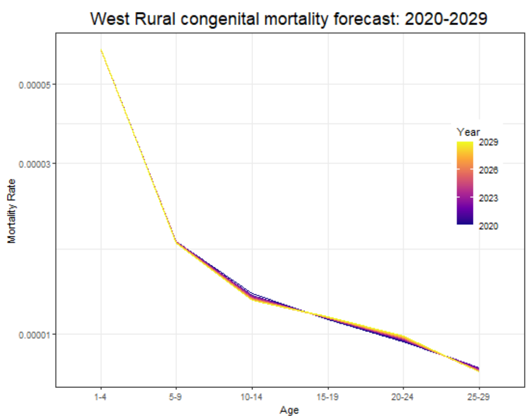


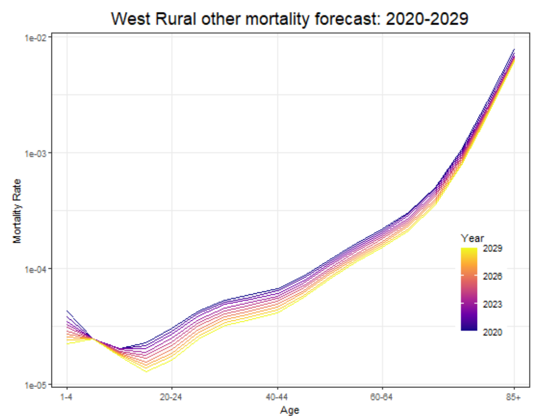

West Rural mental mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Rural respiratory mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Rural digestive mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Rural diabetes mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Rural congenital mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020


West Rural other mortality forecast: 2020-2029
Mortality Rate
Age
Year
2029
2026
2023
2020

Section 5: Scenario-based analysis

Scenario-based analysis is a useful way to predict future mortality levels, and it is also a key component of this project. In this section, we conduct mortality prediction under several cause-elimination scenarios based on the method proposed in Li et al. (2019). We focus on cancer, external, and circulatory mortality eliminations but also present the results on cause-elimination for all other causes of death included in this research.

5.1 CANCER ELIMINATION

Monitoring cancer mortality is of particular importance to the life insurance industry. No cancer history or no family history of cancer deaths are common criteria set by insurers for a policyholder to qualify for "preferred" or the "super preferred" insurance rating classifications. Substantial changes in cancer mortality will, in turn, lead to changes in the rating scheme for certain life insurance products.

We present the average mortality reduction percentage under cancer elimination in Table 8 and Table 9 for males and females, respectively. These numbers are based on the reconciled forecasts produced in Section 4.3 for 2020–2029, converted into an annual rate. If cancer deaths could be eliminated, male mortality rates would be reduced by about 22% on average, while female mortality rates would be reduced by about 31%. Overall, the reduction is most significant for ages 40–65. It is interesting to see that for the "oldest old" aged 80–84 and 85+, cancer elimination would lead to an increase in mortality rates. We suspect that this is because as more people survive to older ages, a larger proportion of them will die due to other causes or "die of old age".

Across East, Central, and West China, the impact of cancer elimination on overall mortality is at a similar level for males. For females, however, the average mortality reduction is slightly higher for East China compared to Central and West China. The tables also show that rural areas seem to be at a slight disadvantage compared to urban areas, except for East Rural (males) and West Rural (females).

To visualize the impact of cancer elimination on different age groups, we plot the mortality forecasts in Figure 17 for males and Figure 18 for females. The figures illustrate that between ages 20–45, the reduction in mortality rate is more apparent for females than for males.

Table 8

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER CANCER ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	6%	7%	6%	6%	5%	7%	6%	7%	6%	6%
5-9	9%	9%	6%	7%	8%	9%	9%	10%	9%	9%
10-14	9%	11%	11%	11%	11%	7%	7%	11%	8%	9%
15-19	13%	14%	18%	17%	9%	12%	11%	12%	14%	13%
20-24	14%	12%	22%	19%	9%	15%	14%	7%	13%	11%
25-29	13%	14%	12%	13%	14%	14%	14%	10%	13%	12%
30-34	20%	13%	18%	17%	20%	23%	22%	22%	22%	22%
35-39	27%	15%	27%	24%	25%	29%	28%	32%	28%	29%
40-44	33%	25%	35%	32%	38%	33%	34%	37%	31%	33%
45-49	40%	23%	46%	40%	44%	42%	43%	36%	39%	38%
50-54	50%	37%	54%	49%	53%	51%	51%	48%	51%	50%
55-59	58%	57%	62%	60%	59%	54%	56%	61%	59%	60%
60-64	52%	63%	56%	59%	60%	36%	43%	62%	51%	55%
65-69	32%	43%	34%	37%	51%	18%	26%	37%	33%	34%
70-74	19%	16%	18%	17%	32%	13%	18%	20%	23%	22%
75-79	8%	5%	4%	5%	17%	7%	10%	14%	11%	12%
80-84	-6%	3%	-11%	-6%	5%	-11%	-6%	2%	-10%	-6%
85+	-8%	3%	-11%	-5%	-1%	-13%	-9%	-5%	-15%	-11%

Average	22%	21%	23%	22%	26%	19%	21%	23%	21%	22%

Figure 17
MORTALITY FORECAST UNDER CANCER ELIMINATION, MALE

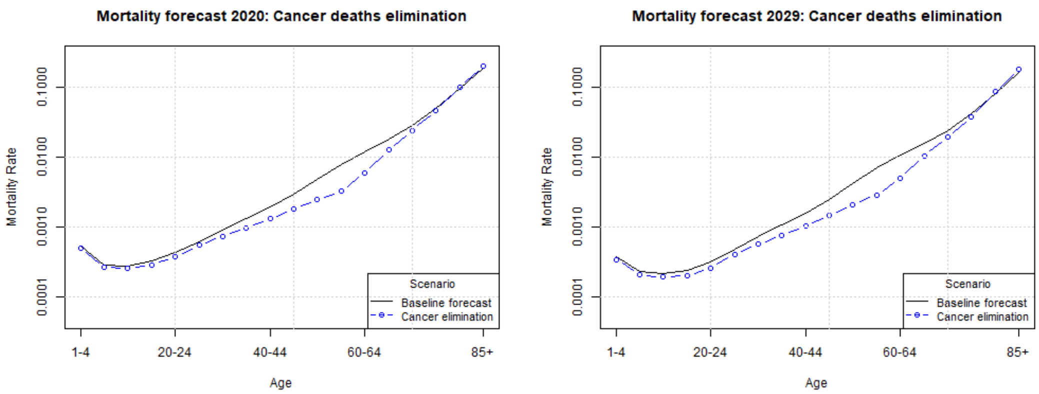
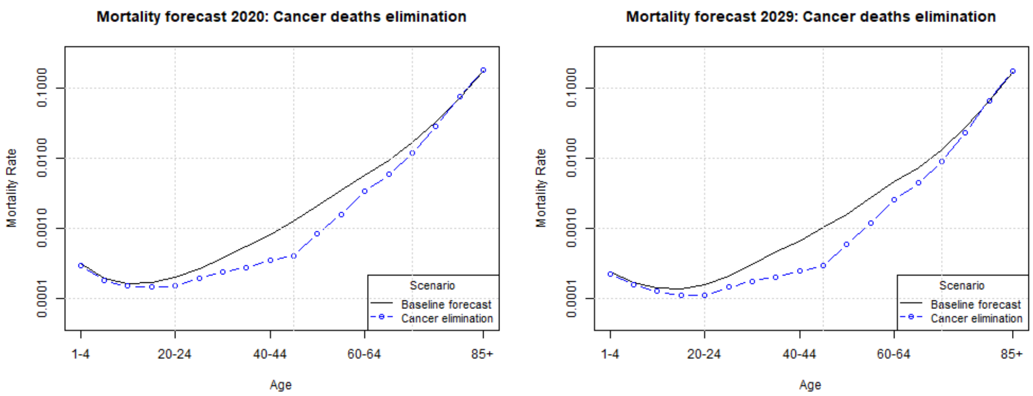


Table 9
AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER CANCER ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	6%	10%	7%	8%	7%	5%	5%	7%	5%	6%
5-9	6%	10%	9%	9%	12%	5%	6%	7%	2%	3%
10-14	9%	9%	15%	13%	4%	10%	9%	6%	8%	7%
15-19	17%	20%	22%	22%	7%	18%	15%	9%	19%	16%
20-24	27%	27%	35%	33%	19%	25%	24%	13%	29%	24%
25-29	28%	30%	30%	30%	20%	28%	26%	22%	31%	28%
30-34	39%	44%	35%	38%	35%	41%	40%	40%	40%	40%
35-39	53%	59%	44%	49%	58%	56%	57%	50%	53%	52%
40-44	60%	58%	55%	56%	65%	64%	65%	53%	60%	58%
45-49	70%	72%	73%	73%	74%	73%	73%	56%	67%	64%
50-54	61%	51%	64%	60%	60%	65%	63%	42%	69%	61%
55-59	56%	63%	57%	59%	61%	49%	52%	46%	60%	55%
60-64	43%	64%	48%	53%	58%	26%	34%	48%	41%	43%
65-69	39%	46%	47%	46%	48%	27%	31%	42%	42%	42%
70-74	31%	40%	34%	36%	37%	22%	26%	34%	30%	32%
75-79	15%	30%	10%	17%	25%	9%	13%	21%	9%	13%
80-84	-2%	10%	-7%	-1%	9%	-5%	-2%	10%	-9%	-3%
85+	-4%	0%	-5%	-3%	0%	-6%	-4%	1%	-7%	-4%
Average	31%	36%	32%	33%	33%	28%	30%	28%	30%	29%

Figure 18
MORTALITY FORECAST UNDER CANCER ELIMINATION, FEMALE



5.2 EXTERNAL DEATHS ELIMINATION

Based on our dataset, external causes are the number one cause of death for people below age 35 (excluding infant mortality) in China. External deaths include accidents, suicide, and homicide.

We present the average mortality reduction percentage under external deaths elimination in Table 10 and Table 11 for males and females, respectively. It is not surprising to see that younger age groups (ages 1–35) are most affected by the elimination of external deaths. Also, the impact is bigger for males than females.

Among the three regions, the impact of external death elimination on mortality levels seems to be larger in Central and West China for both males and females. Rural areas also have higher mortality reduction compared to urban areas.

Under external deaths elimination, we plot the mortality forecasts in Figure 19 for males and Figure 20 for females. We observe that the reduction in mortality rate seems to be more apparent for males compared to females.

Table 10
AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER EXTERNAL ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	40%	26%	36%	33%	40%	48%	46%	42%	37%	39%
5-9	49%	40%	43%	43%	40%	59%	56%	42%	49%	47%
10-14	44%	30%	34%	33%	34%	51%	48%	42%	47%	46%
15-19	46%	46%	36%	39%	37%	51%	48%	47%	50%	49%
20-24	49%	45%	41%	42%	35%	55%	51%	50%	51%	51%
25-29	46%	37%	43%	42%	37%	52%	49%	48%	47%	47%
30-34	40%	22%	40%	35%	32%	46%	42%	43%	41%	41%
35-39	28%	22%	26%	25%	29%	31%	30%	34%	27%	29%
40-44	22%	24%	21%	22%	24%	22%	22%	25%	19%	21%
45-49	14%	3%	17%	13%	12%	15%	14%	13%	16%	15%
50-54	10%	-4%	14%	8%	7%	12%	11%	7%	15%	13%
55-59	9%	1%	12%	8%	6%	11%	9%	5%	14%	11%
60-64	6%	4%	7%	6%	5%	5%	5%	4%	9%	7%
65-69	3%	3%	3%	3%	3%	2%	2%	2%	5%	4%
70-74	2%	1%	1%	1%	2%	1%	2%	2%	3%	3%
75-79	1%	1%	0%	0%	2%	1%	1%	2%	2%	2%
80-84	-2%	0%	-3%	-2%	-1%	-2%	-2%	0%	-2%	-1%
85+	-2%	-1%	-3%	-2%	-2%	-3%	-3%	-1%	-3%	-2%
Average	22%	17%	21%	19%	19%	25%	24%	23%	24%	23%

Figure 19

MORTALITY FORECAST UNDER EXTERNAL ELIMINATION, MALE

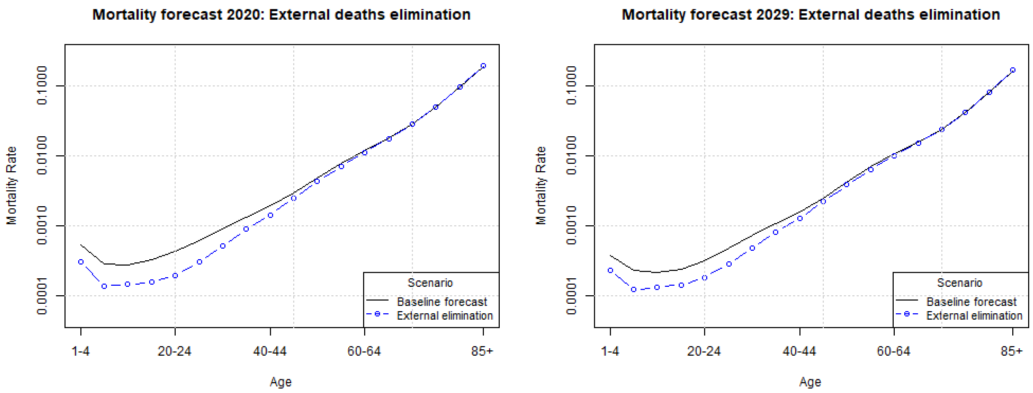
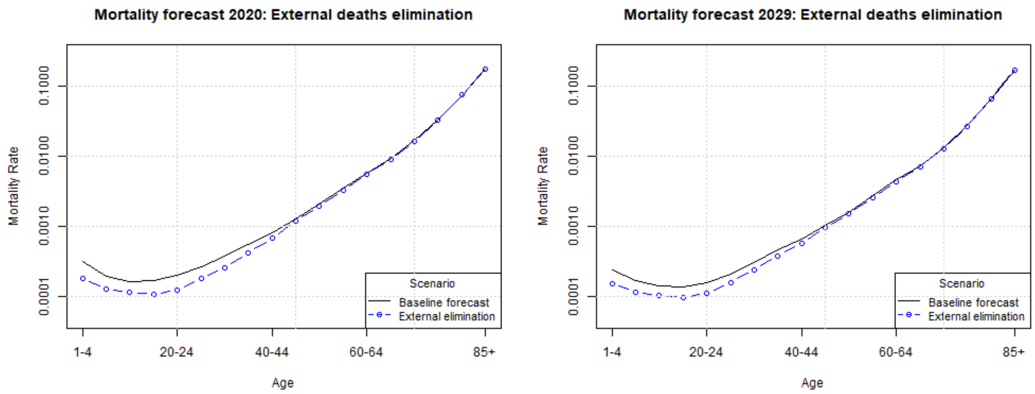


Table 11

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER EXTERNAL ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	39%	30%	38%	36%	24%	44%	39%	45%	39%	41%
5-9	33%	25%	25%	25%	30%	35%	34%	47%	33%	37%
10-14	28%	21%	26%	25%	20%	28%	26%	28%	33%	32%
15-19	34%	25%	33%	31%	22%	37%	33%	26%	41%	36%
20-24	33%	23%	34%	31%	20%	35%	31%	27%	39%	36%
25-29	28%	20%	28%	26%	19%	29%	27%	27%	32%	31%
30-34	26%	20%	22%	22%	26%	29%	28%	32%	27%	28%
35-39	20%	17%	15%	15%	22%	23%	23%	27%	20%	23%
40-44	13%	11%	8%	9%	13%	15%	15%	15%	12%	13%
45-49	8%	5%	6%	5%	8%	10%	10%	7%	8%	7%
50-54	7%	2%	6%	5%	6%	9%	8%	4%	9%	7%
55-59	7%	6%	7%	6%	6%	7%	7%	5%	8%	7%
60-64	5%	5%	5%	5%	5%	4%	4%	5%	5%	5%
65-69	4%	3%	5%	4%	4%	4%	4%	4%	4%	4%
70-74	3%	3%	4%	3%	3%	3%	3%	4%	3%	3%
75-79	2%	3%	1%	2%	2%	2%	2%	3%	1%	2%
80-84	-1%	0%	-1%	-1%	0%	-1%	-1%	2%	-2%	-1%
85+	-2%	-1%	-2%	-2%	-2%	-3%	-2%	0%	-3%	-2%
Average	16%	12%	14%	14%	13%	17%	16%	17%	17%	17%

Figure 20
MORTALITY FORECAST UNDER EXTERNAL ELIMINATION, FEMALE



5.3 CIRCULATORY ELIMINATION

Circulatory deaths are the leading cause of death for people over 65 in our dataset. Table 12 and Table 13 show the reduction percentage under circulatory elimination for males and females, respectively. As in the previous two subsections, the numbers are based on the reconciled forecasts produced in Section 4.3 for 2020–2029, converted into an annual rate.

If circulatory mortality could be eliminated, male mortality rates would be reduced by about 34% on average, while female mortality rates would be reduced by about 33%. These numbers are substantially higher than those for cancer elimination (male: 22%, female: 31%) reported in Table 8 and Table 9, and external elimination (male: 22%, female: 16%) reported in Table 10 and Table 11.

The reductions in mortality rates under circulatory death elimination are higher for older ages. For men, our model estimates the highest mortality reduction (62%) at ages 80–84. The maximum mortality reduction for women is reached at 75–79 (69%).

For both males and females, the impact of circulatory death elimination on overall mortality is slightly higher in Central China and West China than in East China. There is no clear pattern of how mortality reductions vary between urban and rural areas. For males, the reduction is highest on average in urban areas in rural China (40% reduction). For females, the reductions are highest on average in rural areas in Central China (36% reduction).

Figure 21 and Figure 22 plot the mortality forecasts for males and females, respectively. The figures show that mortality reductions under circulatory death elimination are higher at higher ages.

Table 12
AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER CIRCULATORY ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	5%	8%	5%	6%	2%	3%	3%	6%	4%	5%
5-9	4%	5%	3%	3%	4%	4%	4%	6%	5%	5%
10-14	5%	7%	5%	6%	6%	3%	4%	6%	6%	6%
15-19	10%	13%	11%	12%	6%	8%	7%	8%	11%	10%
20-24	12%	17%	16%	16%	8%	12%	11%	6%	12%	10%
25-29	12%	21%	9%	12%	15%	12%	13%	9%	13%	12%
30-34	23%	29%	19%	22%	25%	23%	24%	23%	24%	24%
35-39	31%	37%	30%	32%	28%	30%	30%	30%	32%	32%
40-44	38%	37%	40%	39%	44%	37%	39%	39%	37%	37%
45-49	43%	24%	48%	41%	46%	45%	45%	37%	43%	41%
50-54	47%	28%	46%	40%	53%	50%	51%	40%	54%	50%
55-59	50%	45%	47%	47%	57%	50%	52%	38%	61%	53%
60-64	49%	48%	47%	48%	56%	43%	47%	42%	63%	56%
65-69	51%	45%	45%	45%	59%	49%	51%	50%	62%	58%
70-74	56%	51%	46%	47%	67%	58%	60%	59%	63%	62%
75-79	59%	55%	47%	49%	75%	67%	69%	62%	58%	60%
80-84	62%	59%	54%	56%	92%	70%	76%	70%	45%	54%
85+	59%	62%	58%	59%	85%	60%	67%	65%	38%	48%
Average	34%	33%	32%	32%	40%	35%	36%	33%	35%	35%

Figure 21
MORTALITY FORECAST UNDER CIRCULATORY ELIMINATION, MALE

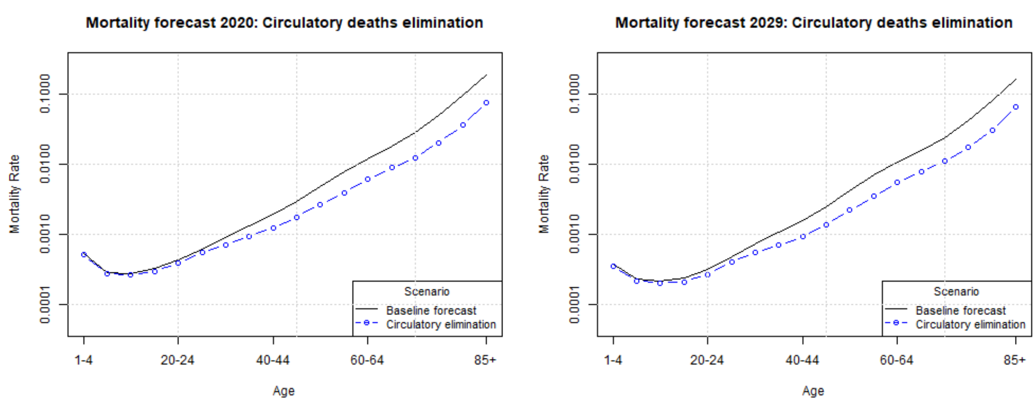


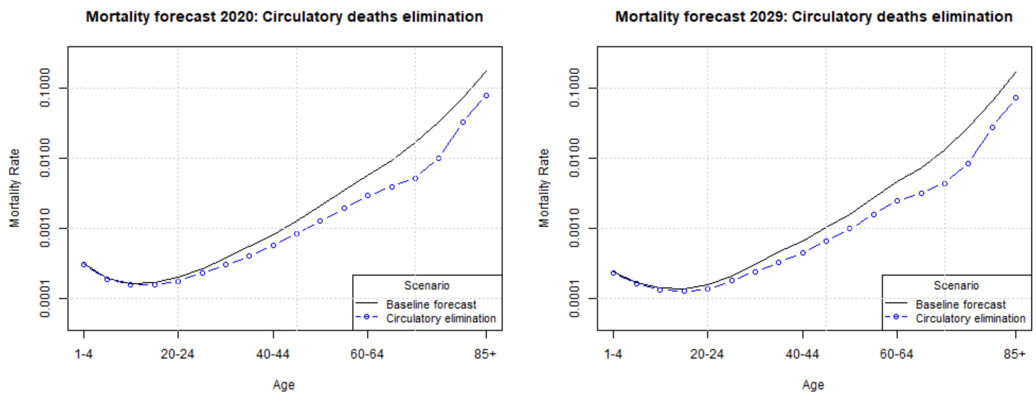
Table 13

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER CIRCULATORY ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	2%	5%	2%	3%	2%	1%	1%	2%	2%	2%
5-9	2%	5%	3%	3%	4%	1%	2%	2%	1%	1%
10-14	4%	4%	5%	5%	2%	3%	3%	2%	4%	3%
15-19	8%	8%	10%	9%	3%	7%	6%	4%	10%	8%
20-24	12%	8%	16%	14%	7%	12%	11%	5%	15%	13%
25-29	14%	7%	14%	12%	7%	15%	13%	10%	18%	16%
30-34	20%	14%	17%	16%	14%	24%	21%	19%	24%	22%
35-39	28%	21%	22%	22%	25%	35%	32%	26%	30%	29%
40-44	30%	20%	22%	22%	26%	40%	36%	27%	34%	32%
45-49	35%	23%	30%	28%	31%	46%	42%	26%	40%	35%
50-54	39%	20%	34%	30%	32%	52%	47%	25%	46%	40%
55-59	44%	28%	40%	36%	39%	54%	50%	35%	54%	48%
60-64	48%	29%	42%	38%	46%	53%	51%	50%	59%	56%
65-69	58%	37%	52%	47%	62%	60%	61%	66%	68%	68%
70-74	68%	56%	65%	62%	72%	69%	70%	70%	73%	72%
75-79	69%	60%	74%	69%	74%	72%	73%	71%	62%	65%
80-84	57%	55%	69%	64%	73%	57%	61%	75%	20%	38%
85+	55%	75%	50%	60%	78%	43%	53%	86%	27%	48%
Average	33%	26%	31%	30%	33%	36%	35%	33%	33%	33%

Figure 22

MORTALITY FORECAST UNDER CIRCULATORY ELIMINATION, FEMALE



5.4 INFECTIOUS ELIMINATION

Table 14 and Table 15 report the mortality reduction percentage under infectious death elimination for males and females, respectively. The average reductions over all age groups are small (2% for males and females), but at ages 1–4, the reductions are substantial (males: 13%, females: 9%).

Figure 23 and Figure 24 visualize the (national) reduction rates for males and females.

Table 14

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER INFECTIOUS ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	13%	10%	10%	10%	10%	15%	14%	13%	16%	15%
5-9	4%	5%	2%	2%	4%	4%	4%	7%	5%	5%
10-14	3%	3%	2%	2%	4%	2%	2%	4%	3%	3%
15-19	3%	4%	3%	3%	2%	2%	2%	3%	4%	4%
20-24	3%	3%	3%	3%	2%	2%	2%	2%	4%	3%
25-29	3%	4%	1%	2%	4%	2%	2%	3%	4%	3%
30-34	4%	4%	3%	3%	5%	3%	4%	5%	6%	6%
35-39	4%	4%	3%	3%	5%	3%	4%	6%	6%	6%
40-44	3%	3%	2%	3%	4%	2%	3%	5%	4%	4%
45-49	2%	0%	2%	1%	2%	1%	1%	3%	3%	3%
50-54	2%	-1%	1%	1%	2%	1%	1%	2%	3%	3%
55-59	2%	1%	2%	1%	2%	1%	2%	1%	3%	3%
60-64	1%	1%	1%	1%	2%	1%	1%	1%	2%	2%
65-69	0%	1%	0%	0%	1%	0%	0%	1%	1%	1%
70-74	0%	1%	0%	0%	1%	0%	0%	1%	1%	1%
75-79	0%	1%	-1%	0%	1%	0%	0%	1%	1%	1%
80-84	-1%	0%	-3%	-2%	1%	-3%	-2%	0%	-1%	-1%
85+	-3%	1%	-4%	-2%	0%	-5%	-3%	-2%	-4%	-4%
Average	2%	2%	2%	2%	3%	2%	2%	3%	3%	3%

Figure 23

MORTALITY FORECAST UNDER INFECTIOUS ELIMINATION, MALE

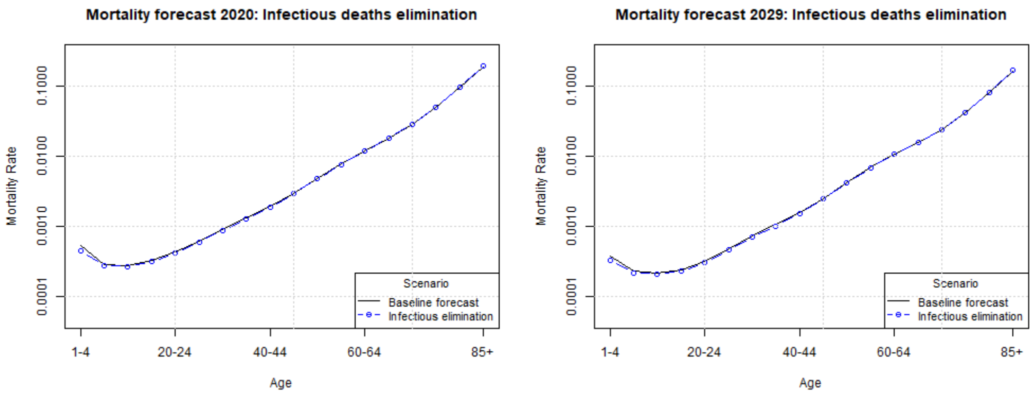
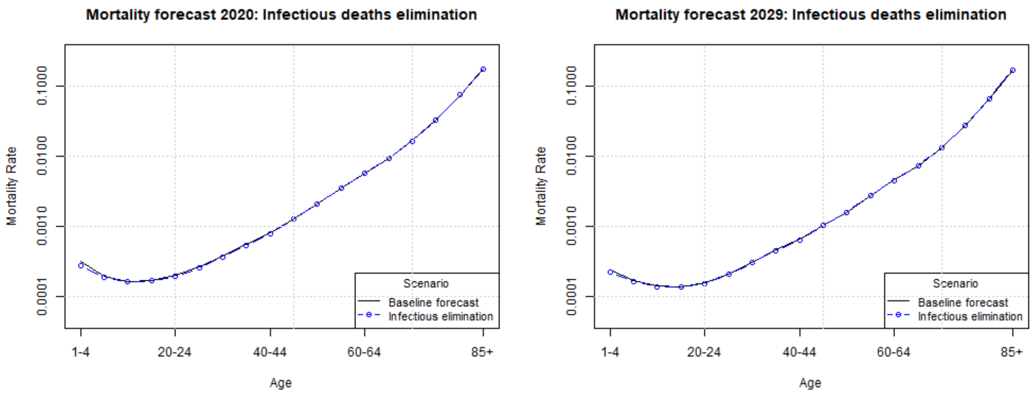


Table 15

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER INFECTIOUS ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	9%	14%	6%	8%	16%	8%	10%	11%	7%	8%
5-9	2%	4%	2%	2%	6%	2%	3%	3%	1%	2%
10-14	2%	2%	2%	2%	1%	2%	2%	1%	2%	2%
15-19	3%	3%	3%	3%	2%	2%	2%	2%	4%	3%
20-24	3%	2%	3%	3%	2%	2%	2%	2%	4%	3%
25-29	3%	2%	2%	2%	2%	2%	2%	3%	4%	4%
30-34	3%	2%	2%	2%	2%	2%	2%	3%	4%	4%
35-39	2%	3%	1%	2%	3%	2%	2%	3%	3%	3%
40-44	1%	1%	-1%	0%	1%	1%	1%	1%	1%	1%
45-49	0%	0%	-1%	-1%	1%	0%	0%	0%	1%	1%
50-54	1%	0%	0%	0%	1%	1%	1%	0%	1%	1%
55-59	1%	1%	1%	1%	2%	1%	1%	1%	2%	1%
60-64	1%	1%	1%	1%	2%	0%	1%	1%	1%	1%
65-69	1%	1%	1%	1%	2%	1%	1%	1%	2%	1%
70-74	1%	2%	1%	1%	2%	1%	1%	1%	2%	2%
75-79	1%	3%	0%	1%	3%	0%	1%	2%	1%	1%
80-84	-1%	2%	-2%	-1%	2%	-1%	-1%	2%	-2%	0%
85+	-2%	0%	-3%	-2%	0%	-3%	-2%	1%	-3%	-2%
Average	2%	2%	1%	1%	3%	1%	2%	2%	2%	2%

Figure 24
MORTALITY FORECAST UNDER CANCER INFECTIOUS, FEMALE



5.5 MENTAL ELIMINATION

Table 16 and Table 17 report the mortality reduction percentage under mental death elimination for males and females, respectively. The average reductions over all age groups are small (2% for males and females). The effects are mostly concentrated at younger ages (age groups 1–4 through 35–39).

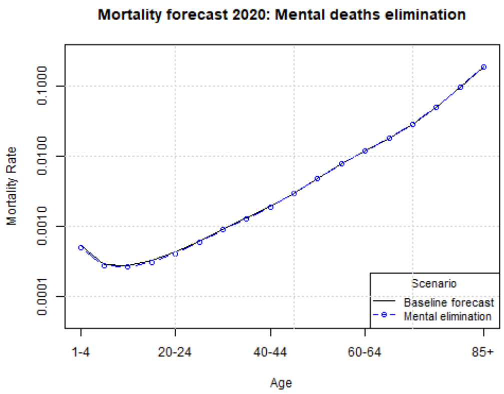
Figure 25 and Figure 26 visualize the (national) reduction rates for males and females.

Table 16
AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER MENTAL ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	5%	8%	5%	6%	5%	5%	5%	7%	5%	5%
5-9	5%	7%	3%	4%	5%	5%	5%	6%	5%	6%
10-14	5%	7%	6%	6%	5%	3%	3%	5%	5%	5%
15-19	6%	8%	9%	9%	4%	5%	5%	5%	7%	6%
20-24	5%	6%	7%	6%	3%	4%	4%	2%	5%	4%
25-29	3%	4%	2%	3%	3%	3%	3%	2%	3%	3%
30-34	3%	3%	2%	2%	3%	3%	3%	4%	4%	4%
35-39	3%	3%	2%	2%	3%	2%	2%	4%	3%	3%
40-44	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%
45-49	1%	0%	1%	1%	1%	1%	1%	1%	1%	1%
50-54	1%	0%	1%	1%	1%	0%	0%	1%	1%	1%
55-59	1%	0%	1%	1%	1%	1%	1%	0%	1%	1%
60-64	1%	1%	1%	1%	1%	0%	0%	0%	1%	1%
65-69	0%	1%	0%	0%	0%	0%	0%	0%	1%	0%
70-74	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
75-79	0%	0%	0%	0%	1%	0%	0%	0%	1%	1%
80-84	-1%	0%	-1%	-1%	0%	-2%	-1%	0%	-1%	-1%
85+	-1%	0%	-2%	-1%	-1%	-2%	-2%	-1%	-2%	-2%
Average	2%	3%	2%	2%	2%	2%	2%	2%	2%	2%

Figure 25

MORTALITY FORECAST UNDER MENTAL ELIMINATION, MALE



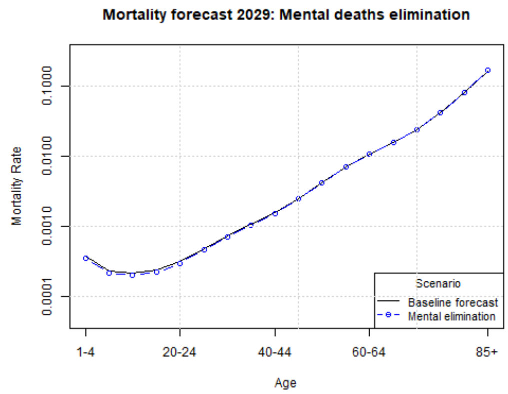


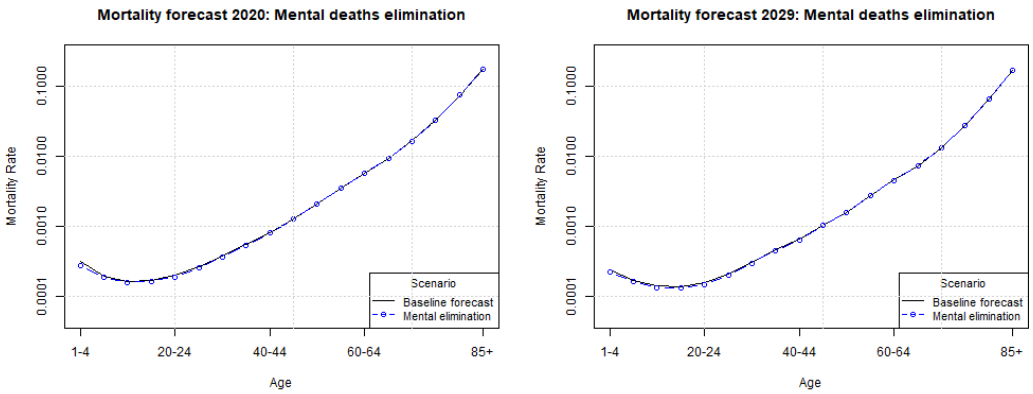
Table 17

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER MENTAL ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	9%	14%	6%	8%	16%	8%	10%	11%	7%	8%
5-9	2%	4%	2%	2%	6%	2%	3%	3%	1%	2%
10-14	3%	3%	5%	5%	1%	4%	3%	2%	3%	3%
15-19	5%	6%	6%	6%	2%	5%	4%	3%	6%	5%
20-24	5%	6%	6%	6%	3%	4%	4%	3%	6%	5%
25-29	4%	4%	4%	4%	2%	3%	3%	3%	5%	4%
30-34	3%	4%	3%	3%	3%	3%	3%	4%	4%	4%
35-39	3%	4%	2%	2%	3%	3%	3%	3%	3%	3%
40-44	1%	1%	0%	0%	1%	1%	1%	1%	1%	1%
45-49	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
50-54	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%
55-59	1%	1%	1%	1%	1%	1%	1%	0%	1%	1%
60-64	1%	1%	1%	1%	1%	0%	0%	0%	1%	1%
65-69	1%	1%	1%	1%	1%	0%	0%	0%	1%	1%
70-74	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%
75-79	1%	2%	0%	1%	1%	0%	0%	1%	0%	1%
80-84	-1%	1%	-1%	0%	0%	-1%	-1%	1%	-1%	0%
85+	-1%	-1%	-2%	-1%	-1%	-2%	-2%	0%	-2%	-1%
Average	2%	3%	2%	2%	2%	2%	2%	2%	2%	2%

Figure 26

MORTALITY FORECAST UNDER MENTAL ELIMINATION, FEMALE



5.6 RESPIRATORY ELIMINATION

Table 18 and Table 19 give the mortality reduction percentage under respiratory death elimination for males and females, respectively. The average reductions over all age groups are small (2% for males and females). The effects are mostly concentrated at older ages (60–64 – 75–79).

Figure 27 and Figure 28 visualize the (national) reduction rates for males and females.

Table 18

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER RESPIRATORY ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	1%	1%	1%	1%	0%	0%	0%	1%	2%	2%
5-9	1%	1%	0%	0%	1%	0%	0%	2%	1%	1%
10-14	1%	1%	1%	1%	1%	0%	0%	1%	1%	1%
15-19	1%	1%	1%	1%	0%	1%	1%	1%	2%	1%
20-24	1%	1%	1%	1%	0%	1%	1%	1%	1%	1%
25-29	1%	1%	0%	1%	1%	1%	1%	1%	1%	1%
30-34	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%
35-39	2%	1%	1%	1%	1%	1%	1%	2%	2%	2%
40-44	2%	1%	1%	1%	1%	1%	1%	2%	2%	2%
45-49	1%	0%	1%	1%	1%	1%	1%	2%	3%	2%
50-54	2%	-1%	2%	1%	1%	1%	1%	3%	4%	4%
55-59	3%	0%	3%	2%	2%	2%	2%	4%	7%	6%
60-64	3%	1%	2%	2%	3%	2%	2%	4%	8%	7%
65-69	3%	2%	1%	1%	3%	2%	2%	5%	10%	8%
70-74	6%	4%	1%	2%	5%	5%	5%	10%	13%	12%
75-79	8%	3%	3%	3%	9%	9%	9%	15%	15%	15%
80-84	1%	-2%	-3%	-3%	2%	0%	1%	13%	7%	9%
85+	-4%	0%	-9%	-5%	-4%	-9%	-8%	5%	0%	2%
Average	2%	1%	0%	1%	1%	1%	1%	4%	5%	4%

Figure 27

MORTALITY FORECAST UNDER RESPIRATORY ELIMINATION, MALE

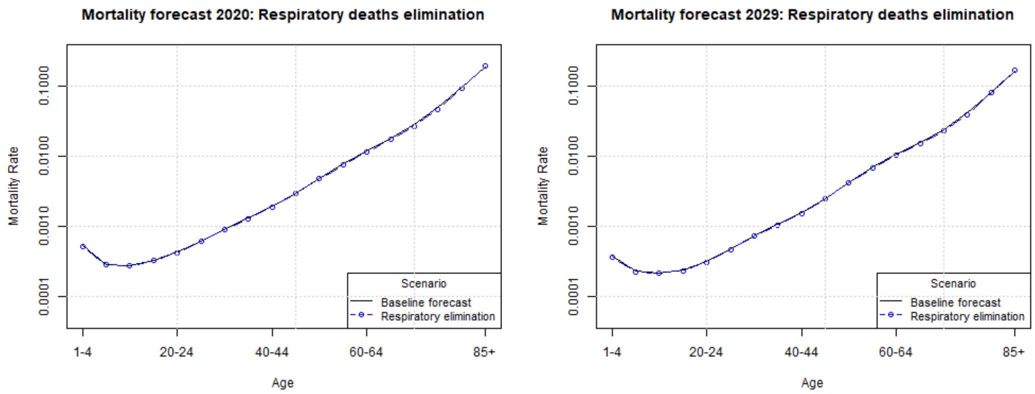


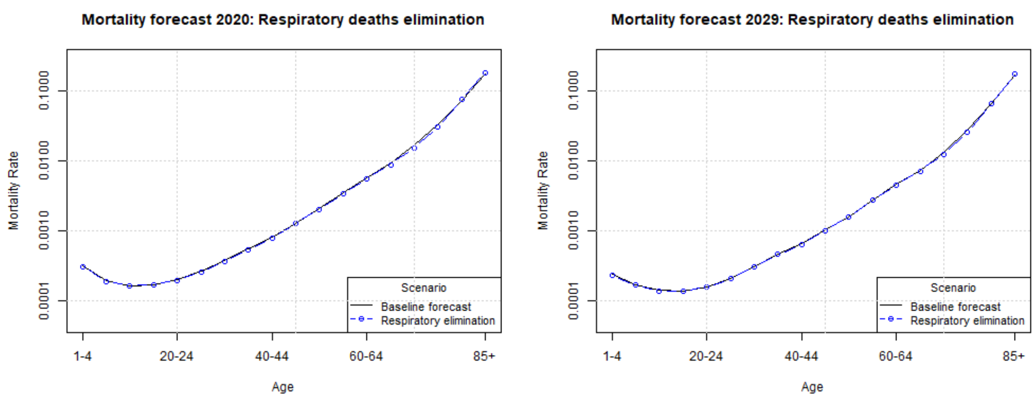
Table 19

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER RESPIRATORY ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	1%	2%	2%	2%	2%	0%	1%	1%	1%	1%
5-9	0%	1%	1%	1%	1%	0%	0%	1%	0%	0%
10-14	0%	0%	1%	1%	0%	0%	0%	0%	1%	1%
15-19	1%	1%	1%	1%	0%	0%	0%	1%	1%	1%
20-24	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
25-29	1%	0%	1%	1%	0%	1%	1%	1%	1%	1%
30-34	1%	1%	1%	1%	1%	1%	1%	2%	1%	1%
35-39	1%	1%	0%	1%	1%	1%	1%	2%	1%	2%
40-44	1%	1%	0%	0%	1%	1%	1%	2%	1%	1%
45-49	1%	0%	0%	0%	1%	1%	1%	1%	1%	1%
50-54	1%	0%	1%	1%	1%	2%	2%	1%	2%	2%
55-59	2%	1%	2%	1%	1%	2%	2%	2%	3%	3%
60-64	3%	2%	2%	2%	2%	2%	2%	4%	4%	4%
65-69	5%	3%	4%	4%	4%	4%	4%	7%	8%	8%
70-74	7%	5%	6%	6%	6%	6%	6%	11%	11%	11%
75-79	7%	7%	5%	5%	6%	7%	7%	14%	10%	11%
80-84	0%	2%	-4%	-2%	1%	0%	0%	12%	-1%	3%
85+	-5%	-4%	-8%	-6%	-5%	-8%	-7%	6%	-3%	0%
Average	2%	1%	1%	1%	1%	1%	1%	4%	2%	3%

Figure 28

MORTALITY FORECAST UNDER RESPIRATORY ELIMINATION, FEMALE



5.7 DIGESTIVE ELIMINATION

Table 20 and Table 21 give the mortality reduction percentage under respiratory death elimination for males and females, respectively. The average reductions over all age groups are small (1% for males and females).

Figure 28 and Figure 29 visualize the (national) reduction rates for males and females.

Table 20

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER DIGESTIVE ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	2%	1%	1%	1%	1%	1%	1%	2%	3%	3%
5-9	1%	1%	0%	0%	1%	0%	0%	2%	1%	1%
10-14	1%	1%	0%	0%	1%	0%	0%	1%	1%	1%
15-19	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
20-24	1%	1%	1%	1%	1%	1%	1%	1%	2%	1%
25-29	1%	2%	1%	1%	1%	1%	1%	2%	2%	2%
30-34	3%	2%	2%	2%	2%	2%	2%	4%	5%	4%
35-39	4%	4%	3%	4%	3%	3%	3%	6%	6%	6%
40-44	4%	4%	4%	4%	4%	2%	3%	5%	6%	5%
45-49	3%	1%	3%	2%	2%	1%	1%	3%	5%	5%
50-54	2%	-1%	2%	1%	2%	1%	1%	3%	5%	4%
55-59	2%	1%	2%	2%	2%	1%	2%	2%	5%	4%
60-64	1%	1%	1%	1%	2%	1%	1%	1%	3%	3%
65-69	1%	1%	0%	0%	1%	0%	0%	1%	2%	1%
70-74	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%
75-79	0%	0%	0%	0%	1%	0%	0%	1%	1%	1%
80-84	-1%	0%	-2%	-1%	-1%	-2%	-2%	0%	-1%	-1%
85+	-2%	0%	-2%	-1%	-1%	-2%	-2%	-1%	-2%	-2%
Average	1%	1%	1%	1%	1%	1%	1%	2%	3%	2%

Figure 29

MORTALITY FORECAST UNDER DIGESTIVE ELIMINATION, MALE

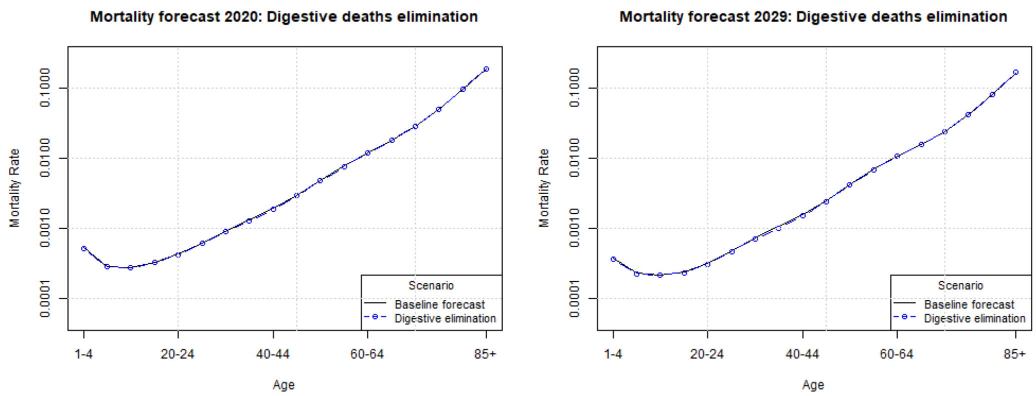


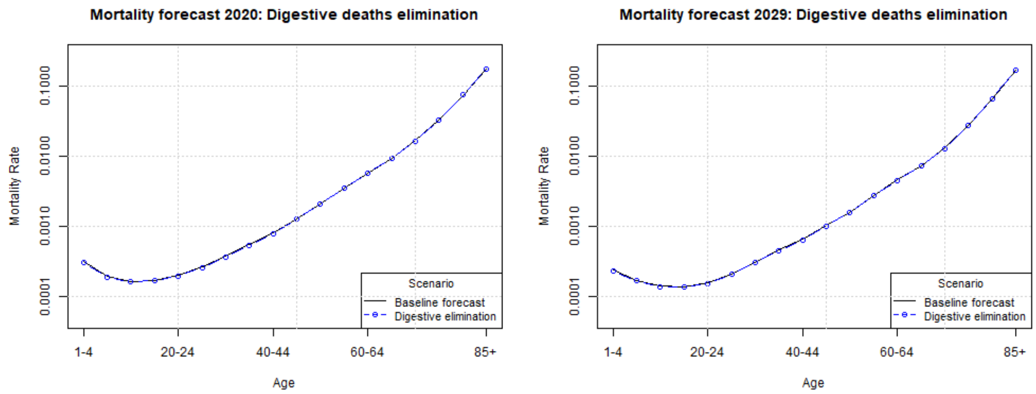
Table 21

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER DIGESTIVE ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	2%	3%	1%	2%	2%	1%	1%	2%	5%	4%
5-9	1%	2%	0%	1%	1%	0%	0%	1%	1%	1%
10-14	1%	1%	1%	1%	0%	0%	0%	0%	1%	1%
15-19	1%	2%	1%	1%	0%	1%	1%	1%	2%	2%
20-24	2%	2%	1%	2%	1%	1%	1%	1%	3%	2%
25-29	1%	2%	1%	1%	1%	1%	1%	1%	3%	2%
30-34	2%	2%	1%	1%	1%	1%	1%	2%	3%	3%
35-39	2%	2%	1%	1%	2%	1%	2%	2%	3%	2%
40-44	1%	1%	0%	0%	1%	1%	1%	1%	2%	2%
45-49	0%	0%	-1%	0%	1%	0%	0%	1%	2%	1%
50-54	1%	0%	0%	0%	1%	1%	1%	1%	2%	2%
55-59	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%
60-64	1%	2%	1%	1%	1%	0%	1%	1%	2%	2%
65-69	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%
70-74	1%	2%	1%	1%	2%	1%	1%	2%	2%	2%
75-79	1%	3%	0%	1%	2%	0%	1%	2%	1%	1%
80-84	-1%	1%	-2%	-1%	0%	-1%	-1%	1%	-1%	0%
85+	-1%	0%	-2%	-1%	-1%	-2%	-1%	0%	-2%	-1%
Average	1%	1%	0%	1%	1%	0%	1%	1%	2%	2%

Figure 30

MORTALITY FORECAST UNDER DIGESTIVE ELIMINATION, FEMALE



5.8 CONGENITAL ELIMINATION

Table 22 and Table 23 give the mortality reduction percentage under congenital death elimination for males and females, respectively. As noted above, we only consider ages below 30 for congenital deaths. The average reductions over the considered age groups are small (males: 4%, females: 5%), but there are substantial reductions at ages 1–4 (males: 11%, females: 13%).

Figure 31 and Figure 32 visualize the (national) reduction rates for males and females.

Table 22

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER CONGENITAL ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	11%	16%	8%	10%	11%	12%	11%	15%	8%	10%
5-9	3%	4%	2%	2%	5%	3%	3%	5%	4%	4%
10-14	2%	4%	2%	3%	4%	2%	2%	3%	2%	2%
15-19	2%	5%	3%	3%	2%	2%	2%	2%	2%	2%
20-24	2%	3%	2%	2%	1%	2%	2%	1%	1%	1%
25-29	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Average	4%	5%	3%	4%	4%	4%	4%	5%	3%	3%

Figure 31

MORTALITY FORECAST UNDER CONGENITAL ELIMINATION, MALE

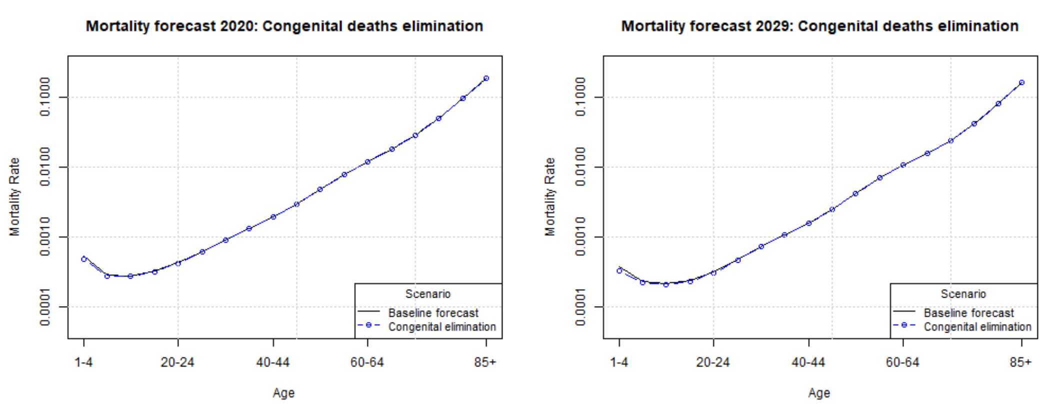


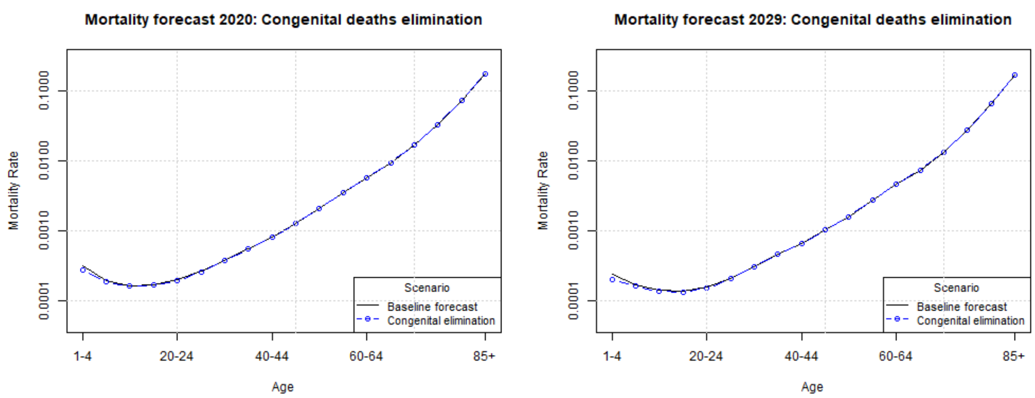
Table 23

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER CONGENITAL ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	13%	11%	10%	11%	24%	12%	15%	15%	12%	13%
5-9	3%	3%	5%	4%	7%	3%	4%	5%	1%	2%
10-14	3%	1%	4%	3%	2%	3%	3%	2%	3%	2%
15-19	4%	4%	4%	4%	2%	3%	3%	2%	4%	4%
20-24	3%	3%	4%	4%	3%	3%	3%	2%	4%	3%
25-29	2%	1%	2%	2%	1%	2%	1%	2%	2%	2%
Average	5%	4%	5%	5%	7%	4%	5%	5%	4%	4%

Figure 32

MORTALITY FORECAST UNDER CONGENITAL ELIMINATION, FEMALE



5.9 DIABETES ELIMINATION

Table 24 and Table 25 give the mortality reduction percentage under congenital death elimination for males and females, respectively. As noted above, we only consider ages from 30+ for diabetes deaths. The average reductions over the considered age groups are small (males: 1%, females: 2%).

Figure 33 and Figure 34 visualize the (national) reduction rates for males and females.

Table 24

AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER DIABETES ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
30-34	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
35-39	1%	2%	1%	1%	1%	1%	1%	2%	1%	1%
40-44	1%	2%	2%	2%	2%	1%	1%	2%	1%	1%
45-49	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
50-54	1%	0%	2%	1%	1%	1%	1%	1%	2%	1%
55-59	2%	1%	2%	2%	2%	2%	2%	1%	3%	2%
60-64	2%	1%	1%	1%	2%	1%	1%	1%	2%	2%
65-69	1%	2%	1%	1%	2%	0%	1%	1%	2%	1%
70-74	1%	1%	0%	0%	1%	0%	0%	1%	1%	1%
75-79	0%	0%	0%	0%	1%	0%	0%	1%	1%	1%
80-84	-1%	0%	-2%	-1%	0%	-2%	-1%	0%	-1%	-1%
85+	-1%	0%	-2%	-1%	0%	-2%	-1%	-1%	-2%	-1%
Average	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%

Figure 33
MORTALITY FORECAST UNDER DIABETES ELIMINATION, MALE

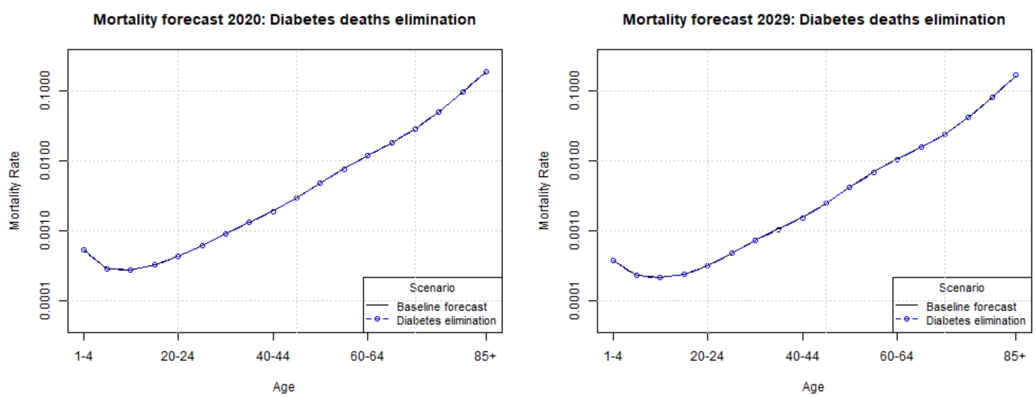
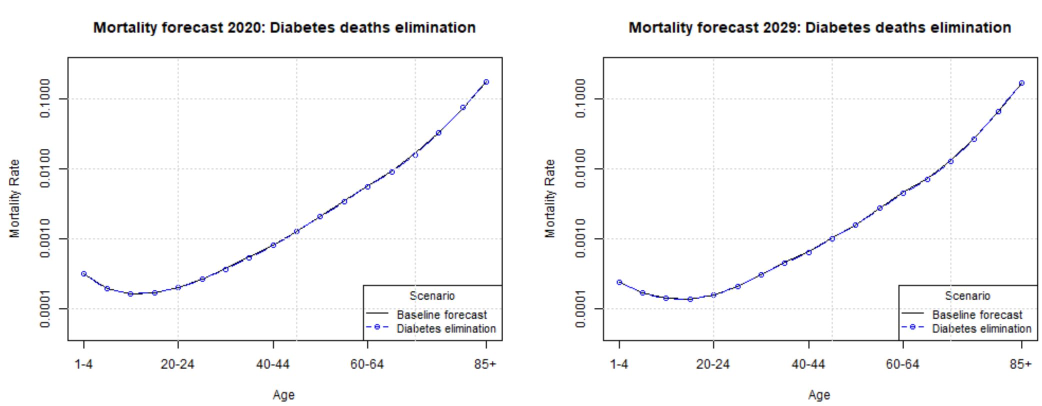


Table 25
AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER DIABETES ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
30-34	1%	2%	1%	1%	1%	1%	1%	1%	1%	1%
35-39	1%	2%	1%	1%	2%	1%	1%	1%	1%	1%
40-44	1%	1%	0%	0%	1%	1%	1%	1%	1%	1%
45-49	1%	0%	0%	0%	2%	1%	1%	1%	1%	1%
50-54	2%	1%	1%	1%	2%	2%	2%	1%	3%	2%
55-59	3%	2%	2%	2%	3%	3%	3%	2%	4%	3%
60-64	3%	3%	3%	3%	4%	3%	3%	3%	4%	3%
65-69	4%	3%	5%	4%	5%	4%	4%	4%	5%	5%
70-74	4%	4%	5%	5%	5%	3%	4%	4%	4%	4%
75-79	2%	5%	1%	2%	4%	1%	2%	3%	1%	2%
80-84	-1%	1%	-2%	-1%	1%	-1%	-1%	2%	-2%	-1%
85+	-1%	0%	-1%	-1%	0%	-2%	-1%	0%	-2%	-1%
Average	2%	2%	1%	2%	3%	1%	2%	2%	2%	2%

Figure 34
MORTALITY FORECAST UNDER DIABETES ELIMINATION, FEMALE



5.10 OTHER ELIMINATION

give the mortality reduction percentage under other death elimination for males and females, respectively. The average reductions over all age groups are small (males: 3%, females: 4%). The reductions are highest at ages 1–4 and then slowly decline with age. We note small negative reductions, i.e., increases at ages 80–84 and 85+. Figure 35 and Figure 36 visualize the (national) reduction rates for males and females.

Table 26
AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER OTHER ELIMINATION, MALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	10%	7%	6%	6%	4%	13%	11%	10%	12%	12%
5-9	6%	6%	3%	4%	4%	6%	6%	8%	7%	7%
10-14	5%	7%	5%	5%	5%	3%	3%	6%	5%	5%
15-19	6%	9%	7%	8%	4%	5%	5%	5%	6%	6%
20-24	6%	8%	8%	8%	3%	6%	5%	3%	5%	5%
25-29	5%	8%	4%	5%	5%	5%	5%	4%	4%	4%
30-34	6%	8%	5%	6%	6%	7%	6%	7%	6%	6%
35-39	6%	8%	6%	6%	5%	6%	6%	7%	6%	6%
40-44	4%	6%	4%	5%	4%	5%	4%	5%	4%	4%
45-49	3%	1%	3%	3%	2%	4%	3%	3%	3%	3%
50-54	3%	0%	3%	2%	1%	4%	3%	2%	4%	3%
55-59	3%	1%	3%	2%	2%	4%	3%	1%	4%	3%
60-64	2%	2%	2%	2%	1%	3%	2%	1%	3%	3%
65-69	1%	1%	0%	1%	1%	2%	2%	1%	2%	2%
70-74	1%	1%	0%	0%	1%	2%	1%	1%	2%	2%
75-79	1%	0%	0%	0%	1%	2%	2%	2%	1%	2%
80-84	-2%	0%	-3%	-2%	0%	-1%	-1%	0%	-2%	-2%
85+	-3%	0%	-4%	-3%	-1%	-4%	-3%	-3%	-6%	-5%
Average	3%	4%	3%	3%	3%	4%	4%	4%	4%	4%

Figure 35
MORTALITY FORECAST UNDER OTHER ELIMINATION, FEMALE

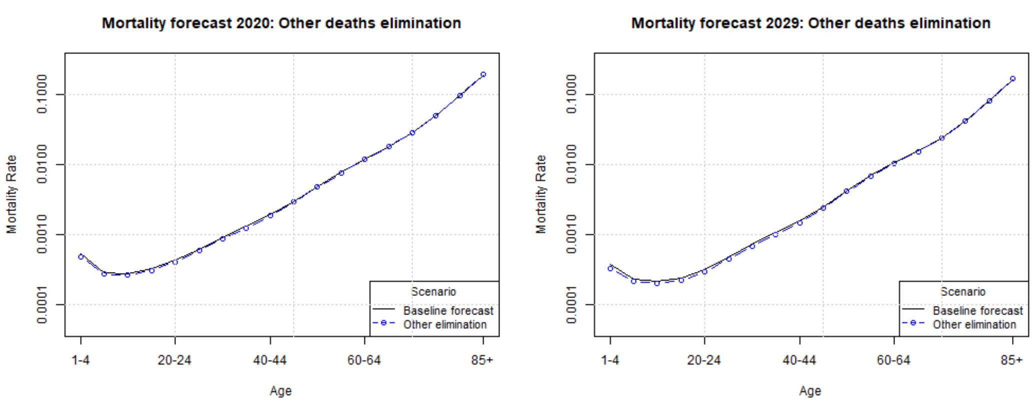


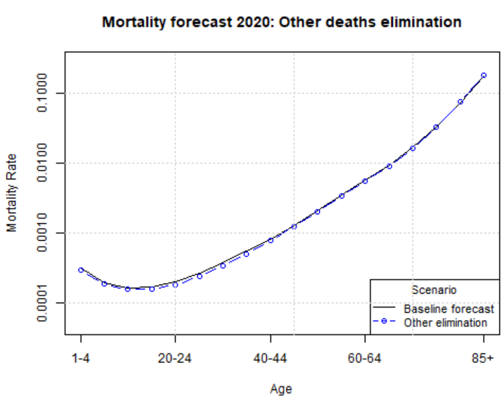
Table 27

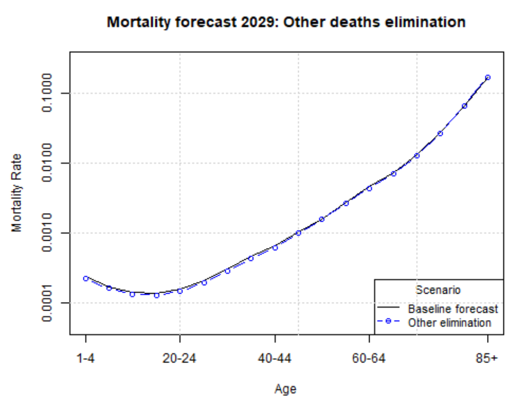
AVERAGE MORTALITY REDUCTION PERCENTAGE UNDER OTHER ELIMINATION, FEMALE

Age	National	East			Central			West		
		Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
1-4	6%	9%	6%	7%	7%	6%	6%	8%	5%	6%
5-9	4%	4%	3%	4%	5%	4%	5%	5%	2%	3%
10-14	5%	5%	6%	6%	1%	5%	4%	3%	4%	4%
15-19	7%	8%	9%	9%	2%	7%	6%	6%	7%	7%
20-24	8%	8%	11%	10%	4%	8%	7%	6%	9%	8%
25-29	8%	8%	8%	8%	4%	7%	7%	7%	9%	9%
30-34	9%	9%	8%	8%	7%	9%	8%	9%	9%	9%
35-39	7%	8%	6%	6%	8%	9%	8%	7%	7%	7%
40-44	4%	3%	2%	2%	4%	6%	5%	4%	4%	4%
45-49	3%	2%	1%	1%	2%	5%	4%	2%	4%	3%
50-54	3%	1%	2%	2%	2%	5%	5%	2%	5%	4%
55-59	4%	4%	3%	3%	3%	6%	5%	3%	5%	4%
60-64	4%	4%	3%	3%	4%	5%	5%	3%	4%	4%
65-69	4%	3%	4%	3%	3%	5%	5%	4%	4%	4%
70-74	4%	3%	3%	3%	3%	5%	5%	4%	3%	3%
75-79	2%	3%	1%	2%	2%	4%	3%	3%	1%	2%
80-84	-1%	1%	-2%	-1%	1%	0%	0%	1%	-3%	-2%
85+	-3%	-1%	-3%	-2%	-1%	-4%	-3%	-1%	-6%	-4%
Average	4%	5%	4%	4%	4%	5%	5%	4%	4%	4%

Figure 36

MORTALITY FORECAST UNDER OTHER ELIMINATION, FEMALE





Section 6: Conclusion

In this report, we analyze the most up-to-date mortality information for China, both at the national level and across geographic regions, urban and rural areas, and causes of death. We first divide the population into three broad regions, namely East, Central, and West. We then further divide the data into urban and rural areas. Finally, we consider 10 leading causes of death to be included in our research. We model and forecast mortality rates at different levels using the forecast reconciliation framework, which ensures the consistency and coherence of forecasts across different levels. The basic idea of forecast reconciliation is to utilize all data available, not just at the top level (i.e., the total/national mortality rate) and not just at the bottom level (i.e., region-area-cause-specific mortality rate). We generate forecasts that consider all information across the hierarchy and ensure there is no conflict in the mortality forecasts across different levels.

In the following, we first summarize the key results from the project and then address the potential limitations of the research.

6.1 SUMMARY OF KEY RESULTS

Our investigation period is from 2004 to 2019. During this period:

- The average mortality improvement rate is estimated to be around 3.2% per annum.
- East China has the highest average mortality improvement rate (around 3.4%), and West China has the lowest average mortality improvement rate (around 2.9%).
- Urban and rural show similar average mortality improvement rates. Urban: higher improvement for older ages; Rural: higher improvement for younger ages.
- Circulatory is the #1 cause for people over age 65; External is the #1 cause for people below age 35 (excluding age 0).

We produce reconciled mortality forecasts for the years 2020–2029 and find,

- The average improvement rate is expected to decrease by 1% for the next 10 years, which is estimated to be around 2.2% per annum.
- The geographical gap across East, Central, and West China is likely to continue.
- The urban and rural mortality gap is predicted to be narrower.

We also conduct mortality prediction under several cause-elimination scenarios and find,

- Cancer elimination: reduces mortality by 25%, on average; largest reduction for ages 40–65.
- External elimination: reduces mortality by 19%, on average; largest reduction for ages 1–35.
- Circulatory elimination: reduce mortality by 33%, one average; reduction largest for ages 65+.

6.2 LIMITATIONS

For readers of this report, particularly those who would like to apply the results produced by this research project, it is important to understand the potential limitations of the research. We note that the CDMD dataset has a much smaller sample size compared to census data. In 2019, the total population exposure is about 277 million. Moreover, the data is collected from the NDSS surveillance sites. Since 2013, there has been a significant expansion of the surveillance sites, and as a result, the sample size is more than doubled compared to earlier years. We suspect that there might be certain sampling issues arising from the expansion. Finally, although the population ratio across East, Central, and West China, as well as urban/rural areas, is relatively stable in each year, there is still some degree of variation from year to year. We suspect that this may also have a slight impact on our results.

Section 7: Acknowledgments

The researchers' deepest gratitude goes to those without whose efforts this project could not have come to fruition: the Project Oversight Group and others for their diligent work overseeing questionnaire development, analyzing and discussing respondent answers, and reviewing and editing this report for accuracy and relevance.

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References

Arnold, S., & Glushko, V. (2021). Short-and long-term dynamics of cause-specific mortality rates using cointegration analysis. *North American Actuarial Journal*, 1-23.

Bo, Z., Wan, Y., Meng, S. S., Lin, T., Kuang, W., Jiang, L., & Qiu, P. (2019). The temporal trend and distribution characteristics in mortality of Alzheimer's disease and other forms of dementia in China: Based on the National Mortality Surveillance System (NMS) from 2009 to 2015. *PloS One*, 14(1), e0210621.

Cao, W., Chen, H. D., Yu, Y. W., Li, N., & Chen, W. Q. (2021). Changing profiles of cancer burden worldwide and in China: a secondary analysis of the global cancer statistics 2020. *Chinese Medical Journal*, 134(07), 783-791.

Fang, L., Gao, P., Bao, H., Tang, X., Wang, B., Feng, Y., ... & Wang, L. (2018). Chronic obstructive pulmonary disease in China: a nationwide prevalence study. *The Lancet Respiratory Medicine*, 6(6), 421-430.

Jiang, D., Zhang, L., Liu, W., Ding, Y., Yin, J., Ren, R., ... & Cao, G. (2021). Trends in cancer mortality in China from 2004 to 2018: A nationwide longitudinal study. *Cancer Communications*, 41(10), 1024-1036.

Li, H., & Hyndman, R. J. (2021). Assessing mortality inequality in the U.S.: What can be said about the future? *Insurance: Mathematics and Economics*, 99, 152-162.

Li, H., & Tang, Q. (2019). Analyzing mortality bond indexes via hierarchical forecast reconciliation. *ASTIN Bulletin: The Journal of the IAA*, 49(3), 823-846.

Li, H., Hanewald, K., & Wu, S. (2021). Healthy life expectancy in China: Modelling and implications for public and private insurance. *Annals of Actuarial Science*, 15(1), 40-56.

Li, H., Li, H., Lu, Y., & Panagiotelis, A. (2019). A forecast reconciliation approach to cause-of-death mortality modeling. *Insurance: Mathematics and Economics*, 86, 122-133.

Li, J., Li, B., Zhang, F., & Sun, Y. (2017). Urban and rural stroke mortality rates in China between 1988 and 2013: An age-period-cohort analysis. *Journal of International Medical Research*, 45(2), 680-690.

Lyu, P., De Waegenaere, A., & Melenberg, B. (2021). A multi-population approach to forecasting all-cause mortality using cause-of-death mortality data. *North American Actuarial Journal,* 25(sup1), S421-S456.

Wang, L., Ning, P., Yin, P., Cheng, P., Schwebel, D. C., Liu, J., ... & Hu, G. (2019). Road traffic mortality in China: analysis of national surveillance data from 2006 to 2016. *The Lancet Public Health*, 4(5), e245-e255.

Wang, Z., Hu, S., Sang, S., Luo, L., & Yu, C. (2017). Age–period–cohort analysis of stroke mortality in China: Data from the Global Burden of Disease Study 2013. *Stroke*, 48(2), 271-275.

Wickramasuriya, S. L., Athanasopoulos, G., & Hyndman, R. J. (2019). Optimal forecast reconciliation for hierarchical and grouped time series through trace minimization. *Journal of the American Statistical Association*, 114(526), 804-819.

Yin, P., Feng, X., Astell-Burt, T., Page, A., Liu, J., Liu, Y., ... & Zhou, M. (2016a). Temporal trends and geographic variations in dementia mortality in China between 2006 and 2012. *Alzheimer Disease & Associated Disorders*, 30(4), 348-353.

Yin, P., Feng, X., Astell-Burt, T., Qi, F., Liu, Y., Liu, J., ... & Zhou, M. (2016b). Spatiotemporal variations in chronic obstructive pulmonary disease mortality in China: multilevel evidence from 2006 to 2012. *COPD: Journal of Chronic Obstructive Pulmonary Disease*, 13(3), 339-344.

Zhou, M., Wang, H., Zeng, X., Yin, P., Zhu, J., Chen, W., ... & Liang, X. (2019). Mortality, morbidity, and risk factors in China and its provinces, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, 394(10204), 1145-1158.

Zhou, M., Wang, H., Zhu, J., Chen, W., Wang, L., Liu, S., Li, Y., Wang, L., Liu, Y., Yin, P., & Liu, J. (2016). Cause-specific mortality for 240 causes in China during 1990–2013: a systematic subnational analysis for the Global Burden of Disease Study 2013. *The Lancet*, 387(10015), pp.251-272.

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