Forecasting US Mortality Using Cohort Smoking Index

(Extended Abstract)

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Demographers are among the many professionals who produce mortality forecasts. There are three major methods in mortality forecasting that are being used today: the Lee-Carter method, the method used by Social Security Administration, and the method used by Census Bureau. All these methods are based on observations of past trends in period levels of mortality and assumptions about how and whether those trends will be modified in the future.

Smoking has long been considered as a key factor that affects the mortality of the population (U.S. Surgeon General, 1964; Preston, 1970; Doll, et. al, 1994; Pampel, 2002 & 2005, Preston & Wang, forthcoming). Since the Surgeon General's report in 1964, the Americans have been well informed about the negative effects of smoking on health and mortality. However, around 44 million Americans aged 20+ in 2000 were current smokers. Another 44 million were former smokers.

Most studies on smoking and mortality focus on micro-level populations. Taylor & et al (2002) argue that the earlier the smokers quit, the greater the life extension can be realized. Smokers who quit at age 35 will realize a 7 years or so life extension compared with those who continue to smoke. Rogers et al (2005) used the 1990 National Health Interview Survey Health Promotion and Disease Prevention Supplement and matched it to the Multiple Cause of Death files (NHIS-MCD) via the National Death Index through 1997. Their study confirms that current smokers have twice the morality risks than non-smokers in the seven-year follow-up period. Former smokers exhibit higher mortality too.

However, in the arena of mortality forecasting, smoking has been rarely taken into consideration. In this paper, we incorporate a cohort-smoking factor into the original Lee-Carter model to project mortality for U.S. We build on the Lee-Carter model by producing mortality forecasts for males and females jointly rather than separately. We utilize years spent as current smoker by age 40 as an indicator of smoking history for each cohort.

The Lee-Carter model (Lee & Carter, 1992) is widely used to forecast mortality:

$$\ln(M_{x,t}) = a_x + b_x \cdot k_t + \varepsilon_{x,t} \qquad \text{(Equation 1)}$$

In this model, $M_{x,t}$ is the central mortality rate for age x at time t, while a_x describes the mortality profile by age, which is constant over time; k_t represents the temporal trend of mortality changes over time; and b_x describes the changes in the mortality rates at age x in response to changes in k_t over time. $\varepsilon_{x,t}$ is the error term, which depicts the age-specific historical influences that are not explained by the model.

In their original 1992 paper, Lee and Carter applied their model to the sex-combined U.S population, instead of applying it separately to male and female population, due to concerns about extrapolating differentials. We estimate the Lee-Cater model separately with male and female U.S populations between 1974 and 2002 for age group 40-85. From figure 1, we can see that the temporal trends of mortality are different for males and females, with male mortality declining faster.

Preston & Wang (2006) argued that sex differences in mortality in the U.S population for the past 50 years or so could be partly explained by the differences in cohort smoking behaviors between males and females. The age/period/cohort analysis they employed showed significant effect of smoking histories on men and women's mortality. Here we argue that the sex difference in temporal changes in mortality over the past 30 years can be explained by the divergent paths of smoking behaviors and histories between men and women in the U.S., and we use this analysis to inform projections. Figure 2 shows that years spent as current smoker has been on a fast declining trend for the male cohorts born after 1910. However, the same index for women had been increasing prior to the cohort born between 1945 and 1949. In general, the gap between men and women in this index had been declining since the cohorts born at the beginning of last century.

In our model, we assume that men and women will share one common temporal trend of mortality change over time when we control the effects of sex differentials in smoking histories. The new model is:

$$\ln(M_{x,t}^{Female}) = a_x^{Female} + b_x^{Female} \cdot k_t + w \cdot S_{x,t}^{F} + \varepsilon_{x,t}^{Female} \quad \text{(Equation 2.1)}$$

$$\ln(M_{x,t}^{Male}) = a_x^{Male} + b_x^{Male} \cdot k_t + c \cdot S_{x,t}^{M} + \varepsilon_{x,t}^{Male} \quad \text{(Equation 2.2)}$$

In the above equations, a_x^{Female} and a_x^{Male} stand for the mortality profile by age for women and men, respectively, when smoking histories are controlled; b_x^{Female} and b_x^{Male} stand for changes in mortality at age x, for women and men respectively, in response to the changes in mortality trend over time, i.e., k_t, which is the same for both men and women when smoking histories are controlled; $S_{x,t}^{F}$ and $S_{x,t}^{M}$ are matrices of cohort smoking index for women and men by single year and single age. The difference between this modified Lee-Carter Model (henceforth MLC) and the original Lee-Carter Model (LC) is that we introduce cohort smoking behaviors into the models, and men and women share a common mortality decline trend, k_t. These two functions can be solved simultaneously by using the method that Lee and Carter (1992) originally proposed.

To solve them, we transform equations 2.1 and 2.2 into the following forms:

$$\ln(M_{x,t}^{Female}) - w \cdot S_{x,t}^{F} = a_x^{Female} + b_x^{Female} \cdot k_t + \varepsilon_{x,t}^{Female} \quad \text{(Equation 2.1.1)}$$

$$\ln(M_{x,t}^{Male}) - c \cdot S_{x,t}^{M} = a_x^{Male} + b_x^{Male} \cdot k_t + \varepsilon_{x,t}^{Male} \quad \text{(Equation 2.2.1)}$$

Then, we can combine the above two equations into one:

$$\begin{bmatrix} \ln(M_{x,t}^{Male}) - c \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female}) - w \cdot S_{x,t}^{F} \end{bmatrix} = \begin{bmatrix} a_x^{Male} \\ a_x^{Female} \end{bmatrix} + \begin{bmatrix} b_x^{Male} \\ b_x^{Female} \end{bmatrix} \cdot k_t + \begin{bmatrix} \varepsilon_{x,t}^{Male} \\ \varepsilon_{x,t}^{Female} \end{bmatrix} \quad \text{(Equation 3)}$$

We get Equation 3 by simply stacking Equation 2.1.1 and 2.2.1 vertically. For example, $\begin{bmatrix} \ln(M_{x,t}^{Male}) - c \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female}) - w \cdot S_{x,t}^{F} \end{bmatrix}$ is a new matrix in Equation 3 by stacking matrices $(\ln(M_{x,t}^{Female}) - w \cdot S_{x,t}^{F})$ and $(\ln(M_{x,t}^{Male}) - c \cdot S_{x,t}^{M})$ vertically. Equation 3 can be solved by the method that Lee and Carter used, i.e., singular value decomposition. However, we must find the proper values for c and w. In order to get the values for c and w, we need to minimize the sum of the squared errors, E, which is defined in the following form:

$$E = Sum\left\{ diag((\begin{bmatrix} \ln(M_{x,t}^{Male})' - c' \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female})' - w' \cdot S_{x,t}^{F} \end{bmatrix} - \begin{bmatrix} \ln(M_{x,t}^{Male}) - c' \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female}) - w' \cdot S_{x,t}^{F} \end{bmatrix}) * (\begin{bmatrix} \ln(M_{x,t}^{Male})' - c' \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female})' - w' \cdot S_{x,t}^{F} \end{bmatrix} - \begin{bmatrix} \ln(M_{x,t}^{Male}) - c' \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female}) - w' \cdot S_{x,t}^{F} \end{bmatrix})^{T}) \right\}$$

Where $\begin{bmatrix} \ln(M_{x,t}^{Male})' - c' \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female})' - w' \cdot S_{x,t}^{F} \end{bmatrix}$ is the estimated matrix given $c = c'$ and $w = w'$. So, E is equal to sum of all the squared elements in the error matrix, which is $(\begin{bmatrix} \ln(M_{x,t}^{Male})' - c' \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female})' - w' \cdot S_{x,t}^{F} \end{bmatrix} - \begin{bmatrix} \ln(M_{x,t}^{Male}) - c' \cdot S_{x,t}^{M} \\ \ln(M_{x,t}^{Female}) - w' \cdot S_{x,t}^{F} \end{bmatrix})$.

The mortality data we use are from Human Mortality Database. We use single-year age-specific mortality rates from age 40 to 85 for every calendar year from 1974 to 2002. Numerators of mortality rates were also obtained from Human Mortality Database. The cohort-smoking index that we used in this paper is reconstructed from the work by Burns et al. (1998). They carefully reconstructed cohort-smoking histories for Americans for every 5-year birth cohort born between year 1885 and 1969 (similar information are only available for African Americans born between 1900 and 1969) from a total of 15 National Health Interview Surveys (NHIS) conducted from 1965 to 1991. They also considered the differential mortality between smokers and non-smokers and obtained estimates for each birth cohorts from the information provided by the living members of the cohorts. David Burns also provided us with information of more recent birth cohorts reconstructed from three additional NHIS surveys conducted though 2001.

We simulated the parameters c and w in R and got the optimized set of parameters, in which $c' = 0.017$, $w' = 0.005$. And the following values, a_x^{Female} and a_x^{Male} (as shown in Table 1), b_x^{Female} and b_x^{Male} (as shown in table 2) and k_t (as shown in table 3), are estimated simultaneously.

The next step is forecasting the mortality index, k_t. After we followed the standard procedures (as suggested by Box and Jenkins, 1970 & Makridakis et.al. 1998) to find the appropriate ARIMA time series model for the mortality trend, k_t, ARIMA(0,1,0), in other words, random walk with a drift, best describes our index. Using this model, we forecast the values of k_t to year 2018(see appendix 1 for detailed results).

In order to get the forecasts of age-specific mortality rates between 2003 and 2018 for age group 40-85, we need the smoking indexes for four more cohorts, i.e., cohort born between 1965-1969, 1970-1974, 1975-1979, and 1980-1984. The data we have are limited in terms of predicting age-specific current smoking prevalence. For white population, we have part of the data that we need (see appendix 2). Based on this incomplete dataset, a reasonable strategy is to get the index we need, that is, years spent as current smoker by age 40, from years spent as current smoker by age 35, by age 30, by age 25 or by age 20.

Since we have the complete data (current smoking prevalence by age up to age 39) for 16 consecutive cohorts before cohort born between 1965-1969, we fit four models first using these data. From appendix 3, we can see that together with a time variable, cohort (here it represents the birth cohort), years spent as current smoker by age 35 can explain more than 99% of the variance of years spent as current smoker by age 40 for both white males and females. And so does years spent as smoker by age 30, 25, and 20, although the percentage of variance explained becomes progressively lower at younger ages. We then use these models to extrapolate the smoking index we want for the next four cohorts (See table 4). The reconstructed indices for our analysis are shown in table 6.

Using the parameters from the fitted model and the projected k_t and smoking index, we can easily produce the age specific mortality rate for age group 40-85 between year 2003 and 2018. The forecasted mortality rates are shown in table 7.

To summarize, the innovations of this research relative to the Lee-Carter model are the following:

- smoking data are utilized in forecasts
- a cohort approach is integrated to complement what had been exclusively a period-based analysis
- males and females are integrated into one model rather than treated separately

Table 1: estimated a_x^{Male} and a_x^{Female}

age	a_x^{Male}	a_x^{Female}	age	a_x^{Male}	a_x^{Female}
40	-6.03566	-6.53617	63	-4.14444	-4.49365
41	-5.94723	-6.43945	64	-4.07297	-4.42568
42	-5.87741	-6.34524	65	-3.98184	-4.33151
43	-5.80826	-6.2582	66	-3.90835	-4.25818
44	-5.75292	-6.18724	67	-3.82946	-4.17404
45	-5.66661	-6.09658	68	-3.73509	-4.08089
46	-5.58304	-6.00532	69	-3.66024	-4.00305
47	-5.50302	-5.91799	70	-3.5598	-3.89381
48	-5.40038	-5.79912	71	-3.48814	-3.81372
49	-5.36345	-5.74977	72	-3.39117	-3.70159
50	-5.26363	-5.64913	73	-3.31228	-3.61269
51	-5.17339	-5.54928	74	-3.23703	-3.53601
52	-5.0855	-5.45573	75	-3.155	-3.43755
53	-5.01034	-5.37204	76	-3.07129	-3.34556
54	-4.93777	-5.30414	77	-2.98849	-3.25631
55	-4.83417	-5.2061	78	-2.91618	-3.16648
56	-4.75272	-5.11201	79	-2.82736	-3.05954
57	-4.67229	-5.0325	80	-2.72105	-2.94176
58	-4.55373	-4.91454	81	-2.63047	-2.84019
59	-4.49999	-4.8565	82	-2.54107	-2.7273
60	-4.39302	-4.754	83	-2.44438	-2.6181
61	-4.31505	-4.6632	84	-2.35572	-2.50913
62	-4.20849	-4.56084	85	-2.26822	-2.40586

Table 2. Estimated b_x^{male} and b_x^{female}

Age	b_x^{Male}	b_x^{female}	Age	b_x^{Male}	b_x^{female}
40	0.001279	0.008103	63	0.014703	0.007209
41	0.001976	0.008638	64	0.014286	0.006576
42	0.004218	0.011031	65	0.014733	0.006643
43	0.004104	0.010239	66	0.014279	0.005522
44	0.005393	0.011439	67	0.014711	0.006267
45	0.007540	0.012133	68	0.013963	0.005668
46	0.007114	0.012364	69	0.013900	0.006230
47	0.008874	0.012704	70	0.016065	0.009141
48	0.010106	0.013154	71	0.013554	0.006947
49	0.011877	0.012837	72	0.015217	0.008368
50	0.014069	0.014756	73	0.014504	0.008560
51	0.013088	0.012833	74	0.014626	0.008990
52	0.014208	0.012479	75	0.014555	0.009661
53	0.013836	0.011475	76	0.013573	0.008736
54	0.015143	0.011549	77	0.013250	0.008187
55	0.014627	0.010832	78	0.011374	0.007761
56	0.014547	0.010779	79	0.011426	0.008434
57	0.014965	0.009816	80	0.013278	0.010114
58	0.014865	0.009357	81	0.011751	0.008730
59	0.015043	0.008691	82	0.012230	0.009171
60	0.016539	0.010717	83	0.011828	0.009456
61	0.014302	0.007737	84	0.011678	0.009416
62	0.015144	0.008464	85	0.010895	0.008850

Table 3. Estimated k_t

Year	k_t	Year	k_t
1974	20.12134	1989	-1.66449
1975	16.22732	1990	-3.73350
1976	14.61115	1991	-5.05725
1977	11.82370	1992	-6.75558
1978	10.56669	1993	-5.45088
1979	7.45922	1994	-6.84476
1980	8.74940	1995	-7.41069
1981	6.50563	1996	-8.68154
1982	4.81656	1997	-10.38270
1983	4.90692	1998	-11.03930
1984	3.80021	1999	-10.85100
1985	3.83902	2000	-12.01810
1986	2.48154	2001	-13.17540
1987	1.15101	2002	-13.87250
1988	0.93515		

Table 4: Smoking Index for U.S. White Population by gender

White Males		White Females	
Birth Cohort	Years Spent as Current Smoker by Age 40	Birth Cohort	Years Spent as Current Smoker by Age 40
Actual Values			
1885-1889	11.57	1885-1889	0.84
1890-1894	12.87	1890-1894	1.36
1895-1899	15.84	1895-1899	2.39
1900-1904	16.62	1900-1904	3.19
1905-1909	17.54	1905-1909	5.28
1910-1914	17.87	1910-1914	7.50
1915-1919	17.84	1915-1919	8.88
1920-1924	17.65	1920-1924	9.31
1925-1929	17.29	1925-1929	10.09
1930-1934	16.42	1930-1934	10.35
1935-1939	15.14	1935-1939	10.49
1940-1944	14.43	1940-1944	10.45
1945-1949	12.49	1945-1949	9.17
1950-1954	10.75	1950-1954	8.43
1955-1959	9.99	1955-1959	8.87
1960-1964	8.71	1960-1964	8.25
Projected Values			
1965-1969	7.68	1965-1969	7.00
1970-1974	7.13	1970-1974	6.18
1975-1979	7.60	1975-1979	6.12
1980-1984	7.28	1980-1984	5.74

Table 5. Cohort Map of Smoking Index for age group 40-85: U.S. 2003-2018

	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
2003	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18	18	18	18	17	17	17
2004	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18	18	18	18	17	17
2005	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18	18	18	18	17
2006	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18	18	18	18
2007	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18	18	18
2008	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18	18
2009	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18
2010	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18
2011	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19
2012	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19
2013	23	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19
2014	24	23	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19
2015	24	24	23	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19
2016	24	24	24	23	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20
2017	24	24	24	24	23	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20
2018	24	24	24	24	24	23	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20

	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
2003	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14	13	13	13	13	13	12
2004	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14	13	13	13	13	13
2005	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14	13	13	13	13
2006	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14	13	13	13
2007	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14	13	13
2008	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14	13
2009	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14
2010	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14
2011	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14
2012	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14
2013	19	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14
2014	19	19	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15	15
2015	19	19	19	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15	15
2016	19	19	19	19	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15	15
2017	20	19	19	19	19	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15	15
2018	20	20	19	19	19	19	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	15

*12: cohort born between 1914-1918; 13: cohort born between 1919-1923; 14: cohort born between 1924-1928; 15: cohort born between 1929-1933; 16: cohort born between 1934-1938; 17: cohort born between 1939-1943; 18: cohort born between 1944-1948; 19: cohort born between 1949-1953; 20: cohort born between 1954-1958; 21: cohort born between 1959-1963; 22: cohort born between 1964-1968; 23: cohort born between 1969-1973; 24: cohort born between 1974-1978;

Table 6. Actual and Projected Cohort Smoking Index

All Males				All Females			
Cohort	Born Between		Years Spent as Current Smoker	Cohort	Born Between		Years Spent as Current Smoker
Actual Values							
7	1889	1893	12.48	7	1889	1893	1.21
8	1894	1898	14.98	8	1894	1898	2.08
9	1899	1903	16.39	9	1899	1903	2.95
10	1904	1908	17.26	10	1904	1908	4.66
11	1909	1913	17.77	11	1909	1913	6.84
12	1914	1918	17.85	12	1914	1918	8.47
13	1919	1923	17.71	13	1919	1923	9.18
14	1924	1928	17.40	14	1924	1928	9.86
15	1929	1933	16.69	15	1929	1933	10.27
16	1934	1938	15.53	16	1934	1938	10.45
17	1939	1943	14.64	17	1939	1943	10.46
18	1944	1948	13.07	18	1944	1948	9.55
19	1949	1953	11.27	19	1949	1953	8.65
20	1954	1958	10.22	20	1954	1958	8.74
Projected Values							
21	1959	1963	9.09	21	1959	1963	8.43
22	1964	1968	7.99	22	1964	1968	7.38
23	1969	1973	7.29	23	1969	1973	6.43
24	1974	1978	7.46	24	1974	1978	6.14

Table 7.1. Projected Age Specific Mortality Rates: U.S. Males; 2003-2018

	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
2003	0.002738	0.002960	0.003069	0.003294	0.003415	0.003673	0.004019	0.004240	0.004612	0.004659	0.005071	0.005632	0.006047	0.006555	0.006911	0.007966
2004	0.002683	0.002953	0.003053	0.003278	0.003392	0.003571	0.003985	0.004194	0.004555	0.004592	0.004896	0.005544	0.005943	0.006446	0.006785	0.007590
2005	0.002679	0.002891	0.003037	0.003261	0.003370	0.003538	0.003876	0.004149	0.004500	0.004527	0.004813	0.005359	0.005842	0.006339	0.006662	0.007456
2006	0.002675	0.002884	0.002966	0.003245	0.003348	0.003506	0.003842	0.004027	0.004445	0.004462	0.004732	0.005275	0.005640	0.006233	0.006540	0.007325
2007	0.002671	0.002877	0.002950	0.003169	0.003326	0.003474	0.003809	0.003984	0.004308	0.004398	0.004652	0.005191	0.005543	0.006020	0.006421	0.007196
2008	0.002667	0.002870	0.002935	0.003153	0.003243	0.003442	0.003776	0.003941	0.004255	0.004253	0.004573	0.005110	0.005448	0.005920	0.006192	0.007069
2009	0.002631	0.002864	0.002920	0.003138	0.003222	0.003348	0.003744	0.003899	0.004203	0.004192	0.004410	0.005029	0.005355	0.005821	0.006079	0.006821
2010	0.002627	0.002823	0.002906	0.003122	0.003201	0.003317	0.003643	0.003857	0.004152	0.004132	0.004336	0.004856	0.005264	0.005725	0.005969	0.006701
2011	0.002623	0.002816	0.002857	0.003106	0.003180	0.003287	0.003611	0.003745	0.004101	0.004073	0.004262	0.004780	0.005076	0.005629	0.005860	0.006583
2012	0.002619	0.002810	0.002842	0.003055	0.003159	0.003257	0.003580	0.003705	0.003976	0.004015	0.004190	0.004704	0.004989	0.005431	0.005753	0.006467
2013	0.002615	0.002803	0.002828	0.003040	0.003102	0.003227	0.003549	0.003665	0.003927	0.003883	0.004119	0.004630	0.004904	0.005340	0.005541	0.006353
2014	0.002618	0.002796	0.002813	0.003024	0.003082	0.003160	0.003519	0.003626	0.003879	0.003828	0.003974	0.004557	0.004820	0.005251	0.005440	0.006123
2015	0.002614	0.002798	0.002799	0.003009	0.003061	0.003132	0.003448	0.003587	0.003832	0.003773	0.003907	0.004402	0.004737	0.005164	0.005341	0.006016
2016	0.002610	0.002791	0.002792	0.002994	0.003041	0.003103	0.003418	0.003507	0.003785	0.003719	0.003840	0.004332	0.004570	0.005078	0.005244	0.005910
2017	0.002606	0.002784	0.002778	0.002988	0.003022	0.003075	0.003389	0.003469	0.003695	0.003666	0.003775	0.004264	0.004491	0.004900	0.005149	0.005806
2018	0.002602	0.002777	0.002764	0.002973	0.003010	0.003047	0.003360	0.003432	0.003650	0.003571	0.003711	0.004197	0.004415	0.004819	0.004961	0.005704

	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
2003	0.008652	0.009318	0.010507	0.011057	0.012357	0.013817	0.015177	0.016289	0.017606	0.019446	0.021072	0.022654	0.025179	0.027161	0.029643	0.033075
2004	0.008501	0.009150	0.010319	0.010857	0.011792	0.013579	0.014900	0.016000	0.017303	0.018816	0.020710	0.022253	0.024756	0.026707	0.028505	0.032535
2005	0.008100	0.008985	0.010134	0.010661	0.011557	0.012993	0.014629	0.015717	0.017006	0.018483	0.020051	0.021859	0.024340	0.026260	0.027954	0.031381
2006	0.007958	0.008557	0.009953	0.010468	0.011327	0.012770	0.013984	0.015439	0.016713	0.018155	0.019706	0.021152	0.023930	0.025821	0.027414	0.030869
2007	0.007819	0.008403	0.009480	0.010278	0.011102	0.012550	0.013729	0.014766	0.016426	0.017833	0.019368	0.020778	0.023177	0.025388	0.026885	0.030365
2008	0.007682	0.008252	0.009310	0.009788	0.010882	0.012334	0.013479	0.014505	0.015718	0.017517	0.019035	0.020410	0.022788	0.024591	0.026366	0.029870
2009	0.007547	0.008104	0.009144	0.009611	0.010343	0.012122	0.013233	0.014248	0.015448	0.016753	0.018707	0.020049	0.022405	0.024180	0.025471	0.029382
2010	0.007283	0.007958	0.008980	0.009437	0.010138	0.011554	0.012992	0.013996	0.015182	0.016456	0.017901	0.019694	0.022028	0.023775	0.024979	0.028472
2011	0.007156	0.007675	0.008820	0.009266	0.009936	0.011355	0.012371	0.013749	0.014921	0.016164	0.017594	0.018835	0.021658	0.023377	0.024496	0.028007
2012	0.007031	0.007537	0.008508	0.009098	0.009739	0.011159	0.012145	0.013098	0.014664	0.015878	0.017291	0.018502	0.020732	0.022986	0.024023	0.027550
2013	0.006907	0.007401	0.008356	0.008775	0.009545	0.010967	0.011924	0.012866	0.013977	0.015596	0.016994	0.018174	0.020384	0.022006	0.023559	0.027100
2014	0.006787	0.007268	0.008206	0.008616	0.009189	0.010778	0.011707	0.012639	0.013737	0.014858	0.016702	0.017853	0.020041	0.021637	0.022495	0.026658
2015	0.006542	0.007137	0.008059	0.008460	0.009006	0.010404	0.011494	0.012415	0.013501	0.014594	0.015920	0.017537	0.019704	0.021275	0.022060	0.025531
2016	0.006427	0.006876	0.007915	0.008307	0.008827	0.010225	0.011083	0.012195	0.013269	0.014335	0.015646	0.016707	0.019373	0.020919	0.021634	0.025115
2017	0.006315	0.006752	0.007627	0.008156	0.008652	0.010049	0.010881	0.011766	0.013041	0.014081	0.015377	0.016411	0.018473	0.020569	0.021216	0.024705
2018	0.006204	0.006631	0.007490	0.007857	0.008480	0.009876	0.010683	0.011558	0.012588	0.013832	0.015113	0.016120	0.018162	0.019615	0.020807	0.024302

Table 7.1. (Continued)

	72	73	74	75	76	77	78	79	80	81	82	83	84	85
2003	0.035540	0.038874	0.041834	0.046016	0.050781	0.055434	0.061301	0.066943	0.072779	0.081536	0.088519	0.098099	0.107436	0.118934
2004	0.034890	0.038195	0.041098	0.044663	0.049951	0.054550	0.060461	0.066020	0.071243	0.080381	0.087214	0.096700	0.105924	0.117095
2005	0.034251	0.037528	0.040375	0.043881	0.048540	0.053679	0.059631	0.065111	0.070103	0.078830	0.085929	0.095321	0.104433	0.115556
2006	0.032969	0.036873	0.039664	0.043112	0.047747	0.052183	0.058814	0.064214	0.068982	0.077713	0.084222	0.093962	0.102963	0.114038
2007	0.032366	0.035524	0.038966	0.042357	0.046967	0.051351	0.057305	0.063329	0.067879	0.076613	0.082981	0.092141	0.101513	0.112539
2008	0.031774	0.034904	0.037535	0.041615	0.046199	0.050531	0.056519	0.061701	0.066794	0.075527	0.081758	0.090827	0.099563	0.111060
2009	0.031192	0.034295	0.036874	0.040090	0.045444	0.049725	0.055744	0.060851	0.064930	0.074457	0.080553	0.089532	0.098161	0.109030
2010	0.030621	0.033697	0.036225	0.039388	0.043831	0.048931	0.054980	0.060013	0.063892	0.072514	0.079365	0.088255	0.096779	0.107598
2011	0.029612	0.033108	0.035588	0.038698	0.043115	0.047213	0.054225	0.059186	0.062870	0.071487	0.077249	0.086997	0.095417	0.106184
2012	0.029070	0.032045	0.034961	0.038020	0.042410	0.046459	0.052441	0.058371	0.061865	0.070474	0.076111	0.084719	0.094074	0.104789
2013	0.028538	0.031486	0.033834	0.037354	0.041717	0.045718	0.051721	0.056446	0.060875	0.069476	0.074989	0.083511	0.091627	0.103412
2014	0.028016	0.030936	0.033238	0.036153	0.041035	0.044989	0.051012	0.055668	0.058736	0.068492	0.073884	0.082320	0.090337	0.100818
2015	0.027503	0.030396	0.032653	0.035519	0.039762	0.044271	0.050312	0.054901	0.057796	0.066207	0.072795	0.081147	0.089065	0.099493
2016	0.026288	0.029866	0.032078	0.034897	0.039113	0.042914	0.049622	0.054145	0.056872	0.065269	0.070326	0.079990	0.087811	0.098186
2017	0.025806	0.028571	0.031514	0.034286	0.038473	0.042230	0.048212	0.053399	0.055963	0.064345	0.069289	0.077314	0.086575	0.096896
2018	0.025334	0.028072	0.030143	0.033685	0.037844	0.041556	0.047551	0.051878	0.055068	0.063433	0.068268	0.076212	0.083695	0.095622

Table 7.2. Projected Age Specific Mortality Rates: U.S. Females; 2003-2018

	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
2003	0.001338	0.001463	0.001550	0.001711	0.001804	0.001958	0.002137	0.002321	0.002596	0.002740	0.002942	0.003347	0.003695	0.004079	0.004361	0.004884
2004	0.001318	0.001447	0.001529	0.00169	0.001779	0.001926	0.002106	0.002285	0.002555	0.002698	0.002892	0.003295	0.003640	0.004023	0.004300	0.004799
2005	0.001305	0.001425	0.001509	0.001669	0.001755	0.001898	0.002071	0.002250	0.002514	0.002656	0.002840	0.003246	0.003585	0.003967	0.004240	0.004736
2006	0.001293	0.001410	0.001481	0.001649	0.001731	0.001870	0.002040	0.002212	0.002474	0.002615	0.002790	0.003196	0.003532	0.003912	0.004181	0.004674
2007	0.001280	0.001395	0.001461	0.001620	0.001707	0.001843	0.002010	0.002178	0.002431	0.002575	0.002740	0.003146	0.003479	0.003860	0.004123	0.004613
2008	0.001267	0.00138	0.001442	0.001600	0.001674	0.001816	0.001980	0.002145	0.002393	0.002531	0.002692	0.003098	0.003427	0.003806	0.004067	0.004553
2009	0.001249	0.001366	0.001423	0.001580	0.001651	0.001780	0.001950	0.002112	0.002355	0.002492	0.002640	0.003050	0.003376	0.003753	0.004011	0.004495
2010	0.001237	0.001345	0.001404	0.001560	0.001628	0.001754	0.001911	0.002080	0.002318	0.002453	0.002593	0.002998	0.003325	0.003702	0.003955	0.004437
2011	0.001225	0.001331	0.001379	0.001541	0.001606	0.001728	0.001883	0.002037	0.002281	0.002415	0.002547	0.002952	0.003270	0.003650	0.003900	0.004379
2012	0.001213	0.001318	0.001360	0.001515	0.001584	0.001703	0.001855	0.002006	0.002233	0.002378	0.002502	0.002906	0.003221	0.003594	0.003845	0.004321
2013	0.001201	0.001304	0.001342	0.001496	0.001555	0.001678	0.001827	0.001975	0.002198	0.002329	0.002457	0.002861	0.003172	0.003545	0.003786	0.004265
2014	0.001187	0.001290	0.001324	0.001478	0.001533	0.001646	0.001800	0.001945	0.002163	0.002293	0.002401	0.002817	0.003125	0.003496	0.003733	0.004203
2015	0.001176	0.001275	0.001307	0.001459	0.001512	0.001622	0.001765	0.001915	0.002129	0.002257	0.002358	0.002759	0.003078	0.003447	0.003681	0.004148
2016	0.001164	0.001262	0.001287	0.001441	0.001491	0.001598	0.001738	0.001877	0.002095	0.002222	0.002316	0.002716	0.003015	0.003400	0.003630	0.004094
2017	0.001153	0.001248	0.001270	0.001422	0.001471	0.001575	0.001712	0.001848	0.002052	0.002188	0.002275	0.002674	0.002970	0.003335	0.00358	0.004040
2018	0.001142	0.001235	0.001253	0.001404	0.001448	0.001552	0.001687	0.001820	0.002019	0.002144	0.002235	0.002633	0.002925	0.003289	0.003511	0.003987

	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
2003	0.005370	0.005900	0.006685	0.007156	0.007724	0.008848	0.009694	0.010566	0.011418	0.012532	0.013715	0.014753	0.016340	0.017513	0.018679	0.020918
2004	0.005301	0.00583	0.006609	0.007081	0.007590	0.008765	0.009595	0.010474	0.011327	0.012432	0.013624	0.014641	0.016228	0.017381	0.018489	0.020742
2005	0.005208	0.005761	0.006535	0.007006	0.007492	0.008643	0.009497	0.010383	0.011237	0.012332	0.013534	0.014530	0.016116	0.017250	0.018285	0.020586
2006	0.005140	0.005667	0.006461	0.006933	0.007395	0.008563	0.009357	0.010292	0.011148	0.012233	0.013443	0.014421	0.016006	0.017120	0.018083	0.020413
2007	0.005073	0.005600	0.006359	0.006860	0.007299	0.008483	0.009262	0.010156	0.011059	0.012135	0.013353	0.014312	0.015897	0.016991	0.017884	0.020242
2008	0.005008	0.005534	0.006287	0.006757	0.007205	0.008403	0.009167	0.010068	0.010921	0.012037	0.013264	0.014203	0.015788	0.016865	0.017686	0.020072
2009	0.004942	0.005468	0.006216	0.006686	0.007080	0.008325	0.009073	0.009980	0.010834	0.011886	0.013176	0.014095	0.015680	0.016737	0.017493	0.019903
2010	0.004880	0.005403	0.006146	0.006616	0.006988	0.008210	0.008980	0.009893	0.010748	0.011791	0.013028	0.013989	0.015573	0.016611	0.017300	0.019737
2011	0.004817	0.005342	0.006076	0.006547	0.006898	0.008133	0.008849	0.009807	0.010663	0.011696	0.012941	0.013819	0.015466	0.016486	0.017109	0.019572
2012	0.004754	0.005278	0.00601	0.006478	0.006809	0.008057	0.008758	0.009677	0.010578	0.011602	0.012855	0.013715	0.015290	0.016362	0.016920	0.019407
2013	0.004692	0.005216	0.005943	0.006413	0.006721	0.007981	0.008669	0.009593	0.010446	0.011509	0.012769	0.013611	0.015185	0.016165	0.016733	0.019244
2014	0.004631	0.005154	0.005875	0.006345	0.006637	0.007907	0.008580	0.009510	0.010363	0.011365	0.012683	0.013508	0.015081	0.016043	0.016473	0.019083
2015	0.004564	0.005093	0.005809	0.006279	0.006551	0.007836	0.008492	0.009427	0.010281	0.011274	0.012542	0.013405	0.014978	0.015922	0.016292	0.018836
2016	0.004505	0.005025	0.005743	0.006213	0.006466	0.007763	0.008409	0.009345	0.010199	0.011183	0.012458	0.013244	0.014875	0.015802	0.016112	0.018678
2017	0.004446	0.004965	0.005670	0.006148	0.006383	0.007691	0.008323	0.009267	0.010118	0.011093	0.012375	0.013143	0.014706	0.015683	0.015934	0.018521
2018	0.004389	0.004907	0.005606	0.006074	0.006300	0.007619	0.008238	0.009186	0.010042	0.011004	0.012292	0.013044	0.014605	0.015495	0.015758	0.018366

Table 7.2 (Continued)

	72	73	74	75	76	77	78	79	80	81	82	83	84	85
2003	0.022903	0.02496	0.026775	0.029188	0.032449	0.035774	0.039389	0.043392	0.047433	0.053611	0.059621	0.066215	0.073884	0.082330
2004	0.022672	0.024702	0.026485	0.028907	0.032107	0.035420	0.03902	0.042950	0.047013	0.053046	0.058961	0.065459	0.073044	0.081741
2005	0.022443	0.024447	0.026197	0.028570	0.031834	0.03507	0.038654	0.042512	0.046439	0.052665	0.058308	0.064712	0.072214	0.080868
2006	0.022235	0.024194	0.025913	0.028237	0.031498	0.034795	0.038291	0.042079	0.045872	0.052109	0.057858	0.063973	0.071393	0.080003
2007	0.022011	0.023965	0.025632	0.027908	0.031166	0.034451	0.038011	0.041650	0.045313	0.051560	0.057217	0.063457	0.070581	0.079148
2008	0.021788	0.023717	0.025376	0.027582	0.030837	0.034110	0.037654	0.041311	0.044760	0.051016	0.056583	0.062733	0.070015	0.078303
2009	0.021568	0.023472	0.025100	0.027285	0.030512	0.033773	0.037301	0.040891	0.044305	0.050478	0.055957	0.062017	0.069220	0.077728
2010	0.021350	0.023229	0.024828	0.026967	0.030216	0.033439	0.036951	0.040474	0.043764	0.050050	0.055337	0.061309	0.068433	0.076898
2011	0.021136	0.022989	0.024558	0.026652	0.029898	0.033137	0.036605	0.040062	0.043230	0.049522	0.054838	0.060609	0.067655	0.076076
2012	0.020922	0.022753	0.024292	0.026341	0.029582	0.032810	0.036293	0.039654	0.042703	0.049000	0.054231	0.060041	0.066886	0.075263
2013	0.020711	0.022518	0.024030	0.026034	0.029270	0.032485	0.035953	0.039284	0.042182	0.048483	0.053630	0.059356	0.066263	0.074458
2014	0.020501	0.022285	0.023769	0.025733	0.028961	0.032164	0.035616	0.038884	0.041703	0.047972	0.053037	0.058678	0.065510	0.073816
2015	0.020294	0.022055	0.023511	0.025433	0.028658	0.031846	0.035282	0.038488	0.041194	0.047508	0.052449	0.058009	0.064765	0.073027
2016	0.019998	0.021827	0.023256	0.025136	0.028356	0.031533	0.034951	0.038096	0.040692	0.047007	0.051914	0.057347	0.064029	0.072246
2017	0.019796	0.021503	0.023003	0.024843	0.028056	0.031221	0.034626	0.037708	0.040195	0.046512	0.051339	0.056742	0.063302	0.071474
2018	0.019596	0.021281	0.022650	0.024553	0.027760	0.030913	0.034301	0.037326	0.039705	0.046021	0.050771	0.056094	0.062637	0.070711

Table 8.1. Life Table for U.S. Males in 2003

Age	${}_nM_x$	a_x	${}_nq_x$	${}_np_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e_x	From NCHS	Diff %*
40	0.00274	0.5	0.00273	0.99727	100000	273.5	99863.3	371953	37.20	37.27	-0.199
41	0.00296	0.5	0.00296	0.99704	99726.5	294.8	99579.1	361967	36.30	36.36	-0.184
42	0.00307	0.5	0.00306	0.99694	99431.8	304.7	99279.4	352009	35.40	35.46	-0.174
43	0.00329	0.5	0.00329	0.99671	99127.1	326.0	98964.1	342081	34.51	34.57	-0.176
44	0.00341	0.5	0.00341	0.99659	98801.1	336.8	98632.7	332184	33.62	33.68	-0.175
45	0.00367	0.5	0.00367	0.99633	98464.3	361.0	98283.8	322321	32.73	32.80	-0.198
46	0.00402	0.5	0.00401	0.99599	98103.3	393.5	97906.5	312493	31.85	31.92	-0.216
47	0.00424	0.5	0.00423	0.99577	97709.8	413.4	97503.1	302702	30.98	31.06	-0.250
48	0.00461	0.5	0.00460	0.99540	97296.4	447.7	97072.6	292952	30.11	30.20	-0.296
49	0.00466	0.5	0.00465	0.99535	96848.8	450.2	96623.7	283245	29.25	29.35	-0.339
50	0.00507	0.5	0.00506	0.99494	96398.6	487.6	96154.8	273582	28.38	28.50	-0.423
51	0.00563	0.5	0.00562	0.99438	95911.0	538.7	95641.7	263967	27.52	27.66	-0.511
52	0.00605	0.5	0.00603	0.99397	95372.3	575.0	95084.8	254402	26.67	26.83	-0.585
53	0.00656	0.5	0.00653	0.99347	94797.4	619.4	94487.7	244894	25.83	26.01	-0.669
54	0.00691	0.5	0.00689	0.99311	94178.0	648.6	93853.6	235445	25.00	25.18	-0.724
55	0.00797	0.5	0.00793	0.99207	93529.3	742.1	93158.3	226060	24.17	24.37	-0.835
56	0.00865	0.5	0.00861	0.99139	92787.2	799.4	92387.6	216744	23.36	23.57	-0.876
57	0.00932	0.5	0.00927	0.99073	91987.9	853.2	91561.3	207505	22.56	22.78	-0.964
58	0.01051	0.5	0.01045	0.98955	91134.7	952.5	90658.5	198349	21.76	21.98	-0.962
59	0.01106	0.5	0.01100	0.98900	90182.2	991.7	89686.4	189283	20.99	21.20	-0.991
60	0.01236	0.5	0.01228	0.98772	89190.5	1095	88642.9	180315	20.22	20.44	-1.071
61	0.01382	0.5	0.01372	0.98628	88095.2	1209	87490.8	171450	19.46	19.69	-1.161
62	0.01518	0.5	0.01506	0.98494	86886.4	1309	86232.0	162701	18.73	18.94	-1.154
63	0.01629	0.5	0.01616	0.98384	85577.6	1383	84886.3	154078	18.00	18.22	-1.195
64	0.01761	0.5	0.01745	0.98255	84195.0	1469	83460.3	145589	17.29	17.50	-1.213
65	0.01945	0.5	0.01926	0.98074	82725.6	1593	81929.0	137243	16.59	16.80	-1.258
66	0.02107	0.5	0.02085	0.97915	81132.4	1692	80286.5	129051	15.91	16.11	-1.254
67	0.02265	0.5	0.02240	0.97760	79440.6	1780	78550.8	121022	15.23	15.43	-1.251
68	0.02518	0.5	0.02487	0.97513	77661.1	1931	76695.5	113167	14.57	14.76	-1.294
69	0.02716	0.5	0.02680	0.97320	75730.0	2029	74715.3	105497	13.93	14.11	-1.265
70	0.02964	0.5	0.02921	0.97079	73700.6	2153	72624.2	980262	13.30	13.48	-1.303
71	0.03308	0.5	0.03254	0.96746	71547.7	2328	70383.8	907638	12.69	12.86	-1.323
72	0.03554	0.5	0.03492	0.96508	69219.8	2417	68011.2	837254	12.10	12.24	-1.198
73	0.03887	0.5	0.03813	0.96187	66802.7	2547	65529.0	769243	11.52	11.65	-1.197
74	0.04183	0.5	0.04098	0.95902	64255.3	2633	62938.8	703714	10.95	11.08	-1.162
75	0.04602	0.5	0.04498	0.95502	61622.3	2772	60236.4	640775	10.40	10.52	-1.155
76	0.05078	0.5	0.04952	0.95048	58850.5	2914	57393.2	580539	9.87	9.99	-1.217
77	0.05543	0.5	0.05394	0.94606	55936.0	3017	54427.4	523145	9.35	9.47	-1.238
78	0.0613	0.5	0.05948	0.94052	52918.8	3148	51345.1	468718	8.86	8.97	-1.235
79	0.06694	0.5	0.06477	0.93523	49771.3	3224	48159.4	417373	8.39	8.48	-1.119
80	0.07278	0.5	0.07022	0.92978	46547.4	3269	44913.0	369214	7.93	8.02	-1.047
81	0.08154	0.5	0.07834	0.92166	43278.7	3391	41583.4	324301	7.49	7.58	-1.126
82	0.08852	0.5	0.08477	0.91523	39888.1	3381	38197.5	282717	7.09	7.16	-0.984
83	0.0981	0.5	0.09351	0.90649	36506.9	3414	34800.0	244520	6.70	6.75	-0.743
84	0.10744	0.5	0.10196	0.89804	33093.1	3374	31406.0	209720	6.34	6.40	-0.926
85+	0.16667	5.46	1	0	29718.9	29716	178314	178314	6.00	6.00	

* diff % =100*(projected 2003-NCHS 2003)/NCHS 2003

Table 8.2. Life Table for U.S. Females in 2003

Age	${}_nM_x$	a_x	${}_nq_x$	${}_np_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e_x	From NCHS	Diff %*
40	0.00134	0.5	0.00134	0.99866	100000	133.8	99933.1	4166912	41.67	41.61	0.134
41	0.00146	0.5	0.00146	0.99854	99866.2	146.0	99793.3	4066978	40.72	40.68	0.118
42	0.00155	0.5	0.00155	0.99845	99720.3	154.4	99643.1	3967185	39.78	39.74	0.104
43	0.00171	0.5	0.00171	0.99829	99565.8	170.2	99480.7	3867542	38.84	38.81	0.081
44	0.00180	0.5	0.00180	0.99820	99395.6	179.2	99306.0	3768061	37.91	37.88	0.067
45	0.00196	0.5	0.00196	0.99804	99216.4	194.1	99119.4	3668755	36.98	36.96	0.036
46	0.00214	0.5	0.00214	0.99786	99022.4	211.4	98916.7	3569636	36.05	36.05	0.006
47	0.00232	0.5	0.00232	0.99768	98811.0	229.0	98696.4	3470719	35.12	35.14	-0.030
48	0.00260	0.5	0.00259	0.99741	98581.9	255.6	98454.2	3372023	34.21	34.23	-0.061
49	0.00274	0.5	0.00274	0.99726	98326.4	269.1	98191.8	3273569	33.29	33.32	-0.082
50	0.00294	0.5	0.00294	0.99706	98057.3	288.1	97913.3	3175377	32.38	32.42	-0.115
51	0.00335	0.5	0.00334	0.99666	97769.2	326.7	97605.9	3077464	31.48	31.52	-0.152
52	0.00370	0.5	0.00369	0.99631	97442.5	359.4	97262.8	2979858	30.58	30.63	-0.174
53	0.00408	0.5	0.00407	0.99593	97083.1	395.2	96885.5	2882595	29.69	29.75	-0.194
54	0.00436	0.5	0.00435	0.99565	96687.9	420.7	96477.6	2785709	28.81	28.87	-0.191
55	0.00488	0.5	0.00487	0.99513	96267.2	469.0	96032.7	2689232	27.94	27.99	-0.213
56	0.00537	0.5	0.00536	0.99464	95798.2	513.1	95541.6	2593199	27.07	27.13	-0.210
57	0.00590	0.5	0.00588	0.99412	95285.1	560.5	95004.8	2497657	26.21	26.27	-0.229
58	0.00668	0.5	0.00666	0.99334	94724.6	631.1	94409.0	2402653	25.36	25.41	-0.196
59	0.00716	0.5	0.00713	0.99287	94093.5	670.9	93758.0	2308244	24.53	24.58	-0.189
60	0.00772	0.5	0.00769	0.99231	93422.6	718.9	93063.1	2214486	23.70	23.75	-0.194
61	0.00885	0.5	0.00881	0.99119	92703.7	816.6	92295.4	2121423	22.88	22.94	-0.232
62	0.00969	0.5	0.00965	0.99035	91887.1	886.5	91443.9	2029127	22.08	22.12	-0.175
63	0.01057	0.5	0.01051	0.98949	91000.6	956.5	90522.4	1937683	21.29	21.33	-0.153
64	0.01142	0.5	0.01135	0.98865	90044.2	1022	89533.0	1847161	20.51	20.54	-0.111
65	0.01253	0.5	0.01245	0.98755	89021.9	1109	88467.5	1757628	19.74	19.76	-0.100
66	0.01372	0.5	0.01362	0.98638	87913.2	1198	87314.4	1669160	18.99	19.00	-0.051
67	0.01475	0.5	0.01464	0.98536	86715.7	1270	86080.7	1581846	18.24	18.24	0.022
68	0.01634	0.5	0.01621	0.98379	85445.8	1385	84753.3	1495765	17.51	17.49	0.067
69	0.01751	0.5	0.01736	0.98264	84060.9	1459	83331.2	1411012	16.79	16.76	0.150
70	0.01868	0.5	0.01851	0.98149	82601.5	1529	81837.2	1327681	16.07	16.04	0.230
71	0.02092	0.5	0.02070	0.97930	81072.9	1678	80233.7	1245843	15.37	15.34	0.205
72	0.02290	0.5	0.02264	0.97736	79394.6	1798	78495.7	1165610	14.68	14.64	0.285
73	0.02496	0.5	0.02465	0.97535	77596.7	1913	76640.3	1087114	14.01	13.96	0.358
74	0.02678	0.5	0.02642	0.97358	75683.8	2000	74683.9	1010474	13.35	13.29	0.445
75	0.02919	0.5	0.02877	0.97123	73684.1	2120	72624.2	935789.8	12.70	12.64	0.471
76	0.03245	0.5	0.03193	0.96807	71564.3	2285	70421.8	863165.6	12.06	12.01	0.469
77	0.03577	0.5	0.03515	0.96485	69279.2	2435	68061.8	792743.8	11.44	11.39	0.480
78	0.03939	0.5	0.03863	0.96137	66844.3	2582	65553.3	724682.1	10.84	10.79	0.466
79	0.04339	0.5	0.04247	0.95753	64262.3	2729	62897.6	659128.8	10.26	10.21	0.493
80	0.04743	0.5	0.04633	0.95367	61533.0	2851	60107.5	596231.1	9.69	9.64	0.476
81	0.05361	0.5	0.05221	0.94779	58681.9	3064	57150.0	536123.6	9.14	9.11	0.297
82	0.05962	0.5	0.05790	0.94210	55618.1	3220	54008.1	478973.6	8.61	8.59	0.241
83	0.06621	0.5	0.06409	0.93591	52398.0	3358	50718.9	424965.6	8.11	8.09	0.216
84	0.07388	0.5	0.07125	0.92875	49039.7	3494	47292.6	374246.7	7.63	7.64	-0.129
85+	0.13930	5.455	1	0	45545.6	29716	326954	326954.1	7.18	7.18	

* diff % =100*(projected 2003-NCHS 2003)/NCHS 2003

Figure 1. Kt estimated using Lee-Cater Model

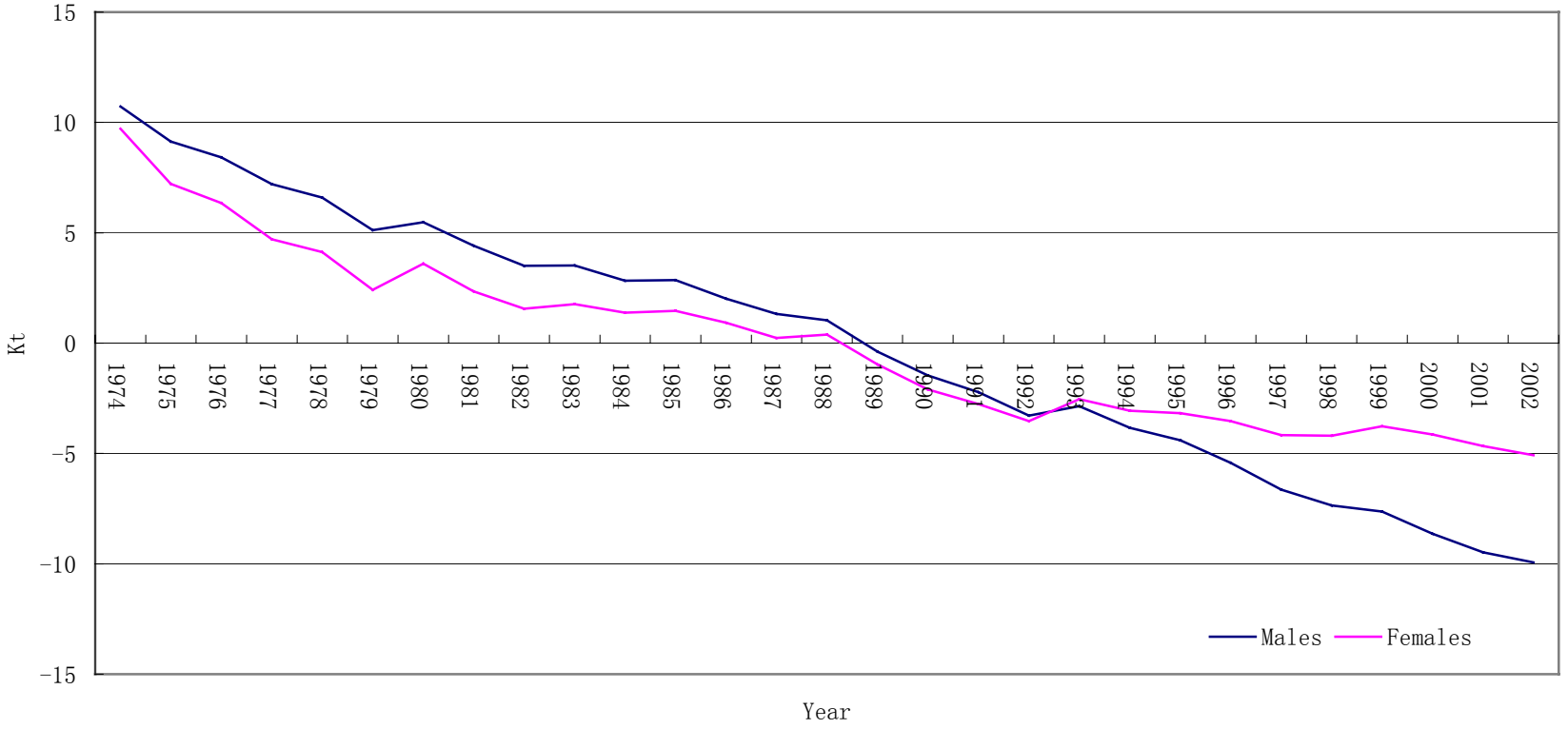


Figure 2. Average Number of Years Spent as Cigarette Smoker by Age 40 Among Men and Women in Different Birth Cohorts

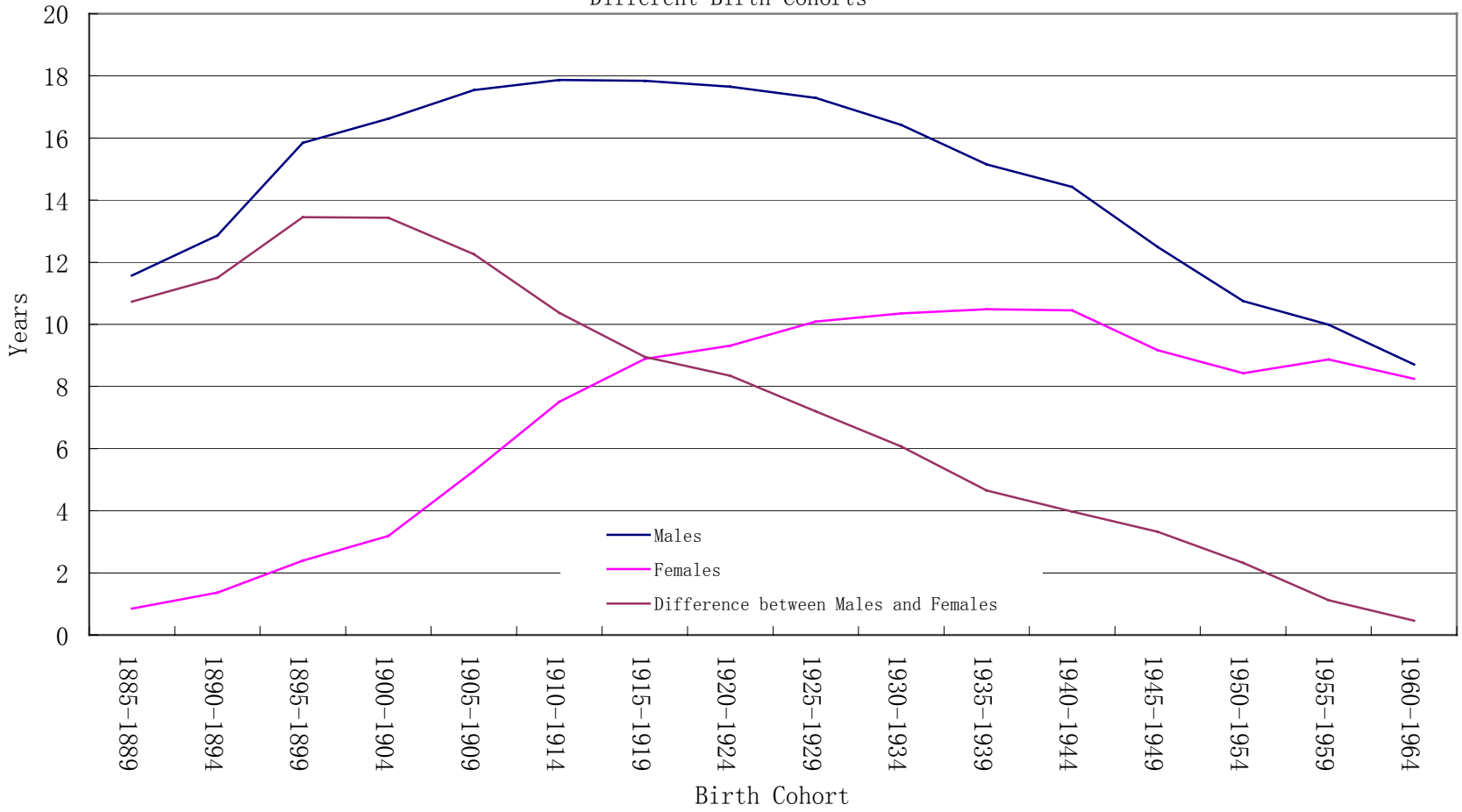
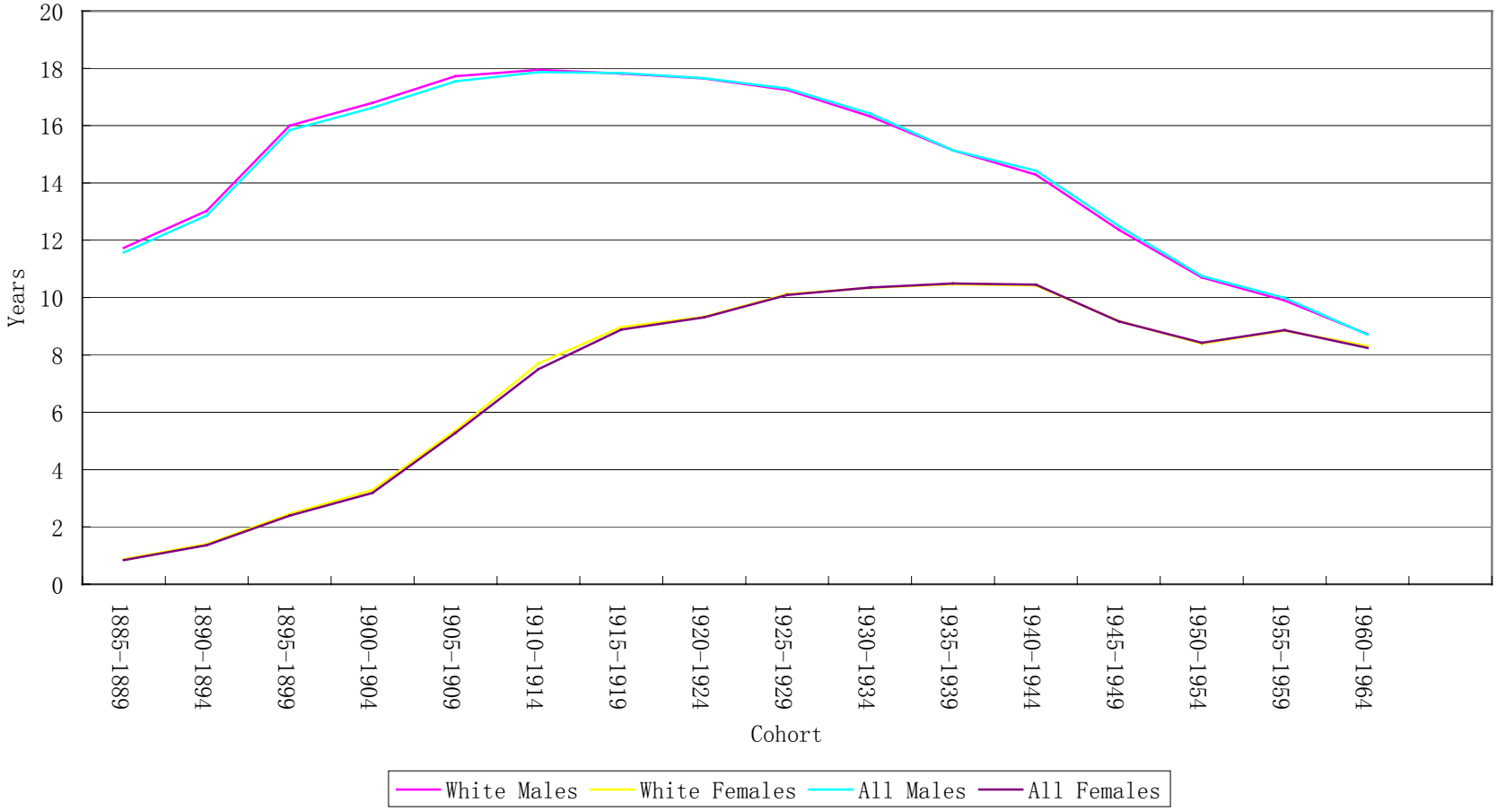


Figure 3. Comparison of Cohort Smoking Index



Appendix 1. Fitted and projected k_t

Year	k_t	Year	k_t
1974	20.121	1988	0.935
1975	16.227	1989	-1.665
1976	14.611	1990	-3.734
1977	11.824	1991	-5.057
1978	10.567	1992	-6.756
1979	7.459	1993	-5.450
1980	8.749	1994	-6.845
1981	6.506	1995	-7.411
1982	4.817	1996	-8.682
1983	4.907	1997	-10.383
1984	3.800	1998	-11.039
1985	3.839	1999	-10.851
1986	2.482	2000	-12.018
1987	1.151	2001	-13.175
		2002	-13.873

Year	k_t	Standard Error	95% confidence interval	
2003	-15.087	1.1826	-17.404	-12.769
2004	-16.301	1.6725	-19.579	-13.023
2005	-17.515	2.0483	-21.529	-13.5
2006	-18.729	2.3652	-23.365	-14.093
2007	-19.943	2.6444	-25.126	-14.76
2008	-21.157	2.8968	-26.835	-15.479
2009	-22.371	3.1289	-28.504	-16.238
2010	-23.585	3.3449	-30.141	-17.029
2011	-24.799	3.5478	-31.753	-17.846
2012	-26.013	3.7397	-33.343	-18.683
2013	-27.227	3.9223	-34.915	-19.54
2014	-28.441	4.0967	-36.471	-20.412
2015	-29.655	4.264	-38.013	-21.298
2016	-30.869	4.4249	-39.542	-22.197
2017	-32.084	4.5802	-41.061	-23.106
2018	-33.298	4.7304	-42.569	-24.026

Appendix 2. Data on smoking for U.S. White Population

White Females					White Males				
	Birth cohort					Birth cohort			
age	1965-1969	1970-1974	1975-1979	1980-1984	age	1965-1969	1970-1974	1975-1979	1980-1984
0	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	1	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	2	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	3	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	4	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	5	0.01	0.00	0.00	0.00
6	0.07	0.04	0.04	0.00	6	0.09	0.04	0.05	0.00
7	0.10	0.10	0.08	0.00	7	0.22	0.04	0.14	0.09
8	0.22	0.29	0.10	0.07	8	0.47	0.25	0.30	0.09
9	0.48	0.55	0.27	0.52	9	0.82	0.40	0.62	0.09
10	0.77	0.91	0.53	0.67	10	1.37	0.91	1.09	0.86
11	1.25	1.54	1.26	1.64	11	1.95	1.58	1.64	1.98
12	2.84	2.94	2.96	4.03	12	3.64	3.18	2.92	3.88
13	5.57	5.29	5.40	7.23	13	6.09	5.61	5.37	6.55
14	8.87	8.67	8.99	11.48	14	9.47	9.20	8.93	9.91
15	14.17	13.07	14.23	16.68	15	15.12	13.55	14.01	15.45
16	20.57	18.47	21.39	22.89	16	21.35	19.87	21.20	21.39
17	25.11	22.28	25.99	28.74	17	25.60	24.67	27.75	26.67
18	29.70	27.10	29.91	31.75	18	30.71	29.70	33.99	29.32
19	31.45	29.01	31.13	32.16	19	33.10	31.87	36.51	30.60
20	32.41	30.30	31.62		20	34.62	33.87	37.06	
21	32.74	30.66	31.25		21	35.48	34.57	37.67	
22	32.65	30.06	30.22		22	35.57	34.83	36.79	
23	32.31	29.66	29.09		23	35.54	34.59	35.69	
24	31.82	29.02	29.09		24	35.14	33.92	33.93	
25	31.60	28.27			25	35.16	33.01		
26	31.09	27.46			26	34.36	32.15		
27	30.63	26.52			27	33.90	31.20		
28	30.01	25.68			28	33.36	30.38		
29	29.41	23.30			29	32.63	25.88		
30	28.70				30	31.38			
31	27.78				31	30.51			
32	26.96				32	29.30			
33	25.46				33	28.21			
34	24.01				34	26.66			

Appendix3.1. Model results of OLS Regression on Years Spent as Current Smoker By Age 40: White Males

	Model 1		Model 2		Model 3		Model 4	
Dependent Variable: Years Spent as Current Smoker By Age 40								
Covariates	Coefficient	P>Z	Coefficient	P>Z	Coefficient	P>Z	Coefficient	P>Z
By 35 (log scale)	0.9984	0.000						
By 30 (log scale)			1.0013	0.000				
By 25 (log scale)					1.0010	0.000		
By 20 (log scale)							1.0219	0.000
Cohort	-0.0051	0.000	-0.0106	0.000	-0.0168	0.000	-0.0195	0.000
Constant	0.2683	0.000	0.6158	0.000	1.1355	0.000	1.9825	0.000
df	15		15		15		15	
R^2	0.9996		0.9979		0.9928		0.9700	

Appendix3.1. Model results of OLS Regression on Years Spent as Current Smoker By Age 40: White Females

	Model 1		Model 2		Model 3		Model 4	
Dependent Variable: Years Spent as Current Smoker By Age 40								
Covariates	Coefficient	P>Z	Coefficient	P>Z	Coefficient	P>Z	Coefficient	P>Z
By 35 (log scale)	0.9569	0.000						
By 30 (log scale)			0.9036	0.000				
By 25 (log scale)					0.8736	0.000		
By 20 (log scale)							0.9747	0.000
Cohort	-0.0127	0.000	-0.0279	0.000	-0.0477	0.000	-0.0946	0.000
Constant	0.4660	0.000	1.0460	0.000	1.7768	0.000	3.1956	0.000
df	14		14		14		14	
R^2	0.9999		0.9995		0.9982		0.9848	