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THE USE OF MODEL LIFE TABLES TO ESTIMATE MORTALITY FOR THE UNITED STATES IN THE LATE NINETEENTH CENTURY

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Abstract—This paper seeks to extend our knowledge about mortality in the late nineteenth century United States by using census mortality data for older children and teenagers to fit model tables. The same method can also be used with partially underregistered death data. The most commonly used model tables, the Coale and Demeny West Model, apparently do not adequately depict the changing shape of mortality over the period 1850–1910. An alternative model life table system is presented, based on the Brass two parameter logit system and available reliable life tables from the period 1850–1910. The two parameter system must be reduced to a one parameter system by means of estimated relationships between the parameters so that the fitting procedure can be used. The resulting model system is, however, heavily dependent on the experience of northern, industrial states, especially Massachusetts.

INTRODUCTION

In spite of the importance of mortality, there is a distinct lack of information for the United States prior to about 1900, when the death-registration area began regular reporting. Although the death-registration area was formed in 1880 with two states (Massachusetts and New Jersey), the District of Columbia, and 19 other cities outside these states, it was not until 1900 that the area was considered sufficiently representative. By that time the area contained ten states (the six New England states, New York, New Jersey, Indiana, and Michigan), the District of Columbia, and 134 cities outside these states, but largely in the Middle Atlantic and East North Central census regions. It covered only about 40.3 percent of the population. The death-registration area did expand rapidly. By 1910 it accounted for 58.3 percent of the population and was complete by 1933. Nevertheless, the period prior to 1900 remains uncertain with respect to mortality in the United States (Taeuber and Taeuber, 1958, pp. 269–272; Thompson and Whelpton, 1933, pp. 228–230; Willcox, 1940, pp. 194–220. A summary of the controversy regarding the trend of mortality in the nineteenth century United States may be found in Easterlin, 1977, pp. 132–139).

One of the reasons for the lack of information was that vital registration, unlike census enumeration, was left to the states. It was, therefore, done in piecemeal fashion. Massachusetts, as is well known, was the first state to institute vital registration in 1842. The U.S. Census, in order to remedy this lack of information, included a question on deaths in the twelve months prior to the census in 1850. This practice was continued through the census of 1900, but the shortcomings of these data were immediately apparent, revealing implausibly low death rates (see, for example, U.S. Bureau of the Census, 1853, p. xl; U.S. Bureau of the Census, 1886, pp. xi, xviii–xix). Among the major causes of defective enumeration of census deaths were reference period error (i.e., inability of the survivors to remember accurately deaths within the previous twelve months), deaths unreported because there were no survivors remaining in the family to report the death, and misunderstandings about the nature and extent of the information desired. (A clear statement of the problems of a retrospective mortality question asked only of heads of families was given in U.S. Bureau of the Census, 1866, pp. xxiii–xxiv.) Meanwhile, it took considerable time for individual states to institute the sorely needed registration systems (U.S. Bureau of the Census, 1971, Table 2–5, p. 29).

The deficiency in age-specific mortality data implies, of course, a paucity of life tables. Those tables which do exist used data largely from Massachusetts, such as those of Wigglesworth (1793), Jaffe and Lourie (1830), Jacobson (1849–50), Elliott (1855), Billings (1878–82) [Wigglesworth, 1793, Jaffe and Lourie, 1942; Jacobson, 1957; Elliott, 1857; U.S. Bureau of the Census, 1886]. The lack of appropriate life tables for other times and places can be an obstacle to the study of social and economic history of the nineteenth century United States.

This paper attempts to provide a method for the use of these nineteenth century census mortality data to construct reasonably reliable life tables. The method is also applicable to cases of defective vital registration as well. What is required is an *appropriate* model life table system in order to fit the entire mortality structure by level, age, and sex to the most reliable portions of census mortality data (or defective vital registration data). Research using various techniques of indirect mortality estimation indicates that the degree of underreporting of deaths in the census may be rather small at ages 5 to 9, 10 to 14, and 15 to 19 (Haines, 1977). Other work on vital registration reveals similar findings with respect to age patterns of underreporting of deaths, with the age group 5 to 9 having the most favorable results (Fulton, 1977; Fulton and Hendershot, 1976). This finding is not without some foundation in social reality. Older children and young adults who die are likely to be remembered and they are likely to have families who remain behind to report the event. As Brass and Coale have noted: "The accuracy of reported mortality, affected by a combination of omission and reference period error, is quite likely to depend on the importance of the decedent in the eyes of the community in general and of the respondent in particular and hence to vary with age and sex" (Brass and Coale, 1968, p. 105). Thus, it would seem plausible to find the location of a life table for any U.S. population within an appropriate one parameter model life table system using death rates for older children or young adults derived from either census or vital registration sources.

The question arises as to the choice of a model life table system. Several such systems already exist, including those of Coale and Demeny (1966), the United Nations (1955), Ledermann (1969), and Brass (1971; 1975, chapters XI-XIII, XVIII-XIX; Carrier and Hobcraft, 1971, pp. 7–12, 43–47). Of these, the most likely candidate would seem to be the West model family of Coale and Demeny, partly because it was based on U.S. experience. The U.S. tables used by Coale and Demeny were, however, only for the period after 1900 after which they appear to perform quite well. Prior to 1900, however, the West Model does not appear to capture the changing shape of mortality adequately (see below). Among the other alternatives, the U.N. tables have been shown to have a number of conceptual difficulties (Carrier and Hobcraft, 1971, pp. 7–9; Gabriel and Ronen, 1958). Of the remaining possibilities, both the Ledermann and the Brass systems were potentially useful. For reasons of simplicity, flexibility, and convenience, the Brass system was chosen to construct a model life table system for the United States for the period 1850–1910 as an alternative to the Coale and Demeny West model. The purpose is to provide a vehicle for fitting census mortality data in a way which more accurately depicts the changing shape of mortality in the late nineteenth century. The Brass system would be based on such life tables as are available and reasonably reliable. This restricts the coverage of the system to the period after about 1850. The system is carried up to 1910 in order to take advantage of the relatively large number of tables which become available during the 1900–1910 decade.

THE BRASS MODEL LIFE TABLE SYSTEM

The Brass system is based on the logit transformation of $(1 - l_x)$ from a life table where

$$\text{logit}\,(1 - l_x) = Y_x = (.5)\ln\left[\frac{1 - l_x}{l_x}\right] \quad (1)$$

and where l_0 equals 1.0. This is, in fact, a mathematical transformation of the non-linear l_x function so that it can be more nearly linear in x. Also, the transformation has limits of $-\infty$ and ∞, rather than unity and zero. Brass proposes a set of standard logits [$= Y_{sx}$], and hence a "standard" life table, since a vector of l_x values uniquely determines a life table. This set of standard logits can be chosen as appropriate to the situation under study, which makes it desirable for the present case in which only one geographic area is considered. The standard logits are then related to the logits of any other life table by the relation

$$Y_x = \alpha + \beta\, Y_{sx}. \quad (2)$$

This is the basis of a two parameter model life table system, with α representing the level of mortality and β representing the "tilt," an approximation to the shape of mortality. In practical experience α can range between about +0.8 (very high mortality) to about −0.8 (low mortality) and β between about 0.7 (infant and child mortality unfavorable *relative* to adult mortality) and about 1.4 (infant and child mortality favorable *relative* to adult mortality). For the standard, of course, $\alpha = 0.0$ and $\beta = 1.0$. (A more complete discussion of the Brass model life table system may be found in Brass [1971] and in Carrier and Hobcraft [1971], pp. 42–47).

It is not particularly easy to fit a two parameter system, however, with the type of data that will be used. As we shall be fitting models based solely (or largely) on ages 5 to 19, it would be difficult to fit the "tilt." What is needed is a way of collapsing the two parameter system to a one parameter system (like the Coale and Demeny system). This will be done by estimating an actual historical relationship between α and β. Thus, for example, given an age specific death rate (such as ${}_5M_5$ or ${}_5q_5$), the level of mortality (α) could be obtained from the standard. Then, with a functional relationship between α and β, the value of β can be derived. Finally, given the standard logits, Y_{sx}, the logits for the desired life table can be calculated and a full life table constructed.

HISTORICAL UNITED STATES LIFE TABLES

In order to build a Brass two parameter model life table system, a series of actual life tables of sufficient quality were necessary. These were collected from available sources, particularly from Glover (1921) and Billings (U.S. Bureau of the Census, 1886, pp. 773–791). The life tables used are listed in Table 1 and include several constructed from the original census and vital registration materials. They were organized into two groups: (I) United States and state life tables (twenty-five tables for each sex); and (II) urban life tables (twenty-seven life tables for each sex). The time span was from about 1850 to 1911. This is not an exhaustive list of all possible life tables but it does include as representative a sampling as is possible. A few tables, such as the Billings 1890 tables (U.S. Bureau of the Census, 1896, pp. 484–486), were not included because of only partial presentation of information (i.e., only $\mathring{e}_x$ values were given). Not all the tables were of uniform reliability but most were of sufficient quality to be used. In particular, Massachusetts mortality data were found to be largely accurate by about 1870 (Gutman, 1956, Table 27), while all the life tables from Glover (1921) were selected on the basis of a high degree of completeness of vital registration. Care was taken only to use those states and urban areas which were deemed efficient enough in death registration to be admitted to the death registration area.

Among the other state and national tables, that of Meech for the United States (1830–1860) has been evaluated and found

Table 1.—Life Tables Used to Construct the Model Life Table System

Geographic Area	Period	Source	$\mathring{e}_0$ Male	$\mathring{e}_0$ Female
I) U.S. and State Life Tables				
Massachusetts/Maryland	1849-50	Jacobson	40.4	43.0
United States[a]	1830-60	Meech	41.01	42.91
Massachusetts (230 towns)	1859-61	Vinovskis	46.4	47.3
Massachusetts	1869-71	Haines	42.77	44.61
Massachusetts	1874-76	Haines	40.59	42.46
Massachusetts	1878-82	Billings	41.74	43.50
New Jersey[a]	1879-80	Billings	45.59	48.05
Massachusetts	1884-86	Haines	42.58	44.85
Massachusetts	1889-90	Glover	42.50	44.46
Massachusetts	1893-97	Abbott	44.09	46.41
United States[b]	1900-02	Glover	47.88	50.70
United States[b]	1900	Preston, et al.	45.65	48.35
United States[a,b]	1901-10	Glover	49.32	52.54
Indiana	1900-02	Glover	52.62	52.91
Massachusetts	1900-02	Glover	46.07	49.42
Michigan	1900-02	Glover	53.45	55.07
New Jersey	1900-02	Glover	46.38	50.45
New York	1900-02	Glover	45.62	49.26
Upstate New York[c]	1900-02	Haines	51.24	53.96
United States[b]	1909-11	Glover	49.86	53.24
Indiana	1909-11	Glover	54.70	56.16
Massachusetts	1909-11	Glover	49.33	53.06
Michigan	1909-11	Glover	53.86	56.24
New Jersey	1909-11	Glover	49.08	52.80
New York	1909-11	Glover	47.89	51.89
United States[b]	1919-21	Keyfitz/Flieger	54.49	56.41
United States[b]	1929-31	Keyfitz/Flieger	57.27	60.67
United States	1939-41	Keyfitz/Flieger	61.14	65.58
United States	1949-51	Keyfitz/Flieger	65.28	70.86
United States	1959-61	Keyfitz/Flieger	66.84	73.40
United States	1969-71	NCHS	67.04	74.64

Table 1.—(Continued)

Geographic Area	Period	Source	$\overset{\circ}{e}_0$ Male	$\overset{\circ}{e}_0$ Female
II) Urban Life Tables				
Suffolk Co., Mass	1859-61	Haines	35.99	43.46
Suffolk Co., Mass	1874-76	Haines	34.71	37.14
District of Columbia[a]	1878-81	Billings	41.06	43.67
Baltimore[a]	1879-80	Billings	36.49	39.86
Boston[a]	1879-80	Billings	37.04	39.11
Brooklyn[a]	1879-80	Billings	37.52	39.70
Chicago[a]	1879-80	Billings	38.11	41.29
Cincinnati[a]	1879-80	Billings	37.73	43.16
New Orleans[a]	1879-80	Billings	33.87	42.33
New York City[a]	1879-80	Billings	33.28	36.77
New York City	1878-81	Billings	29.04	32.77
Philadelphia[a]	1879-80	Billings	40.16	43.70
St. Louis[a]	1879-80	Billings	36.75	41.16
San Francisco[a]	1879-80	Billings	38.02	44.62
Suffolk Co., Mass	1884-86	Haines	35.97	37.86
Suffolk Co., Mass	1894-96	Haines	37.13	40.97
U.S. Urban[a,b]	1900-02	Glover	43.97	47.90
Boston	1900-02	Glover	41.64	45.14
Chicago	1900-02	Glover	46.31	50.79
New York	1900-02	Glover	40.65	44.86
Philadelphia	1900-02	Glover	42.51	46.23
U.S. Urban[a,b]	1909-11	Glover	47.32	51.39
Boston	1909-11	Glover	46.05	50.28
Chicago	1909-11	Glover	45.92	51.68
New York	1909-11	Glover	45.30	49.46
Philadelphia	1909-11	Glover	45.47	49.60

a--White population only.

b--Registration states or cities.

c--New York State minus New York City.

Source: Tables labeled Haines were computed directly from census and vital registration data. The other tables were taken directly from Abbott (1899), Glover (1921), Jacobson (1957), Meech (1898), Vinovskis (1972), Keyfitz and Flieger (1968), Preston et al. (1972), and NCHS (1975). The Vinovskis table required some additional computations to extract the ℓ_x values. The Billings tables are found in U.S. Bureau of the Census (1886).

to be based on sophisticated methods and probably reasonably accurate (Haines and Avery, 1978). The Massachusetts/Maryland table for 1849-50 has recently been examined by Vinovskis (1976) and, although it was based on a high mortality period in Massachusetts, probably also gave an accurate picture of mortality. The

Massachusetts table of 1859–61 was based on a selection of 230 towns (both rural and urban areas are included in New England towns) which gave evidence of accurate death registration (Vinovskis, 1972, pp. 210–211). Finally, the New Jersey table of 1879–80 was based on vital registration data from one of the earliest states admitted to the death registration area (in 1880).

The urban tables are, however, probably less accurate. Several were excluded because of implausible values. The tables in Glover and those based on registration data for Boston (Suffolk County, Massachusetts) are of good quality for the same reasons that the state and national tables in Glover and the Massachusetts registration data after about 1870 were considered good. Both sources had data regarded as reliable. The urban tables from the Billings report (in the 1880 census) need to be viewed with some care. Overall, the system based on the urban tables should be accepted with considerably more care than that based on state and national tables.

FITTING A BRASS MODEL LIFE TABLE SYSTEM TO HISTORICAL U.S. EXPERIENCE

Once the life tables had been collected, the question arose as to the best procedure to estimate α and β for each table. First, a standard had to be chosen. Two were selected for the two separate models. For the national and state life table model, the United States registration state table for 1900–02 was chosen. The life table for the urban white population of the registration states of 1900–02 was selected as the standard for the urban life table model. It was hoped that these tables, being of good quality and within the period, would be adequate and in some sense representative.

The α and β parameters were estimated using a weighted least squares (WLS) regression procedure suggested by Carrier and Goh (1972). This was because ordinary least squares (OLS) regression gives an exaggerated weight to l_x observations for extreme ages (e.g., l_1 and l_{70}) which are often based on less reliable data. The weights chosen for the WLS were $(l_x)\cdot(1 - l_x)$ in order to weight extreme observations less. Thus, in the stochastic version of equation (2), each Y_x (the logit of the l_x for the table in question) and Y_{sx} (the logit of the l_x for the standard table) were weighted by $(l_x)\cdot(1 - l_x)$ for the table in question. In order to obtain a correct estimate of α, a vector of weights was substituted for the vector of ones used to estimate the constant term. The observations consisted of the logits of $l_1, l_5, \cdots l_{70}$ for both the standard table and the table in question. Estimates done using WLS gave a better fit in almost all cases (as measured by R^2, adjusted R^2, mean deviation, and mean square error) than OLS equations, although the fits were very good for both OLS and WLS. Most adjusted R^2 values were above .99 and only a very few fell below .98 (and none below .97).

An examination of the residuals revealed that the logits did not result in a completely linear transformation of the l_x function and hence there was some "patterning" (or autocorrelation) in the residuals. Further, the pattern of autocorrelation appeared related to α. Thus, for tables with a high level of mortality relative to the standard (i.e., α significantly greater than zero), the predicted l_x values were frequently too low relative to the actual l_x values at the youngest and oldest ages. Predicted l_x values were then slightly too high in the intermediate ages. The reverse was true when mortality was low relative to the standard (i.e., when α was below zero). This might possibly have arisen if the earliest tables (with high mortality) were underregistered by some percent at all ages, if the 1909/11 tables were based on virtually complete registration, and if the 1900/02 tables were intermediate. Then, the use of the 1900/02 tables as the standard would lead to the relationship observed. One possible remedy would be to add a quadratic parameter to the system in the form:

$$Y_x = \alpha + \beta\ Y_{sx} + \gamma(Y_{sx})^2. \quad (3)$$

This was, in fact, suggested by Brass (1971, p. 98) and also recently by Barrett (1976, p. 9). But because the addition of a third parameter will make the reduction to a one parameter system more complex and because the fit is already very good, it seems appropriate to remain with the conventional Brass two parameter model for the time being. (Brass [1971, p. 98] also noted that the improvement in adding higher order polynomial terms would be very small.)

The results of the fitting procedures are presented in Table 2 for the state and national tables (using the U.S. 1900–02 standard) and in Table 3 for the urban life tables (using the U.S. white urban 1900–02 standard). In order to study patterns in the level and shape of mortality, α and β values for females from Tables 2 and 3 were plotted. (The patterns for males were roughly similar.) The results are given in Figures 1 and 2. It appears that there was an increase in β over time as the level of mortality (α) declined. The pattern was clearest for the state and national tables for females but was apparent for all the models. It is of interest to note that the pattern continued after 1909–1911, as the α's and β's for life tables for 1919–21 through 1969–71 indicate. These post-1909–11 tables are included only for this illustrative purpose and are not used in the subsequent analysis.

It is interesting to speculate as to the causes of this rise in β as α fell. One explanation that cannot be excluded is that registration of adult mortality improved relative to that of infant and child mortality over time. This is, however, not wholly plausible since it is usually mortality among infants and very young children which is initially the worst and which improves most rapidly.

Furthermore, the pattern occurs both among the more reliable state and national tables and among the somewhat less reliable urban tables. Thus, it does not appear related to data quality. Another more plausible explanation is that as mortality in general became more favorable during the period 1850–1910 that cohort mortality improvement took place and manifested itself as relative improvement among children and younger adults. The improvement in infant mortality appeared somewhat delayed, however. At any rate, the phenomenon of relatively greater reduction of mortality of younger ages (excluding infants) has been documented for Western Europe after 1850 (Wrigley, 1969, pp. 169–172). As may be seen from Table 4, it was true for England and Wales and for Massachusetts. It should be noted, however, that Carrier and Goh (1972, pp. 33–34) did not find a real increase in β for British life tables until about the decade of the 1920s, even though child mortality was relatively improving earlier. For the whole United States, on the other hand, there was a continuous upward shift in β as α declined (i.e., the level of mortality improved) from 1900–02 up to 1969–71. This may be seen in Table 2. Thus there has been for the United States, at any rate, a steady improvement in the level of child to adult mortality. The evidence presented in this paper indicates that the trend originated in the later nineteenth century.

A striking fact about Table 2 and Figure 1 is the heavy reliance on Massachusetts data for much of the nineteenth century. A separate analysis was done just with Massachusetts life tables using the 1900–02 Massachusetts table as the standard. The relationship between α and β was not unexpectedly similar to that in Figure 1 (for both males and females), although it was a much tighter pattern. The assertions about United States mortality in the late nineteenth century made here do rest heavily and unavoidably on the Massachusetts experience. It is encouraging that life tables from the other states give quite similar results; but Massachusetts was a more urban and industrial state than most. Therefore, the results here may be less appropriate for more rural areas.

Table 2.—α and β for a Brass Logit Two Parameter Life Table Model Fitted by Weighted Least Squares: National and State Life Tables, 1830–1911. U.S. 1900–02 Standard

Life Tables		Male α	Male β	Female α	Female β
Mass./Md.	1849-50	.21694	.94889	.22545	.92614
U.S.	1830-60	.18725	.90624	.21100	.90936
Mass. (230 towns)	1859-60	.01592	.81490	.09226	.89440
Mass.	1869-71	.13008	.87473	.16293	.87868
Mass.	1874-76	.18680	.85754	.21655	.86572
Mass.	1878-82	.15316	.84114	.19220	.86695
N.J.	1879-80	.05625	.87521	.05578	.85628
Mass.	1884-86	.13857	.90063	.16241	.91527
Mass.	1889-90	.15136	.94780	.17454	.93569
Mass.	1893-97	.10399	.94758	.11547	.94400
U.S.	1900-02	.00000	1.00000	.00000	1.00000
U.S.	1900	.05493	.94633	.05936	.96313
U.S.	1901-10	-.01086	1.02540	-.01175	1.01070
Indiana	1900-02	-.15904	.91882	-.07046	.97350
Mass.	1900-02	.04317	.96652	.02603	.95882
Mich.	1900-02	-.18654	.91219	-.14038	.97611
N.J.	1900-02	.01583	1.04716	.00400	.99407
N.Y.	1900-02	.08369	1.04786	.04917	1.03074
N.Y. (upstate)	1900-02	-.10192	.98959	-.09832	1.00343
U.S.	1909-11	-.05532	1.05271	-.07894	1.02963
Indiana	1909-11	-.21683	.97835	-.17078	1.02230
Mass.	1909-11	-.04666	1.03768	-.07631	1.01733
Mich.	1909-11	-.19820	.94261	-.18201	.98420
N.J.	1909-11	-.02503	1.09600	-.06368	1.04648
N.Y.	1909-11	.01851	1.12658	-.03322	1.05641
U.S.	1919-21	-.19591	1.05936	-.15781	1.11387
U.S.	1929-31	-.27984	1.20863	-.30034	1.19034
U.S.	1939-41	-.42262	1.29522	-.49360	1.22882
U.S.	1949-51	-.59087	1.45501	-.72360	1.33362
U.S.	1959-61	-.66750	1.52658	-.85050	1.35552
U.S.	1969-71	-.67884	1.56885	-.89587	1.39117

Source: Life Tables, see Table 1. Methods of computation, see text.

Since another likely candidate for a model life table system to use with defective nineteenth century mortality data is Model West of Coale and Demeny, a parallel fitting procedure was carried out for comparative purposes for Model West tables level 9 (female $\mathring{e}_0 = 40.00$) through 15 (female $\mathring{e}_0 = 55.00$) using the 1900–02 U.S.

Table 3. α and β for a Brass Logit Two Parameter Life Table Model Fitted by Weighted Least Squares: Urban Life Tables, 1859–1911. U.S. Urban 1900–02 Standard

Life Tables		Male α	Male β	Female α	Female β
Suffolk Co., Mass.	1859-61	.24345	.98792	.29800	.95021
Suffolk Co., Mass.	1874-76	.26150	.88735	.28968	.86357
D.C.	1878-81	.08920	.93754	.10923	.86484
Baltimore	1879-80	.19420	.79301	.19139	.76748
Boston	1879-80	.18629	.81510	.23464	.86126
Brooklyn	1879-80	.17341	.83174	.21921	.85953
Chicago	1879-80	.14088	.70984	.15389	.76609
Cincinnati	1879-80	.17185	.88863	.10638	.80063
New Orleans	1879-80	.34639	1.20162	.17174	.97418
New York City	1879-80	.30524	.91592	.30933	.91189
New York City	1878-81	.44421	.97009	.42842	.93286
Philadelphia	1879-80	.10968	.91234	.11354	.86490
St. Louis	1879-80	.19861	.80892	.15907	.73982
San Francisco	1879-80	.20943	1.13830	.10504	.97706
Suffolk Co., Mass.	1884-86	.25067	.95768	.29068	.95765
Suffolk Co., Mass.	1894-96	.20968	1.01497	.20504	.97462
U.S. Urban	1900-02	.00000	1.00000	.00000	1.00000
Boston	1900-02	.07339	1.02774	.08769	1.03237
Chicago	1900-02	-.06641	1.06993	-.08237	1.03318
New York City	1900-02	.11393	1.10192	.10062	1.06714
Philadelphia	1900-02	.04527	1.02963	.05000	1.01220
U.S. Urban	1909-11	-.10395	1.02713	-.10927	1.01619
Boston	1909-11	-.05609	1.09697	-.06149	1.07475
Chicago	1909-11	-.05062	1.11035	-.11670	1.00712
New York City	1909-11	-.03048	1.11412	-.04328	1.06213
Philadelphia	1909-11	-.04509	1.03584	-.05295	1.01219

Source: Life tables, see Table 1. Methods of computation, see text.

standard. These were the mortality levels which corresponded to the range of the national and state tables used in this study. The resulting α's and β's for females are plotted in Figure 3. (The results for males are very similar.)

Although the pattern was quite regular, indeed much more regular than for the actual U.S. tables, it was different from that in the United States over the late nineteenth century. It is notable, however, that the Coale and Demeny Model West is similar to the U.S. experience beyond about level 13 which roughly corresponds to mortality in the 1900–02 standard. After 1900, Model West does quite well. It in fact fits the 1900–02 U.S. table for the registration states closely. For the period

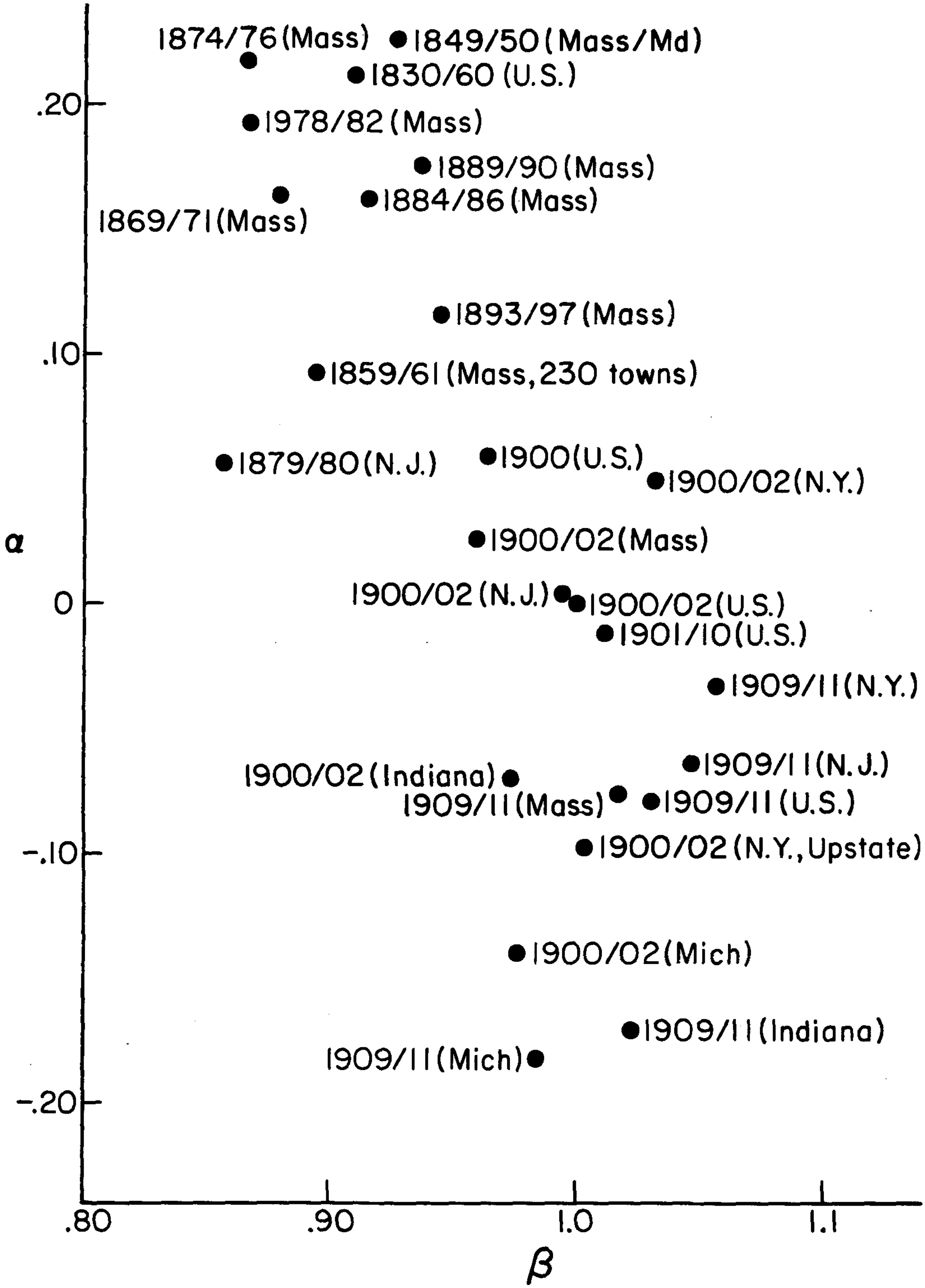

Figure 1.—α and β for a Brass Logit Two Parameter Life Table Model Fitted by Weighted Least Squares. Females. National and State Life Tables, United States, 1830–1911 (U.S. 1900–02 Standard)

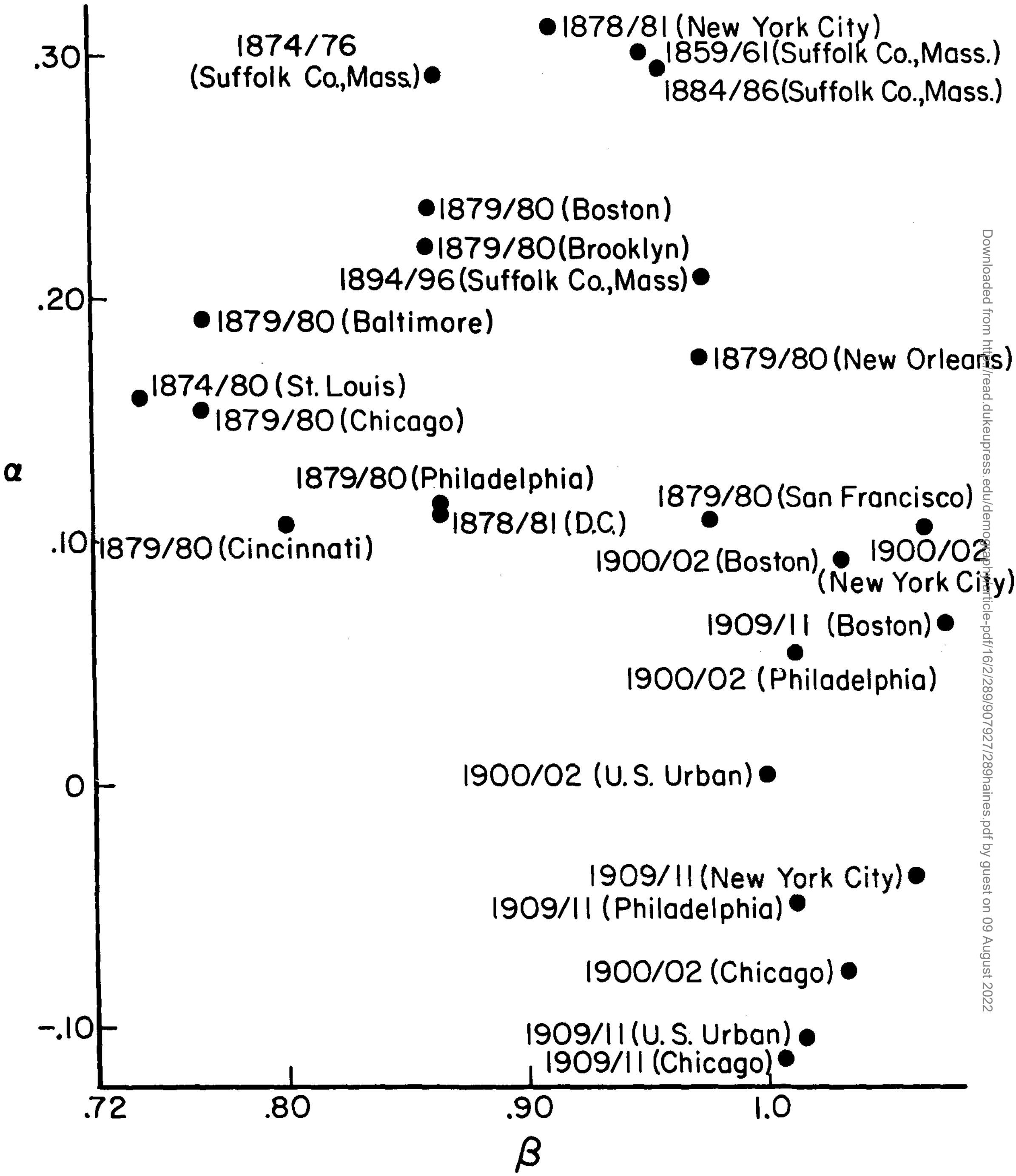

Figure 2.—α and β for a Brass Logit Two Parameter Life Table Model Fitted by Weighted Least Squares. Females. Urban Life Tables, United States, 1859–1911 (U.S. Urban 1900–02 Standard)

Table 4.—Age Specific Death Rates in Massachusetts and England and Wales, 1865 and 1900 (Rates per 1000 Population by Age)

	Massachusetts				England and Wales		
Age	1865	1900	% Change	Age	1865	1900	% Change
0	205.3	190.1	- 7.40%	0-4	75.0	61.6	-17.87%
1-4	68.6	57.8	-15.74				
5-9	9.6	5.3	-44.79	5-9	8.1	4.2	-48.14
10-14	5.1	2.9	-43.14	10-14	4.7	2.3	-51.06
15-19	9.6	4.8	-50.00	15-19	6.4	3.7	-42.19
20-29	12.6	7.0	-44.44	20-24	9.2	5.1	-44.56
30-39	11.7	8.8	-24.79	25-34	10.6	6.7	-36.79
40-49	11.9	12.0	+ 0.84	35-44	14.2	11.7	-17.61
50-59	17.5	21.3	+21.71	45-54	20.5	19.9	- 2.93
60-69	32.9	41.0	+24.62	55-64	34.7	37.1	+ 6.92
70-79	70.5	85.8	+21.70	65-74	68.6	74.2	+ 8.16
80 & over	168.2	197.8	+17.60	75-84	151.8	153.7	+ 1.25
				85 +	325.6	304.3	- 6.54
Total	20.6	18.2	-11.65	Total	23.2	18.2	-21.55

Source: U.S. Bureau of the Census, 1975, Series B 201-213. Mitchell and Deane, 1971, Chapter I, Tables 12 and 13.

before 1900, however, an argument against the application of the Coale and Demeny system to the United States is that while β increased (i.e., child mortality improved relative to adult mortality) as the level of mortality (α) improved, the Coale and Demeny West Model showed a decline in β as mortality improved from level 9 to about level 13. Similar results were found by Brass when he examined the Coale and Demeny models. He discovered an analogous curvilinear pattern of the relationship of level to shape (i.e., higher β's at high and low levels of mortality and lower β's at intermediate levels) for the U.N. model system and for long-term Swedish data. His explanation was that environmental factors which were responsible for the mortality decline affected age groups differentially and that only at lower levels of mortality were the benefits of these environmental improvements more evenly distributed. He did not, however, find the higher β's at high mortality levels for England and Wales (Brass, 1971, pp. 91, 96–104, 107). The fact that this curvilinear relationship between α and β did not also appear in the nineteenth century U.S. data used here makes it worthwhile to pursue further an alternative to the Coale and Demeny model (at least for the period prior to about 1900). The alternative attempted here is based on a Brass model system using actual U.S. experience.

As mentioned earlier, it is desirable to reduce the two parameter Brass logit system to a one parameter system by determining a functional relationship between α and β. This is because the available reliable census mortality data used to fit a model system (i.e., ${}_5q_5$, ${}_5q_{10}$, ${}_5q_{15}$) are best used to fit the level of mortality (α) but are inadequate to provide information on

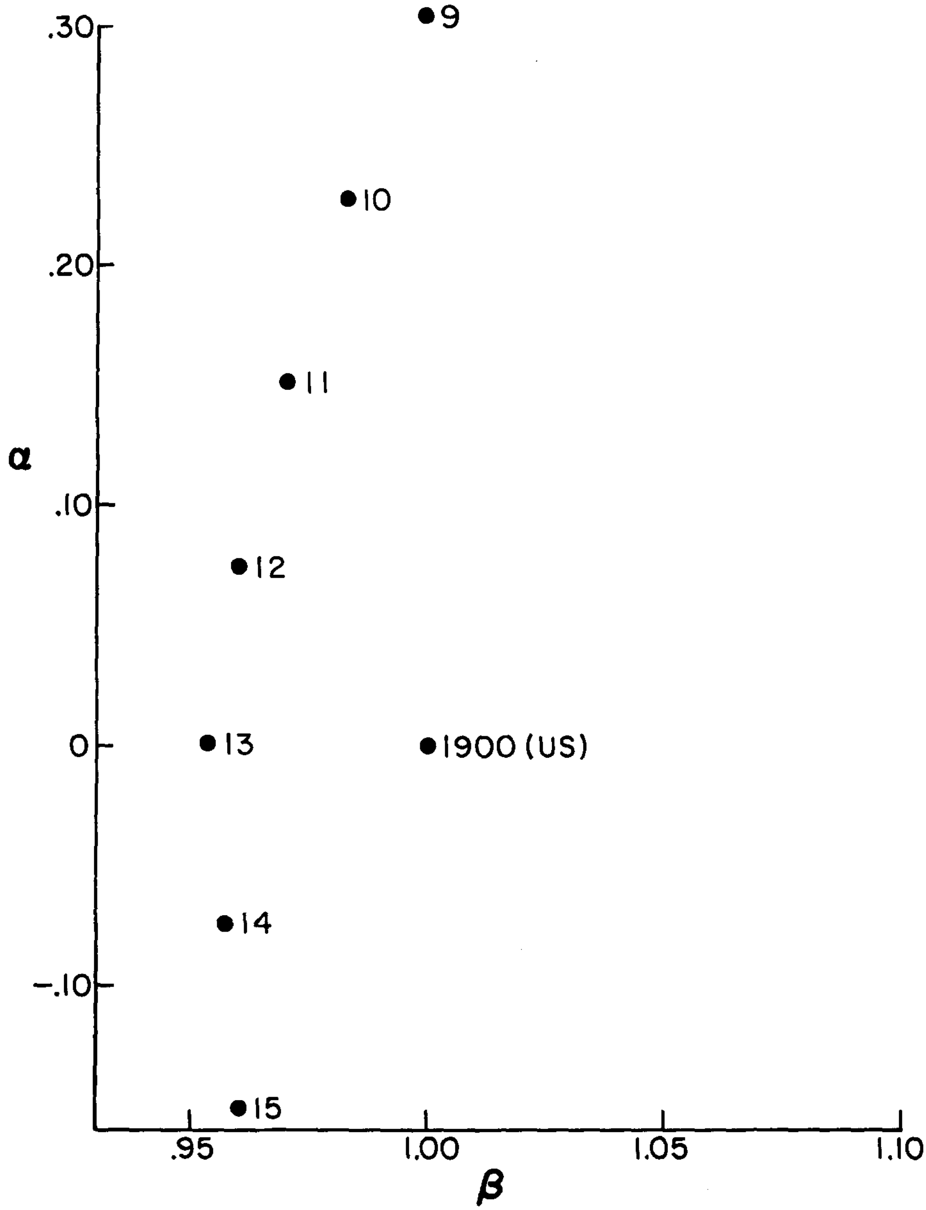

Figure 3.—α and β for a Brass Logit Two Parameter Life Table Model Fitted by Weighted Least Squares. Females. Coale and Demeny West Model, Levels 9–15 (U.S. 1900–02 Standard)

shape (β) because they are so close together. Unfortunately, as Figures 1 and 2 indicate, the relationship between α and β was not particularly tight. In order to specify a more accurate relationship, additional variables (the degree of urbanization and time) were added to the equation linking α and β, shown in Table 5. This is, in effect, adding parameters to the system, but these are parameters which can be readily determined (unlike β which is a priori unknown.) Urbanization was

Table 5.—Regression Equations to Predict β in Four Brass Logit Two Parameter Life Table Models: U.S., 1830–1911

	Model	Independent Variables[a]									
		Constant	α	α^2	URB	Time I	Time II	Time III	Time IV	N	R^2 (R^2adj)
1)	Males: State & National Model U.S. 1900-02 Standard	.977426	.514497	-1.033726	-.001164	-.083308	-.085171	.095986	.200636	25	.873
		(14.03)	(4.60)	(1.61)	(1.43)	(2.05)	(3.03)	(3.24)	(6.39)		(.821)
2)	Females: State & National Model U.S. 1900-02 Standard	.933816	.158308	-.393045	-.000207	-.029649	-.066808	.073248	.127322	25	.914
		(24.17)	(1.58)	(.88)	(.44)	(1.19)	(3.88)	(3.66)	(5.09)		(.879)
3)	Males: Urban Model U.S. 1900-02 Urban Standard	.970210	.070957	---------	--------	-.101415	-.136690	.073276	.110734	23	.798
		(14.27)	(.28)			(1.49)	(3.27)	(1.11)	(1.30)		(.739)
4)	Females: Urban Model U.S. 1900-02 Urban Standard	.930970	.109237	.013307	--------	-.100161	-.096586	.094529	.111798	25	.713
		(13.15)	(.31)	(.01)		(1.38)	(1.98)	(1.34)	(1.20)		(.617)

a--URB = Percentage urban at census nearest the life table date.

For State and National Model:

Time I = 1 if time period was 1830-65
Time II = 1 if time period was 1866-82
Time III = 1 if time period was 1898-1902
Time IV = 1 if time period was 1903-1911

For Urban Model:

Time I = 1 if time period was 1859-76
Time II = 1 if time period was 1877-81
Time III = 1 if time period was 1900-02
Time IV = 1 if time period was 1903-11

Source: α and β values from Tables 2 and 3. URB from U.S. Bureau of the Census, 1975, Series A-195, 202. Figures in parentheses are t-statistics.

added (to the state and national life table model only) because it appeared that the less urban the area, the lower the general level of mortality at any given level of β. This may be seen in Figure 1 as low β's for females in Indiana and Michigan relative to New York, New Jersey, and Massachusetts. If β was dependent on general public health and medical improvements, then it could be considered a function of time as well. Time was introduced as a series of dummy variables in order to allow for a shifting relationship of time to β. Thus, the relationship of time to β was not constrained to be the same throughout. Finally, the relationship between α and β appeared curvilinear and therefore a polynomial in α was specified.

The regression equations aimed at obtaining an estimate of β from information on α, the degree of urbanization, and time period are presented in Table 5. Equations are given for both the national-state model and the urban model for each sex separately. The urban variable was eliminated from the urban model as meaningless in that context. The equations were specified as linear in all variables except α. A linear specification in α was made, however, for the urban male model since the α^2 term gave an incorrect orientation to the polynomial. Because of doubts about the quality of a few of the life tables, several observations were removed from the urban model. Two tables (for San Francisco and New Orleans for 1879–80) gave implausibly high levels of β for males and so were removed. Also, the New York City table for 1878–81 gave an extraordinarily high level of mortality and was eliminated for males as well as females.

The equations in Table 5 give an encouragingly good fit, as measured by R-square and adjusted R-square. At least 60 percent of the variation in β was accounted for by the independent variables. For the state and national model 80 to 90 percent of variation was "explained." The dummy variables for time (Time I through Time IV) showed that β was increasing significantly over time. The percent urban (in the state and national models) unexpectedly has a negative coefficient. Evidently urban residence had an even greater relative unfavorable effect on children than on adults, leading to a lower β. Finally, α and α^2 gave plausible signs (with the exception of the urban model for males). The α^2 coefficient was negative when included, indicating a parabola in α that was concave downward, which is what can be observed in Figures 1 and 2 if they are rotated 90 degrees counterclockwise. The general insignificance of urbanization and α may, however, be partly attributed to the substantial collinearity between them and the time variable. For example, the zero-order correlations between the year of the life table and α were -0.690 and -0.810 for males and females, respectively, for the state and national model. They were -0.787 and -0.746 respectively for the urban model. When α and α^2 were in the equations alone, they were significant and showed the correct signs. It was decided that since the model was reasonably specified in the first instance and since collinearity was partly to blame for the low t-ratios, that the insignificant variables be allowed to remain in the equations.

The entire discussion of the equations in Table 5 must be qualified by two important points. First, it is quite apparent that the observations in the equations are *not* independent, which means that a fundamental assumption of the classical least squares regression model is violated. So, for example, the data underlying the state tables in 1909–11 are part of the national table for 1909–11. An alternative would have been to exclude either the state data or the national data. With so few accurate life tables available, however, it was felt best to pool the observations. The estimates resulting from such equations will be unbiased, although the t-ratios will not be accurate. The second problem involves the fact that the life tables are all weighted equally while, in fact, they arose from populations of varying size. An unweighted regression was chosen because weighting would have further complicated the procedure. The effect of weighting would have been to assign much greater importance to the observations for the entire United States and probably would have made the relationship between α and β tighter.

A small puzzle is provided by the positive coefficient for α in the urban model for males and the urban model for females, given the relatively small and insignificant α^2 coefficient in the urban model for females. (When the α^2 term is included, the sign of the α term ceases to have the interpretation of a simple slope coefficient. This is relevant for the national and state model for males and females with their large α^2 coefficients, but probably not for the urban female model because of its small and insignificant α^2 coefficient.) Based on Table 3, one would have expected a negative coefficient. When α was in the equation alone, it was indeed negative and significant. Evidently, once the time trend had been taken into account, the relationship between α and β became positive.

As a test of the accuracy of the system, the actual β values were compared to β's predicted by the equations in Table 5. As

Table 6.—Actual and Predicted Values of β for Brass Logit Two Parameter Life Table Models: U.S., 1830–1911

Life Tables		Male Actual β	Male Predicted β	Male Predicted/Actual	Female Actual β	Female Predicted β	Female Predicted/Actual
I) National & State Model							
Mass/Md.	1849-50	.949	.906	.955	.926	.911	.984
U.S.	1830-60	.906	.931	1.028	.909	.916	1.008
Mass.(230 towns)	1859-61	.815	.833	1.022	.894	.903	1.010
Mass.	1869-71	.875	.864	.987	.879	.869	.989
Mass.	1874-76	.858	.870	1.104	.866	.868	1.002
Mass.	1878-82	.841	.860	1.023	.867	.867	1.000
N.J.	1879-80	.875	.855	.977	.856	.863	1.008
Mass.	1884-86	.901	.938	1.041	.915	.933	1.020
Mass.	1889-90	.948	.936	.987	.936	.932	.996
Mass.	1893-97	.948	.922	.972	.944	.930	.985
U.S.	1900-02	1.000	1.000	1.000	1.000	.994	.994
U.S.	1900	.946	1.025	1.084	.963	1.002	1.040
U.S.	1901-10	1.025	1.013	.988	1.010	.992	.982
Indiana	1900-02	.919	.926	1.008	.974	.987	1.013
Mass.	1900-02	.966	.994	1.029	.959	.993	1.035
Mich.	1900-02	.912	.896	.982	.976	.969	.993
N.J.	1900-02	1.047	1.015	.969	.994	.993	.999
N.Y.	1900-02	1.048	1.024	.977	1.031	.999	.969
N.Y. (upstate)	1900-02	.990	.954	.963	1.003	.978	.975
U.S.	1909-11	1.053	1.065	1.011	1.030	1.032	1.002
Indiana	1909-11	.978	.969	.991	1.022	1.014	.992
Mass.	1909-11	1.038	1.048	1.010	1.017	1.028	1.011
Mich.	1909-11	.943	.980	1.039	.984	1.010	1.026
N.J.	1909-11	1.096	1.076	.982	1.047	1.034	.988
N.Y.	1900-11	1.127	1.095	.972	1.056	1.039	.984

Table 6.—(Continued)

Life Tables		Male Actual β	Male Predicted β	Male Predicted/Actual	Female Actual β	Female Predicted β	Female Predicted/Actual
II) Urban Model							
Suffolk Co., Mass.	1859-61	.988	.988	1.000	.950	.965	1.016
Suffolk Co., Mass.	1874-76	.887	.855	.964	.864	.858	.993
D.C.	1878-81	.938	.840	.896	.865	.846	.978
Baltimore	1879-80	.793	.847	1.068	.767	.856	1.116
Boston	1879-80	.815	.847	1.039	.861	.861	1.000
Brooklyn	1879-80	.832	.846	1.017	.860	.859	.999
Chicago	1879-80	.710	.844	1.189	.766	.852	1.112
Cincinnati	1879-80	.889	.846	.951	.801	.846	1.056
New Orleans	1879-80	----	----	----	.974	.854	.877
New York City	1879-80	.916	.855	.933	.912	.869	.953
New York City	1878-81	----	----	----	----	----	----
Philadelphia	1879-80	.912	.841	.922	.865	.847	.979
St. Louis	1879-80	.809	.848	1.048	.740	.852	1.151
San Francisco	1879-80	----	----	----	.977	.846	.866
Suffolk Co., Mass.	1884-86	.958	.988	1.031	.958	.964	1.006
Suffolk Co., Mass.	1894-96	1.015	.985	.970	.975	.954	.978
U.S. Urban	1900-02	1.000	1.043	1.043	1.000	1.026	1.026
Boston	1900-02	1.028	1.049	1.020	1.032	1.035	1.003
Chicago	1900-02	1.070	1.039	.971	1.033	1.017	.984
New York City	1900-02	1.102	1.052	.955	1.067	1.037	.972
Philadelphia	1900-02	1.030	1.047	1.016	1.012	1.031	1.019
U.S. Urban	1909-11	1.027	1.074	1.046	1.016	1.031	1.015
Boston	1909-11	1.097	1.077	.982	1.075	1.036	.964
Chicago	1909-11	1.110	1.077	.970	1.007	1.030	1.023
New York City	1909-11	1.114	1.079	.969	1.062	1.038	.977
Philadelphia	1909-11	1.036	1.077	1.040	1.013	1.037	1.024

Source: Actual β's from Tables 2 and 3. Predicted β's calculated from equations in Table 5.

may be seen in Table 6 the predicted β's were generally close in the case of the state and national model. The urban model was not as accurate but also gave reasonable predictions. Overall, the system seemed to perform well.

APPLICATION OF THE SYSTEM TO THE HISTORICAL U.S. EXPERIENCE

The equations in Table 5 have effectively eliminated β as an exogenous parameter in the system by making it endogenous. The system is not, however, completely general and requires information on time period and degree of urbanization in order to obtain a specific table. This information is readily available and what remains is really only the problem of fitting a specific table from a chosen mortality parameter.

Since the mortality parameter needed to estimate β is, in fact, α, it is necessary to estimate an α from mortality data. As mentioned earlier, an available but little used source of mortality information is the U.S. Census from 1850 to 1900. Vital statistics reporting deaths by age could also be used. Since deaths in the ages 5 to 9, 10 to 14, and 15 to 19 are best reported, it is proposed that death rates for these ages be used to estimate α. Two procedures were tried.

The first involved estimating a direct relation between α and the q_x functions for the relevant age groups using the life tables which had been employed in constructing the system. A series of regression equations were estimated (one for each sex for both the state/national model and the urban model) in the following form:

$$\alpha = b_0 + b_1 ({}_5q_5) + b_2 ({}_5q_5)^2 + b_3 ({}_5q_{10}) + b_4 ({}_5q_{10})^2 + b_5 ({}_5q_{15}) + b_6 ({}_5q_{15})^2. \quad (4)$$

Using these equations, a value of α can be predicted for each model and, then, given information on the time period and urbanization (for the state and national model), β can be estimated. With values of α and β and the standard logits, a vector of l_x values can be created (using the equation $l_x = {}^1/[{}_{1+e}2(\alpha + \beta\ Y_{sk})]$. A life table can then easily be created using standard relationships (U.S. Bureau of the Census, 1971, pp. 434–446). This is, however, a somewhat laborious process and has the further disadvantage of providing a life table where, for example, the ${}_5q_5$ is not quite the same as that calculated from the original data. This is because the estimations of α and β are only approximate.

Due to these shortcomings, a second procedure was tried. This involved using the α and β from the procedures already mentioned as a starting point, and then iterating a table which, for example, gives the same ${}_5q_5$ as used to estimate the α starting point. The α and β values will, therefore, be slightly different from the starting point α and β but the fit to ${}_5q_x$ will be exact.

Fitting to one value of ${}_5q_x$ at the younger ages 5 to 19 has some disadvantages, however. These are the ages having the lowest death rates and, generally, the fewest total deaths. The variation in death rates from year to year is relatively larger than for other age groups. To circumvent this, in part, average tables were made. These could be obtained by averaging the α's and β's from the three tables fitted to ${}_5q_5$, ${}_5q_{10}$, and ${}_5q_{15}$. Any combination of two of these could also be used if there was reason to believe that the death rate for one age group was particularly inaccurate. (Since these operations are obviously best done by computer, a program with documentation can be supplied to potential users.)

These methods were tried out on U.S. census mortality data for 1850 through 1900 for the total and white populations by sex. The age specific death rates were calculated without adjustment to the original data (except to move the estimated population at risk from June 1 of the census year to December 1 of the previous year). Although some underenumeration of the population has been noted, at least after 1880, no estimates of underenumeration of deaths are available (Coale and Zelnik, 1963, Tables 14 and 15). Therefore, it was felt better to apply no corrections.

The results are reported in Table 7. The U.S. model tables calculated by the methods outlined above are averages of three tables each fitted by the iterative procedure to the three ${}_5q_x$ values. Analogous average tables were fitted to Coale and Demeny Model West by fitting a table to each of the three ${}_5q_x$ values separately and then averaging the tables together (via the $\mathring{e}_{10}$ value). The selected life table values in Table 7 indicate a slightly lower $\mathring{e}_0$ and $\mathring{e}_{10}$ for the U.S. model than for the West Model and an also considerably higher infant and child mortality (as seen by ${}_1q_0$ and l_5) for the U.S. Model. The differentials between the two models were usually smaller for males than for females at younger ages and diminished for the years closer to 1900. Mortality differences at older ages (as measured by ${}_{20}q_{40}$) exhibited

Table 7.—Selected Life Table Values for the United States, Total and White Populations, 1850–1900

	$_1q_0$		$\mathring{e}_0$		$\mathring{e}_{10}$		ℓ_5		$_{20}q_{40}$	
	U.S. Model	West Model	U.S. Model	West Model	U.S. Model	West Model	U.S. Model	West Model	U.S. Model	West Model
Total Population										
Males										
1850	.24092	.20352	36.51	37.79	45.04	44.74	67,805	70,433	.34448	.39064
1860	.20210	.17386	40.67	41.80	47.06	46.95	72,639	74,692	.31185	.35250
1870	.19210	.16259	42.07	43.44	47.88	47.84	73,993	76,342	.29775	.33756
1880	.22015	.18492	38.69	40.26	46.32	46.10	70,462	73,091	.32295	.36691
1890	.16334	.15568	43.91	44.48	47.93	48.41	77,125	77,362	.30311	.32826
1900	.13356	.14531	46.26	46.13	48.33	49.29	78,748	78,961	.30270	.31396
Females										
1850	.21712	.16099	38.53	42.57	46.14	47.87	70,155	75,085	.30980	.29798
1860	.19153	.14822	41.16	44.65	47.28	49.05	73,316	77,061	.29359	.28163
1870	.17724	.13192	43.73	47.46	48.99	50.62	75,469	79,619	.26505	.26034
1880	.22980	.16078	38.16	42.60	46.53	47.89	68,981	75,117	.30022	.29772
1890	.15765	.13172	44.52	47.50	48.53	50.65	77,454	79,651	.27781	.26007
1900	.12476	.12067	47.40	49.52	49.19	51.77	81,389	81,409	.27361	.24537
White Population										
Males										
1850	.22829	.19548	37.66	38.84	45.51	45.32	69,303	71,577	.33748	.38046
1860	------	------	-----	-----	-----	-----	------	------	------	------
1870	.18513	.15584	43.09	44.45	48.49	48.39	74,944	77,338	.28739	.32848
1880	.21436	.18007	39.58	40.92	46.69	46.47	71,206	73,790	.31683	.36063
1890	.15675	.14822	45.06	45.63	48.67	49.03	78,086	78,471	.29010	.31811
1900	.12784	.13524	47.56	47.78	49.24	50.09	81,503	80,617	.28601	.30103
Females										
1850	.20596	.15524	39.62	43.49	46.60	48.39	71,514	75,971	.30347	.29066
1860	------	------	-----	-----	-----	-----	------	------	------	------
1870	.16633	.12615	45.11	48.50	49.68	51.21	76,886	80,535	.25485	.25270
1880	.21526	.15359	39.57	43.76	47.12	48.54	70,732	76,227	.29193	.28854
1890	.14490	.12388	46.28	48.92	49.44	51.44	79,171	80,897	.26394	.24966
1900	.11206	.10946	49.55	51.72	50.42	52.85	83,219	83,435	.25416	.23153

Source: Fitted to Coale and Demeny Model West and to the Brass Logit Model constructed for the U.S. The tables were fitted to $_5q_5$, $_5q_{10}$, and $_5q_{15}$ from census mortality data. The Brass Logit Model (U.S. Model) was fitted by the iterative procedure described in the text. The tables presented here were averages of the three tables fitted to each of the q's. For Model West, the tables were averaged on $\mathring{e}_0$. For the Brass Logit U.S. Model, the α and β values were each averaged.

Table 8.—Values of α and β for Brass Two Parameter Logit Model Life Tables Fitted to U.S. Census Mortality Data, 1850–1900

	Male		Female	
	α	β	α	β
Total Population				
1850	.29282	.93634	.29870	.91093
1860	.16713	.92242	.22339	.91430
1870	.12266	.90851	.13627	.87594
1880	.21825	.91906	.29656	.87344
1890	.08282	.97195	.13258	.94051
1900	.02546	1.03760	.06436	1.00635
White Population				
1850	.25945	.93829	.26774	.91335
1860	------	------	------	------
1870	.09021	.89803	.09482	.87294
1880	.19699	.91448	.25635	.87519
1890	.04482	.95738	.07883	.93655
1900	-.01970	1.01600	-.00539	.99772

Source: See Table 7.

quite an interesting pattern. Male mortality was generally lower at older ages in the U.S. Model relative to Model West while female mortality was usually higher. Male mortality at these ages tended to converge between the two models between 1850 and 1900 while female mortality diverged. Another notable feature of the differences between the two models was the general downward tendency of both adult and child mortality in the West Model while the U.S. Model showed a much more pronounced decline of infant and child mortality relative to adult mortality. This is, of course, the result of the rise in β over time, as may be seen in Table 8.

The results in Table 8 merit some remarks. First, as estimated by the U.S. Model (and confirmed by the West Model), the level of mortality showed a rather uneven behavior. From 1850, α declined to 1870 (for both total and white population) but then increased in 1880. Thereafter, the decline was marked and steady. Part of this variation may have been due to the particular conditions in the twelve months before each census, but a high degree of mortality variability also implies a low degree of control over death rates. A further problem was that the 1880 census was the first to include registration data in lieu of the census mortality inquiry for those states and cities which had reasonably accurate vital registration. It is thus difficult to make any judgment about the trend in mortality if the registration data were more accurate at these younger ages than the census materials. Given that the registration areas were only a small part of the total nation at that time, however, the effect of this problem should be small and so it seems likely that a sustained decline in mortality was not achieved until after about 1880. Second, the pattern of change of β was not uniform, but showed a slight decline between about 1850 and 1870 before commencing its final rise. It must be noted, however, that the level of β in, say, 1850 in the U.S. model was well below that in the West Model table at a comparable level. (For example, for 1850, β was .938 for white males but would have been about 1.06 for Model West at a comparable level.) It appears, however, that the relative improvement in child mortality also began in the late nineteenth century along with the general mortality decline.

As a final test of the relative value of the U.S. Model versus Model West and of the general validity of fitting model life tables to $_5q_x$ values from census data at younger ages, some census-survival estimates were made using the native white population in 1880, 1890, and 1900. It may be argued that native whites constituted a relatively closed population in the nineteenth century (since little out-migration of native white took place). In Table 9, the ratios of projected to actual populations are compared for 1890 and 1900 for males using the two methods and two different sets of population data: the actual populations in 1880, 1890, and 1900 and the Coale and Zelnik adjusted populations (Coale and Zelnik, 1963). The results are rather close, with the U.S. model perhaps having the edge at older ages. The actual population figures suffer from varying degrees of underenumeration and age misreporting. The Coale and Zelnik estimates attempt to correct for this, although their method involves the use of model life tables rather similar to the West Model for the nineteenth century. Thus, the West Model might be expected to perform quite well under these circumstances, which it does. The U.S. Model also, however, does a virtually comparable job.

The result of this test would seem to be that the U.S. Model and the West Model both do a good job of projection. It is unfortunate that this test cannot be applied to an earlier date. (The 1870 Census had problems of undercounting in the South and earlier censuses did not give native white population by age.) One encouraging result of the test was that the procedure of fitting tables using $_5q_x$ for ages 5 to 9, 10 to 14, and 15 to 19 seemed to give very reasonable results. The superiority of the U.S. Model would seem to rest on its ability to embody the particular changes in the shape of mortality which seem to have occurred over the late nineteenth century in the United States.

CONCLUSIONS

This paper has presented a method of using historical U.S. experience to construct a model life table system based on Brass logit procedures. The purpose has been to allow anyone interested in using historical U.S. mortality experience to calculate life tables based either on census mortality data or vital registration which is not entirely accurate. The Brass system was adopted in preference to the more commonly used Coale and Demeny one parameter models because it was felt that historical changes in the shape of mortality would best be embodied in a system based solely on U.S. experience, 1850–1910.

The validity of this alternative system rests critically on the assumptions (a) that the Brass model accurately captures the shape of mortality and its changes; (b) that the limited selection of life tables used in constructing the national-state and urban models was both accurate and representative; and (c) that mortality among the ages 5 to 19 is better reported in the census than at other ages. This last assumption is necessary to allow tables to be fitted to state, city, or local U.S. mortality data in the late nineteenth century. The most likely choice would be census mortality tabulations. The most vulnerable assumption would seem to be representativeness. The life tables used to construct the models came mostly from northern industrial states (particularly Massachusetts) and cities, and thus the system may best represent such populations. It is probably less reliable for Southern and especially black populations. But the most utilized alternative system, Coale and Demeny Model West, is less representative of the changing shape of mortality

Table 9.—Ratios of Projected to Actual Populations, 1890 and 1900, Using Alternative Mortality Models

Age in Year	Actual Populations 1890 U.S. Model	Actual Populations 1890 West Model	Actual Populations 1900 U.S. Model	Actual Populations 1900 West Model	Coale-Zelnik Estimates 1890 U.S. Model	Coale-Zelnik Estimates 1890 West Model	Coale-Zelnik Estimates 1900 U.S. Model	Coale-Zelnik Estimates 1900 West Model
10-14	.95193	.95192	1.00229	1.00131	.99099	.99098	1.00161	1.00063
15-19	1.23030	1.02237	1.00982	1.00934	.99623	.99559	1.00456	1.00408
20-24	1.00099	1.00152	.99136	.99176	.99478	.99530	1.01466	1.01509
25-29	.99087	.99273	1.00488	1.00845	.99212	.99398	1.00674	1.01032
30-34	1.11668	1.12214	1.05648	1.06249	.98414	.99894	.99819	1.00388
35-39	1.01235	1.01518	.99975	1.00559	.96407	.95681	.99189	.99768
40-44	1.02730	1.02538	.96300	.96555			.99143	.99405
45-49	.97994	.96979	.99008	.98658			1.02153	1.01791
50-54	.94224	.92552	.89069	.88026				
55-59	.99153	.95988	.98850	.96889				
60-64	1.00434	.95889	.95566	.92799				

Source: Projections were done forward, using $({}_5L_{x+10}\ /{}_5L_x)$ from life tables calculated by the two models. Life table survival ratios were averaged for the 1880 and 1890 tables for the projection from 1880 to 1890 and for the 1890 and 1900 tables for the projection from 1890 to 1900. The populations were obtained from the Censuses of 1880, 1890 and 1900 and from Coale and Zelnik (1963). The 1890 populations were adjusted to compensate for the question "age at nearest birthday" asked in that census.

during the late nineteenth century, although a test of the two methods for the 1880s and the 1890s showed only small differences in projections.

The method is potentially applicable to any area in the United States at census dates for which age specific mortality rates for ages 5 to 19 may be calculated. Published data or tabulations from the manuscripts for populations and deaths could be used. The substantive results for the total and white populations of the United States in the late nineteenth century show mortality fluctuating up to 1880 and declining thereafter. Following 1880, infant and child mortality declined considerably relative to adult mortality. Finally, the method of using ${}_5q_5$, ${}_5q_{10}$, and ${}_5q_{15}$ from census data to fit tables which are then averaged seems to give very reasonable results.

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