Intercensal life tables consistent with population projections

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Intercensal methods have been broadly used to estimate mortality in developed and less developed countries with deficient or incomplete data. These methods have several advantages over indirect methods because they do not require the use of model life tables and provide sufficiently accurate results even in the presence of age distortions and death under-registration. The drawback of these methods, however, is that generated life tables do not provide projections of the initial population that are consistent with the subsequent enumeration. This article demonstrates these inconsistencies using three different methods and introduces a simple procedure to solve this inconsistency and to provide life tables that are accurate and compatible with projected populations. The empirical illustration demonstrating its efficacy draws on data from Vietnam, but the method can be extended to any context and time period.

In the early 1980s a series of articles demonstrated how to estimate mortality using consecutive age distributions and intercensal deaths (Bennett and Horiuchi 1981, Bennett and Horiuchi 1984, Preston and Bennett 1983, Preston and Coale 1982). In the 1990s, these procedures were further developed to enhance their accuracy and facilitate their applicability (Merli 1998, Preston et al 1996). These procedures are advantageous because they do not depend on the use of model life tables - as is the case of indirect mortality methods-, they circumvent the assumption of stability, and they are sufficiently accurate even when the registry of deaths is incomplete. Intercensal techniques are particularly useful in developing countries with deficient registration of deaths because they allow the estimation of life tables directly from census age distributions and age-specific growth rates (Preston and Bennett 1983). Alternatively, these age-specific growth rates can also be used to adjust the reported number of deaths and estimate life tables even in populations with fairly accurate age reporting (Bennett and Horiuchi 1984, Merli 1998, Preston et al 1996).

These methods, however, generate life tables that are inconsistent with projected populations. The inconsistency lies in the numerical difference between the expected population and the population projected with survival probabilities from estimated intercensal life tables. The mortality estimation from two age distributions and from intercensal deaths overcomes several problems regarding data quality and availability, but they are internally inconsistent when it comes to a posteriori cohort-component projections. Using intercensal survival probabilities to project the population by age results in a projected population that differs from the one initially used the estimate the life table. The goal of this paper is to demonstrate the inconsistency in the projected population stemming from intercensal life tables and to suggest a methodological adjustment to improve previous procedures that will allow the construction of life tables that are accurate and consistent with projected populations.

The first section of this article reviews past intercensal methods of mortality estimation and demonstrates how much projected and expected populations differ when intercensal probabilities of survival are utilized to project the population using the cohort-component method. The second section suggests a new technique to build life tables consistent with projected populations. The third section compares the life expectancies, survival ratios and the demographic projections generated by intercensal methods and evaluates their efficacy in light of actual populations.

Methods

We start by describing and presenting the results of three direct procedures of mortality estimation. The first one was introduced by Preston and Bennett (1983) to estimate life tables using two successive age distributions. The second procedure was developed by Bennett and Horiuchi (1984) and improved by Preston et al (1996) to estimate mortality from a set of registered deaths by age and age-specific growth rates. The third one was suggested by Merli (1998) and uses an iterative mechanism between the two aforementioned methods to overcome some of the limitations present in both procedures and to reconcile their results. To assure analytical comparability we replicate the results from Merli (1998) using male data from 1979 and 1989 Vietnamese Censuses. The demographic equations are presented in discrete form to reflect its common usage and to facilitate its application and replication to alternative empirical data.

Census-based method

The advantage of this procedure, also known as r-method, is its ability to infer mortality conditions using only two consecutive age distributions. The method does not require the use of model life tables and does not assume population stability. The r-method only assumes that the average growth between population counts is constant by age. With this assumption, the number of person-years in the life table can be estimated as:

$$ {}_nL_x = {}_nN_x^* \times e^{Sx} \qquad (1)$$

where,

$$ {}_nN_x^* = \left[{}_nN_x(t1) \times {}_nN_x(t2)\right]^{1/2} = \text{geometric mean of the population between } t1 \text{ and } t2 \qquad (2)$$

$$ S_x = 5 \cdot \sum_{a=0,5}^{x-5} {}_5r_a + 2.5 \times {}_5r_x = \text{cumulation of age-specific growth rates to midpoint of interval} \qquad (3)$$

$$ {}_nr_x[t1,t2] = \frac{\ln\left({}_nN_x(t2) / {}_nN_x(t1)\right)}{(t2-t1)} = \text{age-specific growth rate} \qquad (4)$$

The remaining functions of the life table are the number of individuals surviving to age x (l_x), the number of person-years lived above age x (T_x), the life expectancy of individuals in age x ($e^o{}_x$), and the survivorship ratios between age x and x+ n (${}_np_x$). These functions are calculated as:

$$ l_x = \frac{1}{2n}\left({}_nL_x + {}_nL_{x-n}\right) \qquad (5)$$

$$ T_x = \sum_{a=x}^{\infty} {}_nL_a \qquad (6)$$

$$ e_x^o = \frac{T_x}{l_x} \qquad (7)$$

$$ {}_np_x = \frac{{}_nL_x}{{}_nL_{x-n}} \qquad (8)$$

$$ {}_\infty p_x = \frac{{}_\infty L_x}{\left({}_nL_{x-n} + {}_\infty L_x\right)} \qquad (9)$$

The survivorship ratios in equations (8) and (9), when multiplied by the baseline population in 1979, provide the projected Vietnamese male population in 1984. When this new projected population for 1984 is multiplied again for the respective survivorship ratio it provides the projected population for 1989. For instance:

$$ {}_n\mathrm{N}_x \mathrm{Proj}(t2) = {}_nN_{x-2n} \times (t1)\, {}_np_{x-n} \times {}_np_x \qquad (10) $$

Equation (10) shows how the number of people at age *x* in 1979 increased, or decreased, ten years later as a consequence of the combined effect of mortality and net migration into that age group. The mortality of Vietnamese males using the census-based method suggested by Preston and Bennett (1983) and the resulting population projections using the survivorship ratios in equations (8) and (9) are reported in Table 1:

[TABLE 1 HERE]

The values in columns (11) and (2) are very similar to each other, but they are not identical. The similarity between projected and expected populations suggests that survivorship probabilities are accurate enough to represent the joint effect of mortality and migration on population growth, but they are not exact.[1]

Death-distribution method

Bennett and Horiuchi (1984) developed a technique to estimate mortality even when deaths are undercounted and age reporting is inaccurate. The method generalizes the idea introduced by Preston and Coale (1982) to non-stable populations to allow the inference of the number of deaths in the life table (${}_nd_x$) from the number of deaths recorded in the population (${}_nD_x$) adjusted by age specific growth rates. Preston et al (1996), for example, used this approach to estimate the mortality rates of African Americans above 64 years old, and Merli (1998) used the method to infer mortality conditions in Vietnam.

The method consists in converting the distribution of deaths in the population into the corresponding distribution of deaths in the life table using intercensal age-specific growth rates. The method assumes that under-registration is constant by age. In the discrete case the other functions of the life table can be expressed as (Preston et al 1996, Preston et al 2001):

$$ \frac{{}_nd_x}{{}_nd_{x-n}} = \frac{{}_nD_x}{{}_nD_{x-n}} \times e^{n \cdot \frac{({}_nr_{x-n} + {}_nr_x)}{2}} \qquad (11) $$

$$ {}_nd_x = {}_nd_{x-n} \times \frac{{}_nd_x}{{}_nd_{x-n}}, \text{ assuming that } {}_nd_0 = {}_nD_0 \text{ in the first age group} \qquad (12) $$

$$ {}_nL_x = n \times l_x + \frac{n}{2} \times {}_nd_x \qquad (13) $$

The death-distribution method assumes that the ratio ${}_nD_x/{}_nD_{x-n}$ is constant by age. When under-registration increases with age, the ratio ${}_nD_x/{}_nD_{x-n}$ decreases and life expectancies are underestimated at all ages bellow the ages at which deaths are omitted (Merli 1998: 352). Moreover, since Bennett and Horiuchi (1984)'s death-distribution method is based on specific growth rates between two age distributions, it is not immune to the presence of differential census coverage, intercensal migration, and incomplete death registration. Nevertheless, the method is less sensitive to these problems than the census-based method (Preston and Bennett

[1] The results displayed in Table 1 are slightly different from Merli (1998: 351) because we constrained the final age group to 80 and more instead of 85.

1983).[2] The method also has the advantage of providing an estimate for the life expectancy at birth.

The mortality estimates based on the death-distribution method are in Table 2. They are slightly different from those in Merli (1998: 353) and in Preston et al (2001: 188) because we use a simpler method to calculate the number of person-years in the first and last age groups.[3]

[TABLE 2 HERE]

The life expectancies shown in Table 2 are less sensitive to the age-specific growth rates derived from the Vietnamese age structures. Nevertheless, once again, projected (column 21) and expected populations are different.

Iterative method

To circumvent the bias implicit in the growth rates associated to age distortions, differential coverage and intercensal migration, Merli (1998) developed a two-stage iterative procedure to conciliate the census-based and the death-distribution methods. In the first stage the population is projected forward using the survival probabilities of the life table calculated according to Bennett and Horiuchi's death-distribution method. As a result of this exercise we obtain two age distributions. The first one refers to the population of Vietnam in 1979, and the second one represents the projected closed population ten years later, which is not influenced by coverage errors or intercensal migration. From these two distributions we then calculate a new life table using Preston and Bennett's census-based model. The difference is that while using the projected population to estimate age-specific growth rates we are simultaneously correcting the sensitivity of the census-based method to differential completeness of census enumeration and residual emigration.[4]

In the second stage of the iterative method, in order to correct the initial growth rates estimated in the death-distribution method, a new round of forward projections is conducted, but this time using new intercensal growth rates estimated in the first stage of the process through the census-based method.[5] This iterative process between the two methods continues until the life expectancies obtained in the previous and in the next iteration do not differ at the second decimal. This convergence in life expectancy occurred after 25 iterations.

At the end of the iterative process we get two new life tables. The first table is based on the census-based method using the projected age distribution corrected for differential completeness of census enumeration and residual emigration. The second life table uses the death-distribution method, but this time employing age-specific growth rates from the iterative process.

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[2] Bennett and Horiuchi (1984: 222) showed that life expectancy at age five is ten times more sensitive to errors in the growth rate in the census-based method than in the death-distribution method.

[3] For the first age group we use ${}_nL_0 = n\, l_x + {}_na_x \times {}_nd_x$ and assume a separation factor equal to 0.78 (See Preston 2001: 188). The final estimates of life expectancy, however, are not very sensitive to the separation factor. In the last age group the number of person-years is ${}_\infty L_{80} = l_{80} \times \log_{10}(l_{80})$.

[4] The impact of migration could also be understood as racial reclassification, when the population is disaggregated by race, or as social mobility, when it is disaggregated by income, wealth, education or occupation.

[5] The under-10 population, ${}_5N_0$ and ${}_5N_5$, is projected using the third equation described in Footnote 6 of Merli (1998, p. 356):

$$ {}_5N_5 = {}_5N_{10} \times \exp\left[-2.5 \times ({}_5r_5 + {}_5r_{10})\right] \times \frac{{}_5L_5}{{}_5L_{10}} $$

[TABLE 3 HERE]

The iterative procedure approximates the life expectancies provided by the census-based and death-distribution methods. The resulting projections are, however, still different from what we should expect. The differences between projected and observed populations in 1989 are shown in the last two columns of Table 3. They demonstrate that the number of people between 15 and 25 years old is underestimated by both projection methods. The survivorship ratios of the iterative census-based and death-distribution methods underestimate the projected population in these age-groups by about one million people. In the next section we introduce a method to solve this inconsistency.

Projection-consistent method

An alternative method to generate life tables whose projected population is compatible with the expected population consists in calculating a new set of survivorship ratios, which in the case of five-year age groups are defined as:

$$ {}_n p_5 * = \frac{{}_n N_5 *}{{}_n N_{5-n}(t1)} \qquad (14)$$

$$ {}_n p_x * = \frac{{}_n N_x(t2)}{{}_n N_{x-2n}(t1) \times {}_n p_{x-n} *} \forall x > 5 \qquad (15)$$

$$ {}_\infty p_x * = \frac{{}_\infty L_x^{NEW}}{\left({}_n L_{x-n}^{NEW} + {}_\infty L_x^{NEW}\right)} \qquad (16)$$

where,

$$ {}_n L_0^{NEW} = {}_n L_0 \text{ in Table 1 defined by the r-method} \qquad (17)$$

$$ {}_n L_x^{NEW} = {}_n p_x * \times {}_n L_{x-n}^{NEW} \qquad (18)$$

The function ${}_\infty L_x^{NEW}$ in the open-age group is defined through mathematical iterations to make projected and observed populations in ($t2$) to have the same size in the last age-group. The remaining functions of the life table, l_x*, T_x*, and e_x*, are calculated as described in equations (5), (6) and (7). The inputs and life table functions for the Vietnamese population using 1979 and 1989 censuses are in Table 4. The survivorships of the projection-consistent method derive from the age structures presented in the census-based and iterative methods. The projection-consistent-method, however, could replace the r-method in cases where the two age structures used the procedure are closed to migration and in situations where has good quality.

[TABLE 4 ABOUT HERE]

Table 4 shows that projected (column 34) and expected (column 25) populations in 1989 are now identical and solve the internal consistency of previous methods. The survivorship ratios reported in column (29), when multiplied by the baseline population in column (1) produce a population that is equal in size to what was indeed observed in the census. Overall, the life expectancies using this methodology are similar but slightly higher than those reported in Tables 1 (r-method) and Table 3 (iterative method).

Comparison between mortality estimates and their demographic projections

A rigorous way to validate the data and the accuracy of life tables is to use the projection as a historical simulation. The idea is to replay past population change by starting the projection from some past census date. As the population projection moves over time from the original census date up to the present, it should give population distributions by age that agree with successive censuses. If the agreement is good, then the demographic estimates for mortality in the past are consistent with the projection.

Figure 1 plots life expectancies and the survivorship ratios between ages x and x+n according to the three variations of the census-based methods of mortality estimation. It shows life expectancies (on the left axis) and survivorship ratios (on the right axis) for the original census-based, and for its iterative and projection-consistent variations:

[FIGURE 1 ABOUT HERE]

In comparison to the iterative and projection-consistent variations, the original census-based method underestimates life expectancies in infancy and overestimates them after age 45, mostly because of its sensitivity to the age population age structure recorded between the two periods. The iterative variation of the census-based method helps to reduce the influence of the population age structure over the life expectancy estimates, but it does not necessarily provide survivorship ratios that are internally valid and consistent with projected populations. If we examine the survivorship probabilities provided by each method, we quickly realize that the census-based projection-consistent method (gray dashed curve) is the only one with survivorship ratios lower than one and without abrupt variations along its distribution. Moreover, this is the only method whose survivorship probabilities provide identical observed and projected populations to reinforce its internal validity. This is particularly important because small absolute differences in survivorship ratios can be responsible for large differences in projected populations.

To illustrate this point, Table 5 shows the absolute size of projected populations and compares it to the baseline and expected populations in each method. It shows that depending on the mortality method used the total projected population can be 28 to 34 percent larger than the population baseline. Bennett and Horiuchi's death-distribution method, for instance, overestimates the expected population by 4.45 percent, which in absolute terms represents a surplus of more than one million people. The projection error using census-based methods is smaller than in the death-distribution method, but the sum of the difference between expected and projected populations is larger than half million people. In relative terms, the difference between projected and expected populations may not be relevant, but in absolute terms that represents a significant contingent of people that should be there and that are not due to an internal inconsistency in the death-distribution and census-based methods. The census-based projection-consistent method is the only procedure where projected and expected populations are identical.

[TABLE 5 ABOUT HERE]

The last row of Table 5 reports Keyfitz's Δ, which is a standard measure of the distance between probability vectors representing the proportion of the population in different ages.[6] It indicates how different the age structures of projected and expected censual populations are in relation to each other. Overall, the age structure of the projected and expected populations is most similar when the projection is generated by the census-based methods than by the death-distribution method. Nevertheless, the only procedure where the projection is fully consistent with the expected population is represented in the last column of Table 5.

Discussion

The comparison between projected and expected populations, total and by age group, demonstrates that the survivorship ratios derived from the life tables provided by current intercensal procedures are not as accurate as they could be to conduct population projections. Using the male population of Vietnam, previously described by Merli (1998), we found that the discrepancy between observed and projected populations can be superior to one million people. In terms of planning and allocation of resources, this is not a small figure. In larger countries such as China, India, Indonesia, Brazil and the United States, the discrepancies between projected and observed populations would be even larger.

With these numerical discrepancies comes the realization that the current intercensal procedures suggested by Preston and Bennett (1983), Bennett and Horiuchi (1984), Preston et al (1996) and Merli (1998) are internally inconsistent with the projections produced by the cohort-component method. The estimated life tables and life expectancies produced by these procedures are good enough as approximations to describe the current mortality status of certain contexts, but they do not produce projected populations that are numerically exact and fully compatible with the observed population in the second census enumeration.

To solve this inconsistency we suggest a procedure based on two age distributions and on the number of person-years derived from the survivorship ratios. The method does not depend on age-specific growth rates, but the estimates of life expectancy will certainly be more accurate if the procedure is used after the last stage of Merli´s (1998) iterative process. Once multiplied by the population baseline, the projection-consistent method generates a projected population that is identical to the one observed in the second enumeration.

Since the projection-consistent procedure of mortality estimation builds on census-based and death-distribution methods, it has the same advantages of previous intercensal procedures, but it also has the added virtue of providing projections that are internally consistent with the age distribution used as an input. The analysis of data from Vietnam shows that employing this refined method results in greater accuracy of the projected population, regardless of the completeness of death registration in destabilized populations.

The results show the relative sensitivity of life tables to different methods of mortality estimation and demonstrated the different projected population sizes and age structures generated by each one of them. In particular, they contribute to advance our knowledge of mortality estimation and projection methods by describing how the future growth and distribution of populations may differ under slightly different mortality scenarios. We show that apparently small differences may have large impacts in the projected number of people. In the case of Vietnam, the net impact

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[6] Keyfitz (1968: 47) proposed a measure equivalent to $\Delta(x,w)=\frac{1}{2}\sum_i |x_i - w_i|$, where x_i is the proportion of the expected population in 1989; w_i is the proportion of the projected population ten years after the baseline, and *i* subscribes five-year age groups between 10 and 80.

could vary between 650,000 and 1,600,000 people depending on the set of survivorship ratios used in the cohort-component projection. In long term projections and stable population analysis, the error of the projection builds up and these discrepancies will be even larger. It is crucial, therefore, to assure that the life tables defined in the baseline are as accurate as possible in order to minimize the propagation of the projection error in the future. The projection-consistent method present here does this. Alternative data and further empirical validations considering other time periods and contexts would, however, be required before making final assertions on this matter.

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Table 1. Application of the Census-based Method to Vietnam's Population, Males: 1979-1989

Age x	$_nN_x$ 1979.75 (1)	$_nN_x$ 1989.75 (2)	$_nN_x$* (3)	$_nr_x$ (4)	S_x (5)	$_nL_x$ (6)	l_x (7)	e_x (8)	$_np_x$ (9)	$_nN_x$ proj. 1984.75 (10)	$_nN_x$ proj. 1989.75 (11)
0	3,946,224	4,710,423	4,311,425	0.0177	0.0443	4,506,510	-	-	-	-	-
5	3,928,795	4,430,179	4,171,962	0.0120	0.1185	4,696,993	920,350	53.90	1.042	4,113,024	-
10	3,632,555	3,898,298	3,763,082	0.0071	0.1662	4,443,543	914,054	49.13	0.946	3,716,797	3,891,086
15	2,954,333	3,427,357	3,182,067	0.0149	0.2210	3,969,043	841,259	48.10	0.893	3,244,656	3,319,902
20	2,281,171	2,974,282	2,604,774	0.0265	0.3245	3,603,110	757,215	48.19	0.908	2,681,953	2,945,509
25	1,742,277	2,832,160	2,221,353	0.0486	0.5122	3,707,500	731,061	44.99	1.029	2,347,262	2,759,655
30	1,177,320	2,361,692	1,667,473	0.0696	0.8077	3,739,856	744,736	39.19	1.009	1,757,482	2,367,747
35	966,580	1,604,918	1,245,505	0.0507	1.1085	3,773,787	751,364	33.86	1.009	1,188,001	1,773,427
40	919,291	1,048,246	981,653	0.0131	1.2681	3,488,963	726,275	29.84	0.925	893,628	1,098,338
45	994,602	877,589	934,265	-0.0125	1.2696	3,325,611	681,457	26.68	0.953	876,250	851,789
50	825,356	866,821	845,834	0.0049	1.2506	2,954,058	627,967	23.66	0.888	883,480	778,351
55	680,996	918,363	790,823	0.0299	1.3376	3,013,024	596,708	19.94	1.020	841,831	901,116
60	540,920	725,079	626,267	0.0293	1.4856	2,766,706	577,973	15.38	0.918	625,324	773,010
65	419,164	533,445	472,865	0.0241	1.6192	2,387,427	515,413	11.88	0.863	466,767	539,600
70	284,003	329,167	305,752	0.0148	1.7163	1,701,228	408,865	9.13	0.713	298,687	332,608
75	183,222	215,510	198,711	0.0162	1.7938	1,194,706	289,593	7.02	0.702	199,444	209,756
80	103,773	145,637	122,936	0.0339	1.9191	837,792	203,250	4.12	0.412	118,299	130,973

Note: The stationary population above age x (T_x) is not shown but it can be easily derived multiplying column (7) by column (8).
Sources: Vietnam General Statistical Office (1983); Vietnam Central Census Steering Committee (1994); Merli (1998: 348)

Table 2. Application of the Death-distribution Method to Vietnam's Population, Males: 1979-1989

Age x	$_nr_x$ (4)	D_x (12)	$_nD_x/_nD_{x-n}$ (13)	$_nd_x/_nd_{x-n}$ (14)	$_nd_x$ (15)	$_nL_x$ (16)	l_x (17)	e_x (18)	$_np_x$ (19)	$_nN_x$ proj. 1984.75 (20)	$_nN_x$ proj. 1989.75 (21)
0	0.0177	48,508	-	-	48,508	2,495,576	546,274	60.90	-	-	-
5	0.0120	8,029	0.1655	0.1783	8,648	2,456,684	497,766	61.82	0.9844	3,884,724	-
10	0.0071	3,928	0.4892	0.5131	4,437	2,434,688	489,118	57.89	0.9910	3,893,619	3,849,943
15	0.0149	3,783	0.9631	1.0173	4,514	2,413,588	484,680	53.39	0.9913	3,601,074	3,859,876
20	0.0265	3,856	1.0193	1.1304	5,103	2,389,164	480,166	48.87	0.9899	2,924,437	3,564,633
25	0.0486	3,469	0.8996	1.0855	5,539	2,363,997	475,063	44.37	0.9895	2,257,142	2,893,631
30	0.0696	3,053	0.8801	1.1826	6,551	2,337,280	469,524	39.85	0.9887	1,722,586	2,231,632
35	0.0507	3,093	1.0131	1.3686	8,966	2,298,471	462,973	35.37	0.9834	1,157,771	1,693,984
40	0.0131	3,345	1.0815	1.2686	11,374	2,254,338	454,007	31.01	0.9808	948,021	1,135,541
45	-0.0125	4,836	1.4457	1.4479	16,469	2,182,736	442,633	26.71	0.9682	890,092	917,910
50	0.0049	6,215	1.2852	1.2609	20,766	2,110,261	426,164	22.62	0.9668	961,578	860,538
55	0.0299	9,138	1.4703	1.6040	33,308	1,987,983	405,398	18.57	0.9421	777,531	905,860
60	0.0293	12,070	1.3209	1.5316	51,014	1,770,150	372,089	14.89	0.8904	606,376	692,333
65	0.0241	13,645	1.1305	1.2920	65,909	1,466,267	321,075	11.75	0.8283	448,060	502,279
70	0.0148	14,310	1.0487	1.1558	76,175	1,101,407	255,166	9.03	0.7512	314,861	336,567
75	0.0162	14,357	1.0033	1.0841	82,582	723,069	178,991	6.72	0.6565	186,447	206,705
80	0.0339	14,787	1.0300	1.1674	96,409	480515	96,409	4.98	0.3992	114,579	120,180

Note: The stationary population above age x (T_x) is not shown but it can be easily derived multiplying column (7) by column (8).
Sources: Vietnam General Statistical Office (1983); Vietnam Central Census Steering Committee (1994); Merli (1998: 348)

Table 3. Application of the Iterative Method to Vietnam's Population, Males: 1979-1989

Age x	Corrected	Death-distributoin method			Census-based method				
	$_nr_x$ (22)	e_x (23)	$_np_x$ (24)	$_nN_x$ proj. (1989.75) (25)	e_x (26)	$_np_x$ (27)	$_nN_x$ proj. (1989.75) (28)	$_nN_x$ (1989.75)-column (25)	$_nN_x$ (1989.75)-column (28)
0	-0.0014	60.27	-	3,892,896	-	-	-	817,526	-
5	-0.0017	61.18	0.9854	3,862,164	61.35	0.9862	-	568,015	-
10	0.0060	57.16	0.9921	3,857,851	57.60	0.9714	3,780,725	40,447	117,574
15	0.0270	52.60	0.9924	3,868,268	53.97	0.9806	3,742,623	-440,911	-315,266
20	0.0448	48.03	0.9903	3,570,009	49.25	1.0100	3,597,797	-595,726	-623,515
25	0.0507	43.51	0.9890	2,893,373	44.03	0.9990	2,980,740	-61,213	-148,580
30	0.0639	39.01	0.9883	2,229,687	39.83	0.9610	2,189,890	132,005	171,802
35	0.0561	34.53	0.9833	1,693,187	34.51	1.0656	1,784,190	-88,269	-179,272
40	0.0210	30.17	0.9801	1,134,638	28.91	0.9681	1,214,514	-86,392	-166,268
45	-0.0084	25.89	0.9652	914,436	24.83	0.9638	901,805	-36,847	-24,216
50	0.0034	21.86	0.9627	854,256	21.72	0.8696	770,464	12,565	96,357
55	0.0273	17.89	0.9345	894,784	18.31	1.0039	868,304	23,579	50,059
60	0.0224	14.31	0.8774	676,742	14.14	0.8776	727,195	48,337	-2,116
65	0.0150	11.28	0.8151	487,059	11.13	0.8200	490,099	46,386	43,346
70	0.0131	8.65	0.7345	323,860	8.54	0.7201	319,430	5,307	9,737
75	0.0049	6.43	0.6248	192,374	6.31	0.6475	195,466	23,136	20,044
80	0.0107	4.93	0.3966	115,534	3.78	0.3775	110,324	30,104	35,313

Table 4. Application of the Projection-consistent Method to Vietnam's Population, Males: 1979-1989, $_{n}N_{5}* = 3{,}895{,}337$

Age x	$_{N}N_{x}$ 1979.75 (1)	$_{N}N_{x}$ proj. 1989.75 (25)	$_{n}p_{x}*$ (29)	$_{n}L_{x}^{NEW}$ (30)	$l_{x}*$ (31)	$e_{x}*$ (32)	$_{n}N_{x}$ Proj. * (1984.75) (33)	$_{n}N_{x}$ proj. * (1989.75) (34)
0	3.946.224	3.892.896	-	3.906.160	-		-	-
5	3.928.795	3.862.164	0,9871	3.855.790	776.195	61,47	3.895.337	-
10	3.632.555	3.857.851	0,9904	3.818.685	767.447	57,15	3.890.987	3.857.851
15	2.954.333	3.868.268	0,9942	3.796.388	761.507	52,58	3.611.345	3.868.268
20	2.281.171	3.570.009	0,9886	3.752.934	754.932	48,01	2.920.518	3.570.009
25	1.742.277	2.893.373	0,9907	3.718.052	747.099	43,49	2.259.969	2.893.373
30	1.177.320	2.229.687	0,9866	3.668.234	738.629	38,96	1.718.932	2.229.687
35	966.580	1.693.187	0,9850	3.613.294	728.153	34,48	1.159.687	1.693.187
40	919.291	1.134.638	0,9784	3.535.246	714.854	30,07	945.702	1.134.638
45	994.602	914.436	0,9669	3.418.367	695.361	25,82	888.898	914.436
50	825.356	854.256	0,9610	3.285.146	670.351	21,69	955.840	854.256
55	680.996	894.784	0,9361	3.075.299	636.045	17,69	772.635	894.784
60	540.920	676.742	0,8759	2.693.622	576.892	14,18	596.477	676.742
65	419.164	487.059	0,8166	2.199.502	489.312	11,21	441.693	487.059
70	284.003	323.860	0,7332	1.612.729	381.223	8,62	307.341	323.860
75	183.222	192.374	0,6259	1.009.453	262.218	6,38	177.766	192.374
80	103.773	115.534	0,3963	662.738	167.219	3,96	113.745	115.534

Figure 1. Life expectancies and survivorship ratios according to three variations of the census-based method: Vietnam, 1979-1989

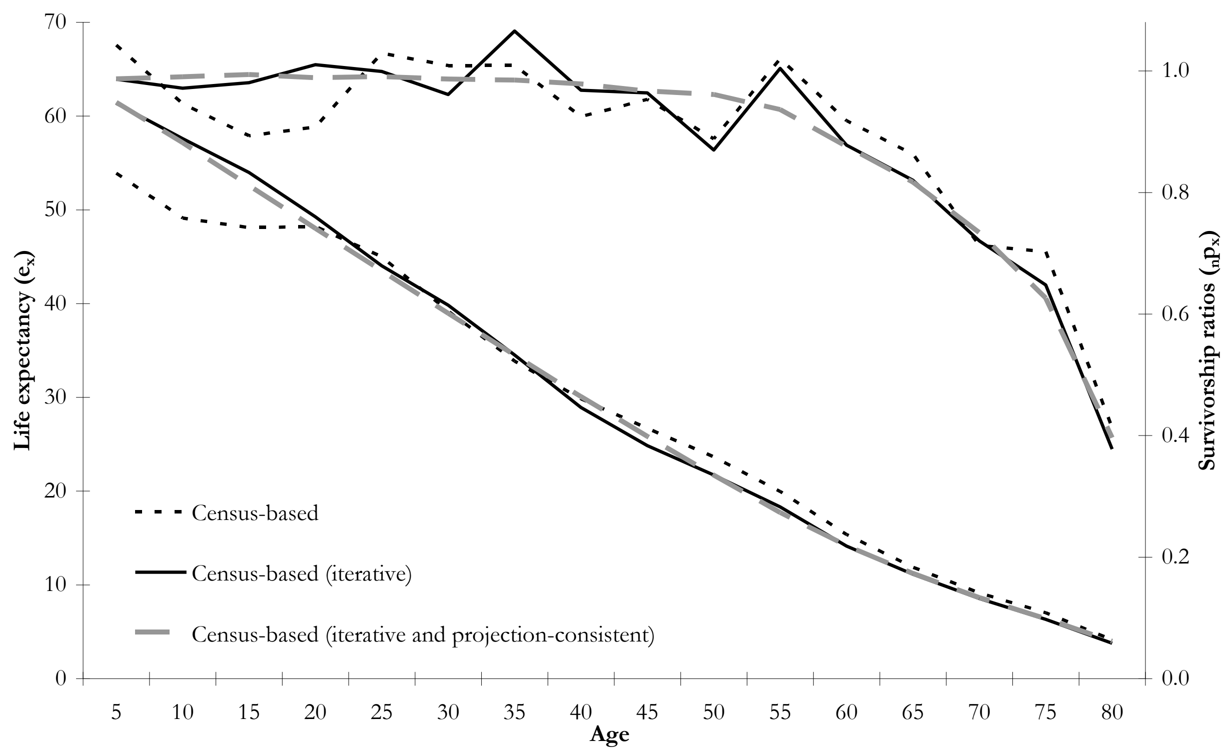

Table 5. Comparisons between projected and expected male populations of Vietnam above age 10

	Census-based	Death-distribution	Iterative method: Census-based	Iterative method: Census-based projection consistent
Projected population above age 10	22,672,867	23,771,611	23,673,564	23,706,057
Σ |expected- projected| [a]	650,063	1,603,798	717,730	0
Projected/ Baseline	1.2806	1.3426	1.3371	1.3389
Projected/ Expected	0.9962	1.0445	0.9986	1.0000
Keyfitz's Δ [b]	0.0139	0.0335	0.0151	0.0000

[a] The expected population in the census-based and death-distribution methods are equal to the observed population in 1989.75. In the iterative methods the expected population is equal to the projected population in the last round of the iterative procedure.

[b] Keyfitz's measure of proximity between vectors compares the age structure of projected and expected populations. Maximum value is 1 and minimum is 0 when the vectors are identical.