PROBLEMS IN AND A SYLLABUS FOR DEMOGRAPHY

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Demography is the study of population dynamics. It is possible to view the matter strictly as a sociologist or strictly as a mathematician. One of the few people in the world who can do both with expertise is Nathan Keyfitz, a professor at Harvard. In reference [5], Professor Keyfitz has an example of population projections, which I often use as a thought stimulus for students. If the number of births in a recent year is B, the number of deaths is D, and the population at mid-year P, the crude rates of birth, death, and natural increase are B/P, D/P, and B/P-D/P, respectively. In 1969, the crude rates of natural increase for Mexico and the United States were 0.035 and 0.008. At those rates, Mexico was increasing $3\frac{1}{2}\%$ per year, and the United States by 0.8%. Although both rates may seem slight, if the rates would continue for 100 years, Mexico would grow 32 times, while the United States would somewhat more than double. In reference [6], Professor Keyfitz explores the theme of population and security, with suggestions that actuaries utilize their techniques to offset the insecurities produced by population waves.

At Ball State University, the Mathematical Sciences Department has offered a course in demography for eight years. During the first three years, reference [4] was the textbook. With the exception of two students, all of the students were actuarial students. One of the other two, Md. Humayun Kabir, earned his doctorate in demography at Brown University. Mr. Kabir applied the techniques of [4] in his Ball State M.S. thesis "Mathematical Demography Applied to Bangladesh Population". This was published as [3] in ARCH, Issue 1975.3. Although

[4] is truly an outstanding textbook, the needs of actuarial students required a switch to Spiegelman's textbook, [7]. Spiegelman's excellent scholarship is evident to the reader, and his treatise is well-known in both demographic and actuarial circles. However, there are no problems in the book, and students are not exposed to the excitement of making demographic projections. To fill those needs, I have tried various approaches. Students were exposed to a part of some of the papers presented in the Harvard Actuarial Conference on "Demographic Projections and Related Actuarial Topics". Those papers appear in ARCH, Issue 1974.1, Appendix. Use of a Markov chain to analyze the growth and migration patterns of a people has been presented. Reference [2], (see [5] also), has been the basis for an example in which a Markov transition matrix was used to study the effects of rural-urban movement on births in future years. Students are told briefly of the work of Dr. Norman Borlaug. Dr. Borlaug won the Nobel Prize for Peace in 1970 for his research in providing high-yield dwarf wheat plants for Latin America, Asia, and Africa. But he has stated in the Reader's Digest, and elsewhere (see [1]) that this "Green Revolution" has won only 30 years delay for the world to solve the population problem.

Actuaries must utilize national, state, and regional mortality statistics, cause of death statistics, and life tables. However, our demography class did not utilize the wealth of data from the U.S. Bureau of the Census. The attached syllabus is designed to remedy that problem. Each student is assigned a Standard Metropolitan Statistical Area (SMSA). For her/his SMSA, the student computes the crude death rate, central death rates by age group and sex, and death rates by two leading causes of death. As another project, students compute the adjusted death rates,

and the age-sex-adjusted death rates for their SMSA's where the standard population figures are for the state or possibly states surrounding the SMSA's. Numerous other demographic projects are described. In addition, two graduation of data projects evolve. Each student should build a life table for his/her SMSA. From the age grouped data, King's formula is used to obtain pivotal values; then the Karup-King interpolation formula is applied to obtain single age life functions, for male and female tables. As a second possible project, Whittaker-Henderson Type B formulas can be applied to create graduated mortality rates for a SMSA. If programmed for a computer, it is easy to use a large spectrum of constants measuring the blend of smoothness and fit. Students have demonstrated eagerness to do such projects, and a significant improvement in learning is apparent.

Acknowledgment

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REFERENCES

[1] Bickel, Lennard, Facing Starvation: Norman Borlaug and the Fight Against Hunger, Readers Digest Press (E.P. Dutton & Co.), N.Y., 1974.

[2] Fish, Mary and A.A. Thompson, "The Determinants of Fertility: A Theoretical Forecasting Model", Behavioral Science 15 (1970), 318-328.

[3] Kabir, Md. Humayun, "Mathematical Demography Applied to Bangladesh Population", ARCH, Issue 1975.3.

[4] Keyfitz, Nathan, Introduction to the Mathematics of Population, Addison-Wesley, Reading, Mass., 1968.

[5] Keyfitz, Nathan, "On Future Population", Journal, Amer. Statistical Assoc., 67 (1972), 347-363.

[6] Keyfitz, Nathan, "Some Implications of Current Demographic Trends", Transactions, Society of Actuaries, XXIII (1971), 203-216.

[7] Spiegelman, Mortimer, Introduction to Demography, Rev. Ed., Harvard Univ. Press, Cambridge, Mass., 1968.

Mathematics 558 SYLLABUS Demography

Textbook: Spiegelman, M., Introduction to Demography, Harvard University Press, Cambridge, Mass., 1968.

Day 1 Chapter 1, Introduction.

Days 2, 3 Chapter 2, The Collection of Census Statistics and Vital Statistics.

Day 4 Spent in Government Documents Room, and the Reference Section of Bracken Library.

Each student is assigned a Standard Metropolitan Statistical Area (SMSA). Report on the five leading causes of death in 1961 and 1976, with the percents of deaths. Are there significant changes for any SMSA, and what are the possible causes?

Days 5, 6 Chapter 3, Errors in Census Statistics and Vital Statistics and Their Adjustments.

Day 7 Assignment based on: Keyfitz, Nathan, "Information and Allocation: Two Uses of the 1980 Census", Journal, Amer. Statistician, Vol. 33 (1979), 45-56.

Days 8, 9 Mortality, pages 80-102. Chapter 4.

Days 10, 11 Government Documents Room. Use "Vital Statistics of the United States, 1975, Volume II, Mortality, Part B". Each student will use Table 7-4 for his/her SMSA. Record deaths for the various age groups, by sex. Then use "1970 Census of Population, Vol. 1, Characteristics of the Population, Part 16, Indiana"--or other state. Chapter B gives numbers alive for various age groups. Use 1960 and 1970 volumes and data to extrapolate to 1975 data.

1. Create central death rates for the various age groups, by sex.

2. Compute crude death rates for 1960, and 1975. For 1960 need Reference Room volumes.

3. Compare the death rates for 1960 and 1975 for your SMSA due to malignant neoplasms versus major cardiovascular diseases.

4. Compute the infant mortality rates for 1960 and 1975.

Day 12 Adjusted Measures of Mortality, pages 103-111.

Days 13, 14 Government Documents Room. Bring hand calculator. Each student should calculate for her/his SMSA:

1. the adjusted death rate (direct method). The standard population figures are for the state or possibly states surrounding your SMSA.

2. the age, sex, adjusted death rates.

3. the adjusted death rate (indirect method).

Day 15 Record all above rates at blackboard, and discuss the differences.

Day 16 Sampling Variance of Crude and Adjusted Rates, pages 111-115.

Day 17 Test 1.

Day 18 Chapter 5, Construction of Life Tables, pages 116-125.

Day 19 Chapter 5, pages 126-135.

Day 20 Chapter 5, pages 135-144.

Day 21 Chapter 5, pages 145-1S2.

Days 22, 23 Create an abridged life table for your SMSA by Greville's method. Note any significant differences with the latest abridged U.S. table: see, for example, Table 5.1 of the 1974 Volume II, Part A.

Days 24, 25, 26 Use various graduation of data techniques to interpolate for single age data for $\{l_x\}$, $\{d_x\}$, $\{q_x\}$, and $\{\mathring{e}_x\}$. Compare with the latest U.S. data: see, for example, Tables 5.2 and 5.3 of the 1974 Volume II, Part A.

Day 27 Class discussion of student reports.

Day 28 Chapter 6. Mortality Projections and Theories, pages 145-160.

Days 29, 30 Study pages 161-170, 406-409, 417-422. Population projections: math. models. Problems based on newspaper report of latest U.S. population.

1. Assume that U.S. population is modeled by $P(t) = Ce^{\mu t}$ for $t \geq 0$. In how many years will our population grow by 100 million?

2. In how many years will our population double?

Days 31, 32 Problems based on: Characteristics of the Population-1970 Census, Vol. 1, Part 1, United States Summary, Section 1. Chapter A, pages 8-9 show SMSA's. Each student should use pages 1-48 and 1-49 to do one of the following 7 projects: Fit a logistic curve to the populations of

1. Indiana from 1800 to 1970

2. Ohio from 1800 to 1970

3. Illinois from 1810 to 1970

4. Michigan from 1810 to 1970

5. Wisconsin from 1840 to 1970

6. Iowa from 1840 to 1970

7. Minnesota from 1850 to 1970

Each student should use pages 1-171 through 1-179 to do the following project.

Set up a differential equation of the form $\frac{dy}{dt} = \mu y$ for your SMSA. Let k = population in 1950. Use the data for 1960 and 1970 to determine μ. Determine the appropriate units for t. Solve for y.

Days 33, 34 Problems based on pamphlets entitled "Current Population Reports". Each student should do one of the following 7 projects:

Problem 1. Consider a differential equation of the form $\frac{dy}{dt} = \mu y$ for Indiana. Let k = population on July 1, 1977. Use the data for July 1, 1978 to determine μ. Here t = 1 corresponds to one year from July 1, 1977. Project the population to 1990.

Problem 2. Do the same for Colorado.

Problem 3. Do the same for Georgia.

Problem 4. Do the same for Hawaii.

Problem 5. Do the same for Idaho.

Problem 6. Do the same for Illinois.

Problem 7. Do the same for Iowa.

Day 35 Discussion of various national population projections, based on writings of Nathan Keyfitz, and my 1975 faculty lecture.

Day 36 Study "Methodology of the National and State Life Tables for the United States: 1969-71", DHEW Publication No. (HRA) 75-1150, Volume 1, Number 3 by Dr. T.N.E. Greville.

Day 37 Study "Some Trends and Comparisons of United States Life-Table Data: 1900-1971", DHEW Publication No. (HRA) 75-1150, Volume 1, Number 4 by Dr. T.N.E. Greville.

Day 38 Review of the quarter, and discussion.

Day 39 Final exam.

NOTES: The following maps will be shared with the class:

1. Standard Metropolitan Statistical Areas, United States Maps, GE-50, No. 55.

2. Population Distribution, Urban and Rural, in the United States: 1970, United States Maps, GE-50, No. 45.

3. Population Distribution, Urban and Rural, in the United States: 1970, United States Maps, GE-70, No. 1.