

Tuljapurkar, Shripad; Boe, Carl

Mortality change and forecasting: how much and how little do we know? (English)

Zbl 1081.91603

N. Am. Actuar. J. 2, No. 4, 13-47 (1998).

Summary: Prospects of longer life are viewed as a positive change for individuals and as a substantial social achievement but have led to concern over their implications for public spending on old-age support. This paper makes a critical assessment of knowledge about mortality change and the potential of existing work to contribute to the development of useful forecasts in Canada, Mexico, and the U.S.

We first examine broad patterns in the historical decline in death rates in the three countries, the effect of these on trends in life expectancy, and the epidemiological transition. Next we review theories of the age pattern and evolution of mortality, including graduations, evolutionary theory, reliability models, dynamic models, and relational models.

The analysis and forecasting of mortality change have been shaped largely by some key historical lessons, which we summarize next. We emphasize issues that have been or are likely to be significant in mortality analysis, especially the questions of the age pattern and time trend in mortality at old ages; we distinguish patterns and facts that are established from those that remain uncertain. Next, we consider mortality differentials in characteristics such as sex, marital status, education, and socioeconomic variables; we summarize their key features and also point to the substantial gaps in our understanding of their determinants.

Finally, we review methods of forecasting, including the scenario method used by the U.S. Social Security Administration and the time series method of Lee and Carter. We set out some important recommendations for forecasters: forecasting assumptions should be made more formal and explicit; there should be retrospective evaluations of forecast performance; and greater attention should be paid to the assessment and consequences of forecast uncertainty.

MSC:

91D20 Mathematical geography and demography

91B30 Risk theory, insurance (MSC2010)

91B84 Economic time series analysis

62P05 Applications of statistics to actuarial sciences and financial mathematics

Cited in **9** Documents

Full Text: [DOI](#)

References:

- [1] Alho J.M., *International Journal of Forecasting* 6 pp 521– (1990) · [doi:10.1016/0169-2070\(90\)90030-F](#)
- [2] Alho J.M., *Mathematical Population Studies* 3 (1) pp 53– (1991) · [Zbl 0900.92134](#) · [doi:10.1080/08898489109525323](#)
- [3] Alho J.M., *Journal of Forecasting* 10 pp 157– (1991) · [Zbl 0900.92134](#)
- [4] Alho J.M., *Journal of the American Statistical Association* 80 pp 306– (1985) · [doi:10.1080/01621459.1985.10478113](#)
- [5] Alho J.M., *The Practical Specification of the Expected Error of Population Forecasts* (1995)
- [6] Arriaga E.E., *Demography* 21 (1) pp 83– (1984) · [doi:10.2307/2061029](#)
- [7] Bah S.M., *Canadian Studies in Population* 18 (2) pp 18– (1991)
- [8] Bayo F.R., *Transactions of the Society of Actuaries* pp 37– (1983)
- [9] Bennett N.G., *Population and Development Review* 22 pp 69– (1996)
- [10] Brass W., *Biological Aspects of Demography* (1971)
- [11] Brillinger D.R., *Biometrics* 42 pp 693– (1986) · [Zbl 0611.62136](#) · [doi:10.2307/2530689](#)
- [12] Bulatao R.A., *Policy, Research, and External Affairs Working Paper* 337 (1989)
- [13] Carey J., *Science* 258 pp 457– (1992) · [doi:10.1126/science.1411540](#)
- [14] Centers for Disease Control/National Aids Clearinghouse, *HIV and AIDS Trends—The Changing Landscape of the Epidemic: A Closer Look* (1996)

- [15] Coale A., Population Index 55 pp 613– (1989) · doi:10.2307/3644567
- [16] Coale A.J., Population Studies 40 pp 389– (1986) · doi:10.1080/0032472031000142316
- [17] Coale A.J., Asian and Pacific Population Forum 4 (1) pp 1– (1990)
- [18] Condran G.A., Population Bulletin of the United Nations 30 pp 23– (1991)
- [19] Consejo Nacional de Población, Proyecciones de la población de México y de las entidades federativas 1990–2030 (1996)
- [20] Corder E., Archives of Neurology 53 (5) pp 418– (1996) · doi:10.1001/archneur.1996.00550050048022
- [21] Crimmins E.M., Demography 31 (1) pp 159– (1994) · doi:10.2307/2061913
- [22] Crystal S., The Gerontological Society of America 30 (4) pp 437– (1990)
- [23] Crystal S., Review of Income and Wealth 3 pp 227– (1990) · doi:10.1111/j.1475-4991.1990.tb00302.x
- [24] Curtsinger J., Science 258 pp 461– (1992) · doi:10.1126/science.1411541
- [25] Das Gupta P., Current Population Reports pp 23– (1993)
- [26] Demetrius L., Proceedings of the National Academy of Sciences 71 (12) pp 4645– (1974) · Zbl 0303.62075 · doi:10.1073/pnas.71.12.4645
- [27] Elo I.T., Population Index 58 (2) pp 186– (1992) · doi:10.2307/3644718
- [28] Elo I.T., Workshop on Racial and Ethnic Differences in Health in Late Life in the United States pp 1– (1994)
- [29] Elo I.T., Demography 31 (3) pp 427– (1994) · doi:10.2307/2061751
- [30] Elo I.T., Social Science and Medicine 42 (1) pp 47– (1996) · doi:10.1016/0277-9536(95)00062-3
- [31] Ewbank D., Population Studies 37 pp 105– (1983)
- [32] Ewbank D.C., Presentation, Population Association of America (1996)
- [33] Finch C., Longevity, Senescence, and the Genome (1991)
- [34] Fogel R.W., American Economic Review 84 (3) pp 369– (1994)
- [35] Fries J., The Milbank Quarterly 67 pp 208– (1989) · doi:10.2307/3350138
- [36] Gavrilov L.A., The Biology of Life Span: A Quantitative Approach (1991)
- [37] Gittelsohn A.M., American Journal of Public Health 72 (2) pp 133– (1982) · doi:10.2105/AJPH.72.2.133
- [38] Gobalet J.G., World Mortality Trends Since 1870 (1989)
- [39] Gómez de León J., Empirical EDA Models to Fit and Project Time Series of Age Specific Mortality Rates (1990)
- [40] Gómez de León J., Estimación de la Población Base para las Proyecciones de Población 1990–2030 (1996)
- [41] Harman D., Proceedings of the National Academy of Science 88 pp 5360– (1991) · doi:10.1073/pnas.88.12.5360
- [42] Hastie T., Generalized Additive Models (1990) · Zbl 0747.62061
- [43] Heligman L., Journal of the Institute of Actuaries 107 pp 49– (1980) · doi:10.1017/S0020268100040257
- [44] Herskind A., Human Genetics 97 pp 319– (1996) · doi:10.1007/BF02185763
- [45] Himes C., Demography 31 (4) pp 633– (1994) · doi:10.2307/2061796
- [46] Himes C.L., Population Index 48 pp 269– (1994)
- [47] Hodge M., American Journal of Public Health 85 (9) pp 1276– (1995) · doi:10.2105/AJPH.85.9.1276
- [48] Holmer M.R., Report of the 1994–1995 Advisory Council on Social Security: Reports of the Technical Panel on Assumptions and Methods; Technical Panel on Trends and Issues in Retirement Savings and Presentations to the Council pp 183– (1995)
- [49] Horiuchi S., Mathematical Population Studies 2 (4) pp 245– (1990) · Zbl 0875.92063 · doi:10.1080/08898489009525312
- [50] Horiuchi S., Gerontologist 35 (1) pp 359– (1995)
- [51] Horiuchi S., Journals of Gerontology. Series A, Biological Sciences and Medical Sciences 52 (1) pp B67– (1996)
- [52] Hu Y., Demography 27 (2) pp 233– (1990) · doi:10.2307/2061451
- [53] Jenkins W.A., Transactions of the Society of Actuaries pp 369– (1949)
- [54] Johansen R.J., Transactions of the Society of Actuaries pp 211– (1995)
- [55] Joseph K., Canadian Medical Association Journal 155 (8) pp 1047– (1996)
- [56] Kannisto V., Development of Oldest-Old Mortality, 1950–1990: Evidence from 28 Developed Countries (1994)
- [57] Kannisto V., Population and Development Review 20 (4) pp 793– (1994) · doi:10.2307/2137662
- [58] Kermack W., Lancet 226 pp 698– (1934) · doi:10.1016/S0140-6736(00)92530-3
- [59] Kestenbaum B., Demography 29 (4) pp 565– (1992) · doi:10.2307/2061852
- [60] Keyfitz N., Introduction to the Mathematics of Population (1968)
- [61] Keyfitz N., Applied Mathematical Demography (1977) · Zbl 1060.91519
- [62] Keyfitz N., Theoretical Population Biology 21 pp 329– (1982) · Zbl 0487.62089 · doi:10.1016/0040-5809(82)90022-3
- [63] Kitagawa E., Journal of the American Statistical Association 50 pp 1168– (1955)
- [64] Kitagawa E.M., Differential Mortality in the United States: A Study of Socioeconomic Epidemiology (1973)

- [65] Kunitz S.J., *Population and Development Review* 13 (3) pp 379– (1987) · doi:10.2307/1973132
- [66] Lee R.D., *International Journal of Forecasting* 8 pp 315– (1992) · doi:10.1016/0169-2070(92)90050-J
- [67] Lee R.D., *Demography of Aging* (1994)
- [68] Lee R.D., *Journal of the American Statistical Association* 87 pp 659– (1992)
- [69] Lee R.D., *Modeling and Forecasting Canadian Mortality: An Application of the Lee-Carter Approach, with Extensions* (1993)
- [70] Lee R.D., *Assessing Knowledge of Retirement Behavior* pp 195– (1996)
- [71] Lee R., *Demography* 34 (1) pp 67– (1997) · doi:10.2307/2061660
- [72] Lew E.A., *Transactions of the Society of Actuaries* pp 257– (1984)
- [73] Lopez A.D., *Sex Differentials in Mortality: Trends, Determinants, and Consequences* pp 53– (1981)
- [74] Manton D.G., *Recent Trends in Mortality Analysis* (1984)
- [75] Manton K.G., *Forecasting Life Expectancy and Active Life Expectancy* (1986)
- [76] Manton K.G., *The Milbank Quarterly* 69 (2) pp 309– (1991) · doi:10.2307/3350207
- [77] Manton K., *Journal of the American Statistical Association* 81 pp 635– (1986) · doi:10.1080/01621459.1986.10478316
- [78] Manton K.G., *Public Health Reports* 96 (6) pp 580– (1980)
- [79] Manton K.G., *Demography of Aging* pp 217– (1994)
- [80] Manton K.G., *Technical Report JG-0321 BS* (1995)
- [81] Manton K.G., *Studies in the Economics of Aging* (1993)
- [82] Manton K.G., *Population and Development Review* 17 (4) pp 603– (1991) · doi:10.2307/1973599
- [83] Manton K.G., *Journal of Gerontology* 49 (4) pp B169– (1994) · doi:10.1093/geronj/49.4.B169
- [84] Manton K.G., *Forecasts of the Theoretical Limits to Human Life Expectancy* (1988)
- [85] Mckeown T., *The Modern Rise of Population* (1976)
- [86] Mcnown R., *Journal of the American Statistical Association* 419 pp 671– (1992)
- [87] Mcnown R., *Demography* 26 pp 645– (1989) · doi:10.2307/2061263
- [88] Mcnown R., *International Journal of Forecasting* 8 pp 413– (1992) · doi:10.1016/0169-2070(92)90056-F
- [89] Menchik P., *Population Studies* 47 (3) pp 427– (1993) · doi:10.1080/0032472031000147226
- [90] Morgan M., *Social Science and Medicine* 17 (6) pp 321– (1980)
- [91] Myers G.C., *The Gerontologist* 24 (4) pp 346– (1984) · doi:10.1093/geront/24.4.346
- [92] Myers R.J., *Actuarial Study No. 23* (1946)
- [93] Myers R.J., *Transactions of the Society of Actuaries* pp 93– (1976)
- [94] Myers R.J., *Transactions of the Society of Actuaries* pp 303– (1985)
- [95] Nagnur D., *Canadian Studies in Population* 13 (1) pp 83– (1986)
- [96] Nagnur D., *Canadian Studies in Population* 17 (1) pp 1– (1990)
- [97] National Center for Health Statistics, *United States Life Tables. US Decennial Life Tables for 1979–1981* (1985)
- [98] National Center For Health Statistics, *Methodology of the National and State Life Tables. US Decennial Life Tables for 1979–1981* (1987)
- [99] National Center For Health Statistics, *Report of Final Mortality Statistics* 45 (11) pp 1– (1995)
- [100] NG E., *Health Reports/Rapports sur la Sante* 4 (4) pp 367– (1992)
- [101] Olichney J.M., *Neurology* 49 (1) pp 76– (1997) · doi:10.1212/WNL.49.1.76
- [102] Olshansky J.S., *The Milbank Quarterly* 66 (3) pp 482– (1988) · doi:10.2307/3349966
- [103] Olshansky J.S., *Milbank Quarterly* 65 pp 355– (1986) · doi:10.2307/3350025
- [104] Olshansky J.S., *Science* 250 (2) pp 634– (1990) · doi:10.1126/science.2237414
- [105] Olshansky S., *Population and Development Review* 20 (1) pp 57– (1994) · doi:10.2307/2137630
- [106] Olshansky S.J., *Population Bulletin* 52 (2) pp 1– (1997)
- [107] Omran A.A., *Milbank Quarterly* 49 pp 509– (1971)
- [108] Pearl R., *The Rate of Living* (1923)
- [109] Pollard J.H., *Sex Differentials in Mortality: Trends, Determinants and Consequences* (1983)
- [110] Pollard J.H., *Population Bulletin of the United Nations* 21 (22) pp 55– (1987)
- [111] Pollard J.H., *Demography* 25 (2) pp 265– (1988) · doi:10.2307/2061293
- [112] Pollard J., *Factors Affecting Mortality and the Length of Life* (1979)
- [113] Preston S.H., *Mortality Patterns in National Populations, with Special Reference to Recorded Cause of Death* (1976)
- [114] Preston S.H., *Convergent Issues in Genetics and Demography* pp 335– (1990)

- [115] Preston S.H., Forecasting The Health of Elderly Populations pp 51– (1991)
- [116] Preston S.H., *Journal of Aging and Health* 74 (4) pp 476– (1995) · doi:10.1177/089826439500700402
- [117] Preston S.H., *Demography* 33 (2) pp 193– (1996) · doi:10.2307/2061872
- [118] Preston S., *Causes of Death: Life Tables for National Populations* (1972)
- [119] Preston S.H., *Demography of Aging* pp 279– (1994)
- [120] Queen S., *MetLife Statistical Bulletin* 75 (2) pp 31– (1994)
- [121] Rogers A., Working paper 83–102 (1983)
- [122] Rogers A., *Gerontologist* 30 (5) pp 640– (1990) · doi:10.1093/geront/30.5.640
- [123] Rogers A., *Public Health Reports* 104 (3) pp 222– (1989)
- [124] Rogers R.G., *Social Biology* 34 (3) pp 234– (1987)
- [125] Rogers R., *Journal of Aging and Health* 1 (4) pp 19– (1992) · doi:10.1177/089826439200400102
- [126] Rogers R.G., *Milbank Quarterly* 65 (3) pp 370– (1990)
- [127] Rose M., *Evolutionary Biology of Aging* (1991)
- [128] Rosenwaike I., *Demography* 16 (2) pp 279– (1979) · doi:10.2307/2061143
- [129] Rosenwaike I., *Demography* 18 (2) pp 257– (1981) · doi:10.2307/2061098
- [130] Rosenwaike I., *Demography* 20 (4) pp 569– (1983) · doi:10.2307/2061120
- [131] Rothenberg R., *Journal of Gerontology: Social Sciences* 46 (2) pp s66– (1991)
- [132] Scriver C., *Proceedings of the Royal Society* 220 pp 273– (1984) · doi:10.1098/rspb.1984.0001
- [133] Smith D.W., *Human Longevity* (1993)
- [134] Smith J.P., *Race, Socioeconomic Status, and Health in Late Life* (1995)
- [135] Society of Actuaries, *Transactions of the Society of Actuaries* pp D428– (1967)
- [136] Society of Actuaries, *Transactions of the Society of Actuaries* pp D895– (1969)
- [137] Society of Actuaries, *Transactions of the Society of Actuaries* pp 675– (1981)
- [138] Society of Actuaries Group Annuity Valuation Table Task Force, *Transactions of the Society of Actuaries* pp 865– (1995)
- [139] Spencer G., *Current Population Reports* pp 25– (1989)
- [140] Stoto M., *American Journal of Public Health* 81 pp 1456– (1991) · doi:10.2105/AJPH.81.11.1456
- [141] Stoto M.A., *The American Statistician* 42 (2) pp 103– (1988)
- [142] Sze M., *Report of the 1994–1995 Advisory Council on Social Security: Reports of the Technical Panel on Assumptions and Methods; Technical Panel on Trends and Issues in Retirement Savings and Presentations to the Council* pp 223– (1995)
- [143] Trovato F., *Canadian Studies in Population* 19 (2) pp 111– (1992)
- [144] Tsevat J., *Circulation* 83 pp 1194– (1991) · doi:10.1161/01.CIR.83.4.1194
- [145] Tuljapurkar S.D., *Nature* 387 pp 760– (1977) · doi:10.1038/42818
- [146] Tuljapurkar S.D., *Biodemography of Aging* (1997)
- [147] United Nations, *Demographic Yearbook* pp 29– (1992)
- [148] U.S. Bureau of the Census, *Current Population Reports, Series P-25* (1989)
- [149] U.S. Department of Commerce, *Statistical Abstract of the United States 1996*, 116. ed. (1996)
- [150] U.S. Social Security Administration, *Actuarial Study No. 107* (1992)
- [151] U.S. Social Security Administration, *Actuarial Study No. 110* (1996)
- [152] Vallin J., *The Decline of Mortality in Europe* pp 38– (1991)
- [153] Vallin J., *Adult Mortality in Developed Countries: From Description to Explanation* pp 179– (1995)
- [154] Vaupel J.W., *Population Studies* 40 pp 147– (1986) · doi:10.1080/0032472031000141896
- [155] Vaupel J.W., *Science* 266 (5186) pp 826– (1994) · doi:10.1126/science.7973641
- [156] Vaupel J.W., *The Future Population of the World* (1994)
- [157] Vaupel J., *Demography* 16 pp 439– (1979) · doi:10.2307/2061224
- [158] Vaupel J., *Sociological Methodology* 1985 pp 179– (1985)
- [159] Vaupel J.W., *Mathematical Population Studies* 1 (1) pp 21– (1988) · Zbl 0900.92123 · doi:10.1080/08898488809525259
- [160] Verbrugge L.M., *Aging And Health: Linking Research and Public Health Policy* pp 24– (1989)
- [161] Verbrugge L.M., *Annual Review of Public Health* 10 pp 333– (1989) · doi:10.1146/annurev.pu.10.050189.002001
- [162] Wachter K., *Biodemography of Aging* (1997)
- [163] Waldron I., *Sex Differentials in Mortality: Trends, Determinants, and Consequences* pp 141– (1981)
- [164] Waldron I., *Science and Medicine* 17 (6) pp 321– (1983) · doi:10.1016/0277-9536(83)90234-4

- [165] Waldron I., Sex Differences in Mortality—Contemporary and Historical Evidence and Predictions of Future Trends (1992)
- [166] Waldron I., *Social Science and Medicine* 36 (4) pp 451– (1993) · doi:10.1016/0277-9536(93)90407-U
- [167] Waldron I., Adult Mortality in Developed Countries: From Description to Explanation pp 161– (1995)
- [168] Weiss K.M., *Genetic Variations and Human Disease: Principles and Evolutionary Approaches* (1993) · doi:10.1017/CBO9781139167987
- [169] White K.M., *Population and Development Review* 22 pp 415– (1996) · doi:10.2307/2137714
- [170] Wilkin J.C., *Transactions of the Society of Actuaries* pp 11– (1981)
- [171] Wilmoth J.R., *Sociological Methodology* pp 295–
- [172] Wilmoth J.R., *The Demographer’s Crystal Ball: How Long Will We Live in the 21st Century?* (1993)
- [173] Wilmoth J.R., *Mathematical Population Studies* 5 (4) pp 293– (1995) · Zbl 0876.92032 · doi:10.1080/08898489509525409
- [174] Wilmoth J.R., *Population Studies* 49 pp 281– (1995) · doi:10.1080/0032472031000148516
- [175] Wilmoth J.R., *Health and Mortality among Elderly Populations* pp 266– (1996)
- [176] Wilmoth J.R., *Rectangularization Revisited: Survival Curves for Humans and Fruit Flies* (1995)
- [177] Wilmoth J.R., *European Journal of Population* 12 pp 63– (1996) · doi:10.1007/BF01797166
- [178] Wilmoth J., *The Gerontologist* 36 (6) pp 783– (1996) · doi:10.1093/geront/36.6.783
- [179] Wingard D.L., *American Journal of Epidemiology* 115 (2) pp 205– (1982)
- [180] Yashin A.I., *Mathematical Biology* 24 pp 119– (1986)
- [181] Yashin A., *Theoretical Population Biology* 27 pp 154– (1985) · Zbl 0577.92014 · doi:10.1016/0040-5809(85)90008-5
- [182] Yashin A., *Mathematical Population Studies* 5 (2) pp 145– (1995) · Zbl 0873.62121 · doi:10.1080/08898489509525394

This reference list is based on information provided by the publisher or from digital mathematics libraries. Its items are heuristically matched to zbMATH identifiers and may contain data conversion errors. It attempts to reflect the references listed in the original paper as accurately as possible without claiming the completeness or perfect precision of the matching.