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MORTALITY IN IRELAND AT ADVANCED AGES, 1950-2006: PART 1: CRUDE RATES

By S. F. Whelan

ABSTRACT

We examine the data and techniques underlying the estimation of mortality rates at older ages in Ireland since 1950. Previous attempts to elucidate the level and trends in mortality at advanced ages in Ireland have been frustrated by significant non-random biases arising from age exaggeration and age heaping, together with a lack of correspondence, growing with increasing age, between the exposed-to-risk estimated from census data and the death count from registration data. Applying the method of extinct generations, we re-estimate crude mortality rates and report the somewhat unexpected result that mortality rates were lower, and did not increase as steeply with age, than those recorded in the official Irish Life Tables. The re-estimated crude rates show, for both sexes, a very slight decrease in mortality rates between the 1950s and 1980s up to age 90 years, with no improvement discernible at older ages. Improvements at advanced ages in Ireland have lagged behind those in England and Wales and other developed countries over the same period. The companion paper, *Mortality in Ireland at Advanced Ages, 1950-2006: Part 2: Graduated Rates*, Whelan (2009), graduates the crude rates and extends the method of extinct generations to estimate mortality rates of more recent, still surviving, generations.

KEYWORDS

Irish Population Mortality; Mortality Trends in Ireland; Method of Extinct Generations; Age Heaping; Centenarians; Oldest Person in Ireland; Longevity

CONTACT ADDRESS

Shane Whelan, School of Mathematical Sciences, University College Dublin, Ireland. Tel: +3531-7167155; Fax: +3531-7161186; E-mail: Shane.Whelan@ucd.ie

1. Introduction

The general trend of mortality in Ireland over the last century follows the well-known pattern for developed nations. Mortality rates at all ages have fallen, with the greatest proportional improvement at the lower ages and being greater for females than males (Whelan, 2008). In more recent years, mortality declines at older ages have been even greater than those observed at younger ages, a secular pattern described as the "aging of mortality improvements" (Wilmoth, 1997). This more recent development may be related to the co-called "cohort effect" evident in Irish, U.K., Japanese and other national mortality statistics (Whelan, 2008; Willets, 2004; Willets *et al.*, 2004).

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Falling mortality at younger ages has shifted the expected age at death upwards so now over three-fifths of females and over two-fifths of males in Ireland can expect to live beyond 80 years of age, according to Irish Life Table 14, CSO (2004) (reflecting the mortality experience in 2001-2003). However, the data underlying mortality estimates for Ireland at ages of 80 years and over fall below international standards of "good quality" (which includes Scotland, England and Wales and most EU countries) and even "acceptable quality", being classed as "conditionally acceptable quality" (Kannisto, 1994). Irish data is believed to be biased in a manner that understates mortality at the more advanced ages: "these data [for Ireland] give probably a roughly correct description of the mortality trend though at a level artificially lowered by age overstatement" (Kannisto, 1994, Section 2).

In this paper we examine the data since 1950 and re-estimate mortality rates at advanced ages in Ireland. Using the method of extinct generations, we provide estimates of Irish crude mortality rates from 1950, for both males and females at ages of 75 years and upwards. We report the somewhat unexpected result that mortality rates were, in fact, lower than those recorded in the official Irish Life Tables. The shape of the curve at advanced ages is also different to that recorded in the official tables, with the rate of increase in mortality rates decelerating more markedly with age.

The layout of the paper is as follows. Section 2 summarises the level and trends in mortality at advanced ages in Ireland as reported in the official Irish Life Tables, which are regarded as the best estimate to date. Quite at odds with the generally accelerating decline in rates observed in England and Wales since the 1930s, Irish rates show no trend improvement until the 1990s.

Section 3 critiques the official Irish mortality record, systematically itemising each type of error that can occur and discussing its significance in the Irish context. We report and appraise the significance of: (i) age heaping in census counts; (ii) age heaping in reported age at death, which is still discernible; (iii) age exaggeration in census returns, especially at age 100 years and over; (iv) errors in estimating the crude mortality rates due to a lack of correspondence between deaths and exposed to risk, which grow in significance with advancing age; (v) the importance of random error, heterogeneity in underlying rates, and stochastic variation in underlying mortality rates; and (vi) materially for official Irish rates as they are estimated by curve fitting to grouped data, the inconsistency created by employing different models to graduate and extrapolate mortality rates at advanced ages from one life table to the next.

Section 4 considers an alternative method to estimate crude mortality rates at late ages, known as the method of extinct generations, an extended version of which has been employed to estimate crude mortality at advanced ages in the Kannisto–Thatcher Database on Old Age Mortality maintained by Max Planck Institute for Demographic Research and has been employed in the estimation of rates in England and Wales since English Life Table 15 (1990-1992). It is shown that the method of extinct generations is preferable to using census data for estimating the exposed to risk, not because it avoids the well-documented problems with age exaggeration at censuses (as previously maintained by, for instance, Thatcher, 1987), but because the method achieves a perfect correspondence between the exposed-to-risk and death count. As an aside, in Appendix B, we provide a better estimate of the number of centenarians in Ireland over the last half century and note the longest lived in Ireland.

Section 5 uses the method of extinct generations to estimate crude Irish mortality rates and their trends. The levels and trends revealed are compared with the recorded official rates and, in Section 6, with international rates from the 1950s to the 1980s. It is shown that the mortality rates lie below the official recorded rates, but their secular decline lags behind that in other developed countries. In particular, we report no discernible improvement in crude mortality rates above age 90 years. Section 7 outlines the conclusions from our investigations.

The companion paper, *Mortality in Ireland at Advanced Ages, 1950-2006: Part 2: Graduated Rates* (Whelan, 2009), graduates the crude rates using different curves, reporting that the curve giving the best fit is Kannisto's version of Perks's Law. The paper evaluates various approaches to extend the method of extinct generations so mortality rates for non-extinct generations can be estimated and concludes that a modest trend of improvement in male and female mortality at advanced ages is evident in Ireland over the last five decades but that the rate of improvement lags behind those evident in England and Wales.

2. Pattern of Irish Mortality at Advanced Ages from Irish Life Tables

Irish Life Tables have been published by the Central Statistics Office (and its forerunner), outlining the mortality experienced by males and females in Ireland around each census year (e.g. CSO, 1965; CSO, 1986; CSO, 2004). In total, 14 censuses have been taken in Ireland between 1926 and 2002 and, accordingly, there are 14 Irish Life Tables (ILTs) for each sex, numbered 1 to 14. Censuses have not been evenly spaced, but have generally been taken every five years. Summary mortality statistics prior to 1926 for the area now in the Republic of Ireland have been published by the Commission on Emigration and Other Population Problems (1956).

The life expectancy at age 75 years computed from the official Irish Life Tables is summarised in Figure 1 for Irish males and females.

Life expectancies at age 75 years have been remarkably stable since the first Irish Life Table in 1926, with a rapid improvement evident only in very

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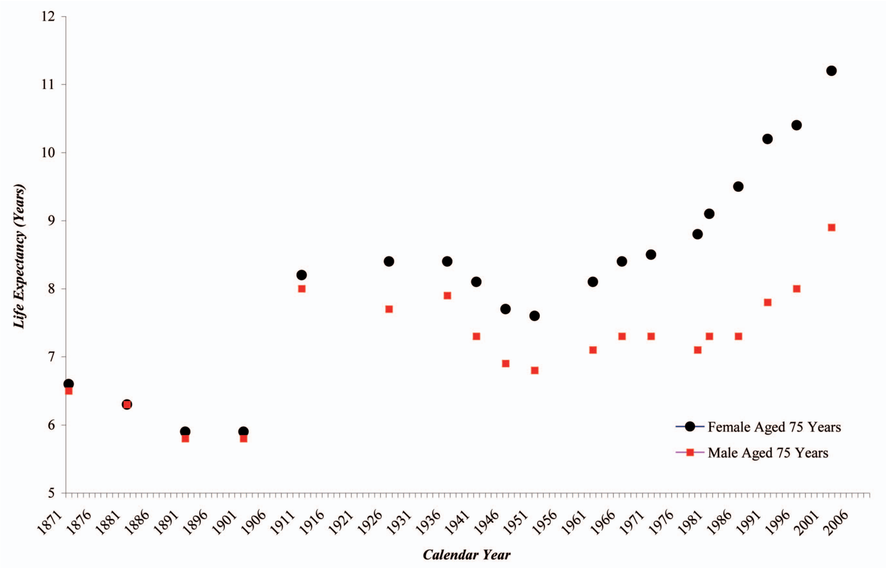


Source: Central Statistics Office (CSO) (2004), figures from Table 3.

Figure 1. Life expectancies for males and females, aged 75 years, Ireland, based on experience around the 3 years centred in calendar year shown

recent times. To better understand trends in mortality rates at advanced ages over this period, Table 1 shows the recorded mortality rates for males at selected ages over time periods separated by approximately a decade.

Reported mortality levels for males in their nineties in 2002 are much the same as those reported in 1926. At all advanced ages, reported mortality increases until the 1960s, with the increases being greatest at the higher ages. However, since the 1960s, there is a trend of improvement evident across all advanced ages. The overall uneven trend in Irish mortality at advanced ages is at odds with those recorded in England and Wales, where mortality at ages up to about 95 years has been in a slow decline since 1930 but showing a rapid acceleration of decline after 1950 (Humphrey, 1970; Thatcher, 1987; Thatcher *et al.*, 1998; Gallop, 2002; Gallop & Macdonald, 2005).

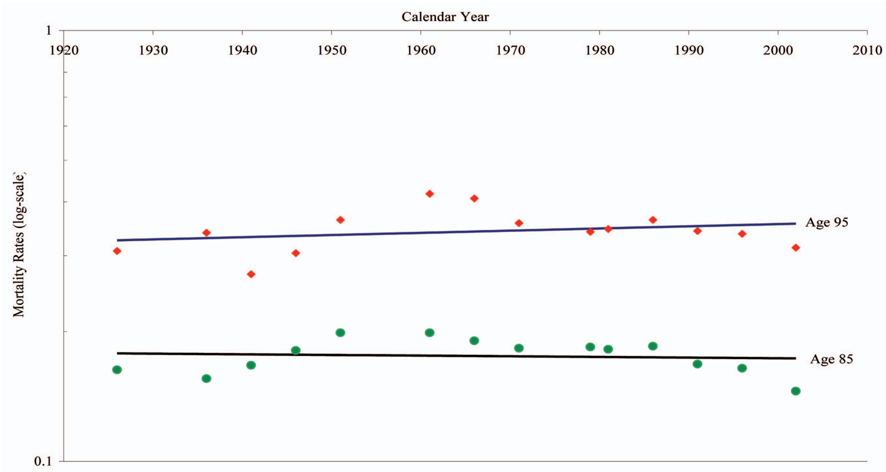
Figure 2 graphs how mortality rates for Irish males at ages 85 and 95 years have evolved since 1926, together with a log-linear trend line fitted by least squares. There appears to be a very weak secular trend — marginal decrease at aged 85 years and marginal increase at age 95 years.

It is evident from the foregoing graphs and tables that reported mortality rates at older ages show neither pronounced nor regular improvement, in contrast to trends at earlier ages (Whelan, 2008). However, as developed in

Table 1. $1000q_x$ from Irish Life Tables, males, 1926- 2002. Ages 80 and over

Source	Period	Mortality rate at age x years, where $x =$				
		80	85	90	95	100
ILT 14	2001-03	89	145	220	313	427
ILT 12	1990-92	109	168	246	342	460
ILT 10	1980-82	122	182	257	346	424
ILT 8	1970-72	122	183	262	357	408
ILT 6	1960-62	125	199	296	418	571
ILT 5	1950-52	136	199	274	363	467
ILT 3	1940-42	123	167	216	272	333
ILT 1	1925-27	114	163	227	308	406

Source: From various Irish Life Tables, published in more recent years by the Central Statistics Office (CSO), and previously published in various reports of the Census of Population when compiled by the Department of Industry and Commerce.



Source: Data from Irish Life Tables 1-14, Males, published by the Central Statistics Office (CSO).

Figure 2. Mortality rate of Irish males, age 85 and age 95, 1926-2002 [log-scale]

the next section, this conclusion must be qualified by the observation that the underlying data and method used to estimate mortality is considerably less reliable at advanced ages than at younger ages. In short, the reported mortality rates for the population of Ireland at advanced ages, and the secular trends in these rates, require further analysis. In particular, we shall

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show that the disimprovement in reported mortality rates at later ages in Ireland in the early 1960s could be simply due to the Central Statistics Office's method of extrapolating rates at later ages rather than any underlying disimprovement in mortality.

3. Critique of Mortality Rates at Advanced Ages Reported in Irish Life Tables

Errors can arise in estimating mortality rates in four generic ways: (1) data errors arising from inaccurate population or death records, (2) errors in estimating crude mortality rates when the death count and the exposed-to-risk do not perfectly match, (3) errors in statistically modelling the crude rates, and (4) model misspecification. We treat each of the four sources of error in turn below, discussing its significance for Irish mortality rates reported at older ages.

3.1 *Data Errors in Population and Death Records*

Errors in the data underlying the construction of crude mortality rates can take two distinct forms: (i) errors in age statement in census, and (ii) errors in age reported at death. Aside from mortality estimation, it is necessary to correct for these errors so as to, for instance, achieve a more accurate estimate of the age distribution of the population.

There is an internationally observed tendency, especially evident in earlier times, for people in declaring ages to round to a number ending with either 0 or 5 (or, to a lesser extent, to prefer to report an even rather than an odd number) (see, for instance, Myers, 1940). This tendency is known as 'age heaping'. Figure 3 shows the person count by age over age 70 years in the censuses of Ireland in 1926 and 2002. Age heaping is evident at a glance in the former — especially at ages 75, 80 and 90 years — but not in the latter.

Age heaping is also evident in reported age at death. Figure 4 graphs the reported age at death in Ireland for all deaths at or over age 75 years reported in the periods from 1950 to 1975 and from 1975 to 2000 (inclusive). There is an unusually large number of recorded deaths at age 80 years in both periods, but also at ages 78, 82 and 84 years. Age heaping seems to be a more pronounced feature of earlier times but it still persists. Myers's Blended Index (Myers, 1940) was calculated from the age reported at death in each calendar year from 1950. This index should take a value of zero if there was no age heaping but, in fact, took a value of about 10% in the 1950s, falling to 3% in the late 1990s and early 2000s, for both males and females.

There is reason to believe that the problem at older ages is not just limited to age rounding, but that there is a bias to overstate ages. Old age pensions were payable in the United Kingdom of Great Britain and Ireland

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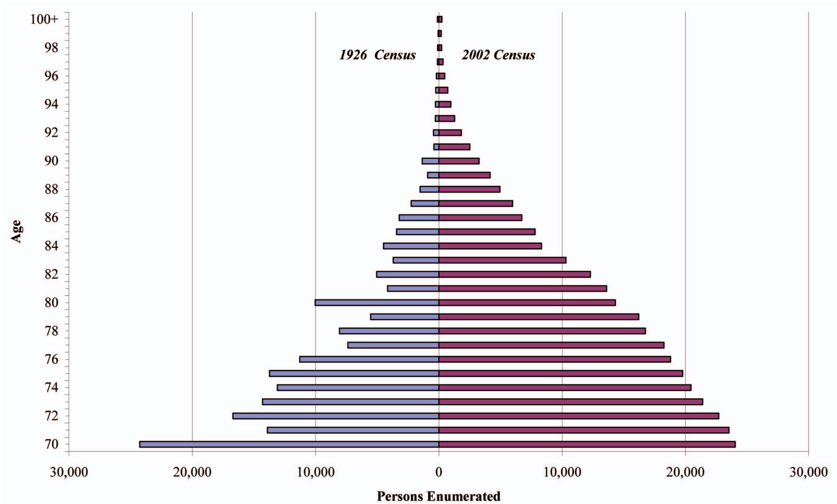
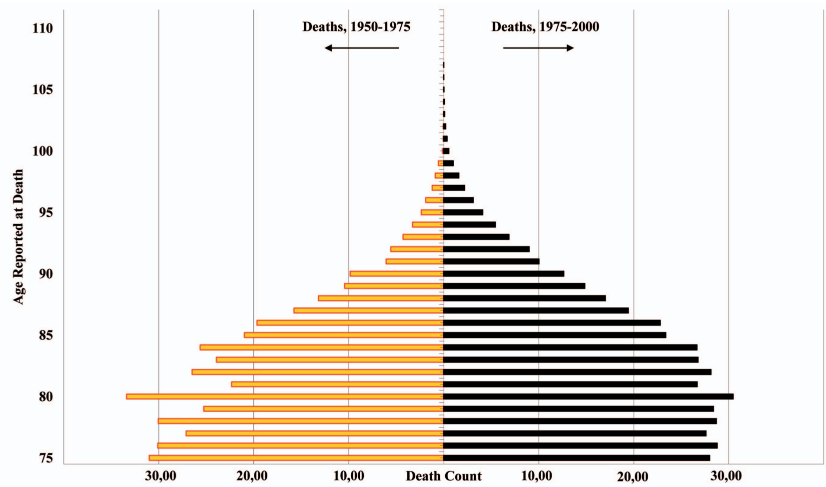


Source: Based on data kindly provided by the Central Statistics Office (CSO).

Figure 3. Age declarations in censuses of Ireland, 1926 and 2002, males and females combined



Source: Based on data kindly provided by the Central Statistics Office (CSO).

Figure 4. Age reported at death in Ireland, both sexes combined, 1950 to 2000

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from 1909 to persons over the age of 70 years, subject to means and other qualifying tests. Unlike England, which had introduced formal registration of births more than 70 years earlier, official registration was only introduced in Ireland from 1864. Accordingly, there was no formal means to verify ages of anyone over 45 years in Ireland in 1909 (Wood, 1908) and, as could reasonably be anticipated, claims for pensions in Ireland far exceeded that expected based on the census of 1901 (Ó Gráda, 2002). It could be expected — and was widely expected at that time (see, for instance, Marr (1909) and Falk (1909) — that a person would report an age at subsequent censuses consistent with their declared age for pension. This would lead to life expectancies at higher ages calculated from census data being exaggerated.

Brown (1930), in reviewing the construction of Irish Life Table 1, disbelieved the exceptionally low mortality at advanced ages reported, preferring to believe that "as the pension age approaches the temptation to misstatement of age has still proved irresistible to a considerable section of the community" (p102). We observe, consistent with this hypothesis, that life expectancies for both Irish males and females at age 75 years show a suspicious jump of more than 20% between 1900-02 and 1910-12 (see Figure 1 earlier). In fact, life expectancies for males aged 75 take until 1995-7 to regain the level reported in 1910-12. With each passing calendar year, new age exaggerations to secure a pension could be expected to decline, so the upward bias to estimated life expectancies could be expected also to decline and this trend could be masking some real underlying improvement. This effect could have persisted to some degree even into the 1950s, but is unlikely to be material thereafter.

Even without a monetary incentive, there is a widely observed tendency for age overstatement at advanced ages (Bowerman, 1939; Easton, 1799; Laslett, 1999). It could be partly because reported dates of birth are misread or mis-keyed from census returns and, while such errors might cancel out and have a negligible effect overall at younger ages where there are comparatively large numbers, the small numbers at higher ages entail that such errors have a large impact.

Whatever the reason, age exaggeration appears to be a factor in Ireland. Consider, for example, the 18 men reported to be centenarians in the 1951 census of Ireland. According to the registration of deaths in that and subsequent years, no man died aged 100 or more in 1951, or aged 101 or more in 1952, or aged 102 or more in 1953, and so on. In fact, we can go all the way to calendar year 2006 and find no man dying aged 155 years or more. There are only two possible explanations for this: either all 18 declared centenarians in 1951 emigrated over the following years or their death certificate reported an age inconsistent with that recorded in the census of 1951.

It is generally believed that the age recorded at time of death is more reliable than age declared at census. Thatcher (1981) reports that investigations of samples of persons reported as centenarians at the time of their death in England and Wales confirmed the reliability of age recorded on the death certificate. This is in contrast with verification checks on census counts at advanced ages in England and Wales, which, when last done, shows that of the 3,727 centenarians enumerated in the 1981 Census, somewhat less than half (1,644) could independently be verified (Gallop & Macdonald, 2005). Accordingly, it would be better for this reason alone to base mortality estimates on deaths records only. Later we re-estimate mortality rates from death certification data only.

It should be noted that age recorded at death, while more accurate than census data, is still not wholly reliable. Previously, we noted a suspicious age heaping still discernible in the recorded ages at death in Ireland, though it appears to be diminishing with time. A study of the accuracy of reported age at death was recently done in Northern Ireland based on a sample of 1,698 death records (Health Statistics Quarterly, 2000). While dates of birth on the death certificate matched an independent source in 86% of cases, errors were proportionately more likely at advanced ages, with 5% of those reported 90 years and over at the time of death inaccurate by at least two years. This increasing inaccuracy must be borne in mind in any modelling exercise of the crude rates.

3.2 *Errors in Estimating Crude Mortality Rates*

There must be a correspondence between the numerator, being the number of deaths, and the denominator, being the exposed-to-risk, in calculating crude mortality rates. However, age is recorded at censuses in Ireland as date of birth but reported as age last birthday at the census date. Deaths are recorded with either age last birthday at time of death or date of birth, together with the date of death. Deaths are often reported as the number of deaths of a particular age and sex in the respective calendar year. It is not possible to make the exposed-to-risk derived from the census correspond exactly with the reported death data. The inevitable errors that any approximation entails, and their growing significance with increasing age, is perhaps best illustrated by attempting to reconcile the numbers reported at each census.

Take, for example, the 2002 and 2006 censuses. We know the number of, say, males aged 90 in April 2002 and the number aged 94 in April 2006. We also know the number of males that died at each age in each intervening year — so the number dying aged 90 in calendar year 2002, aged 91 in calendar year 2003, up to those dying aged 94 in 2006. Migration flows, which have been particularly high over recent years in Ireland, will also affect the reconciliation, especially at the younger adult ages. To attempt to reconcile these data, we need to make some assumptions about the distribution of deaths over each calendar year and over each year of age. We make three alternative assumptions to illustrate the impact such assumptions have of the attempted reconciliation:

(1) First, the crudest assumption, is that the population aged $x+4$ in the 2006 census can be approximated by the number aged x counted in the 2002 census, reduced by the recorded deaths aged $x+y$ in calendar year $2002+y$, for $y=0, 1, 2, 3$.

(2) Second, a better approximation, is to apply (1) but with the number of deaths from the population aged $x+y$ in year to April $2002+y+1$ estimated as two-thirds the deaths aged $x+y$ in calendar year $2002+y$ and one-third of the deaths aged $x+y$ in calendar year $2002+y+1$, for $y=0, 1, 2, 3$.

(3) Third, and a better approximation again, is to use (1) but now apportioning the deaths in each year to April as determined in (2), by the ratio of the population count of the two adjacent ages that could contribute to the deaths.

We can see the impact of assumptions (1) to (3) on the final result from Figure 5.

The assumptions produce a negligible difference in the estimated population

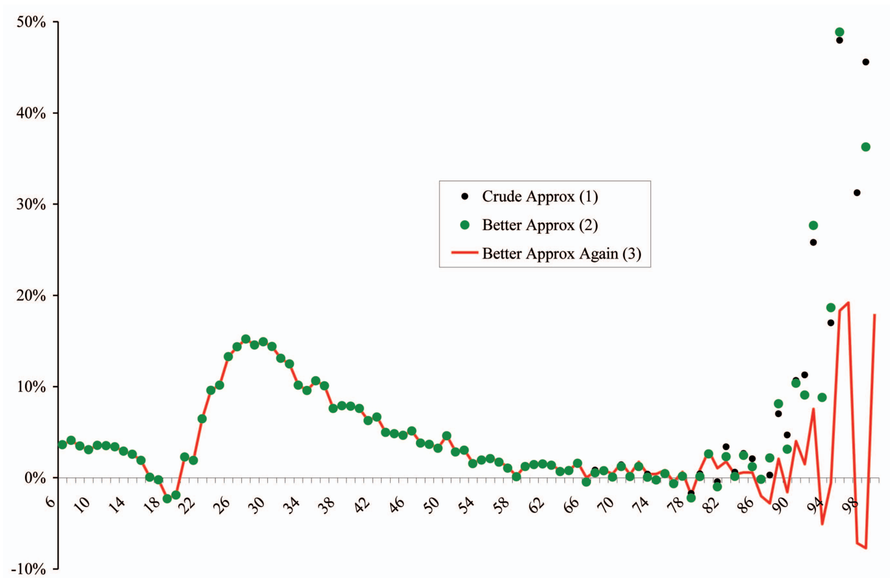

Figure 5. Relative error in reconciliation Irish censuses, 2002 and 2006, males, differing approximations

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in 2006 at ages up to 80 years (the difference between the three approximations being no greater than 1% in this age range). Migration flows is the reason the population estimates do not coincide with the number enumerated. However, for later ages, when the exposed-to-risk population changes rapidly with age, the approximations show increasingly large deviations from one another. Migration is not a significant factor at these later ages, so these deviations are deviations also from the true value. It immediately follows that the approximation used to ensure that the deaths correspond to the exposed-to-risk becomes less reliable as age increases. Accordingly, the resultant estimates of the crude mortality rates also become less reliable with increasing age.

3.3 *Errors in Statistically Modelling the Crude Rates*

Statistical variation is present in crude mortality rates. This can give rise to mis-estimation of parameters when fitting models to the crude rates. Variation in crude rates arises from the following sources.

3.3.1 *Statistical variation*

There are relatively few survivors to very advanced ages, so the mortality rates at these later ages must be estimated from a smaller sample. This introduces progressively larger random errors in estimating the underlying mortality rate, until at ages of say, 105 years and over, the Irish data is too sparse to provide an acceptable estimate of the underlying mortality rate. Random error, though, is not a significant problem up to ages of about 95 or so, even for a country with a population as small as that of Ireland. Figure 6 plots the coefficient of variation (standard deviation of the mortality estimator divided by its mean) against age, based on the numbers of males at each age enumerated in the 2002 census and the mortality rate from Irish Life Table 14 Males (2001-2003), (CSO, 2004).

At ages over 95 years or so, we must become progressively more reliant on the graduation method, and less on the estimated crude mortality rates, as the relative error in the mortality rates increase dramatically as the exposed to risk declines.

3.3.2 *Heterogeneity and secular variation in underlying mortality rates*

Random error is just one form of error that must be guarded against in modelling crude mortality rates. Other types of statistical variation that affect the standard error arise from heterogeneity in mortality rates and stochastic variation in the underlying mortality rate. Heterogeneity in mortality rates, perhaps counter-intuitively, reduces the standard error of the mortality rate (estimated by the usual deaths divided by the initial exposed to risk) while stochastic variation in the underlying mortality rate increases the standard error (Benjamin & Pollard, 1980, especially Chapter 17). Stochastic variation in the underlying mortality rates can be anticipated to

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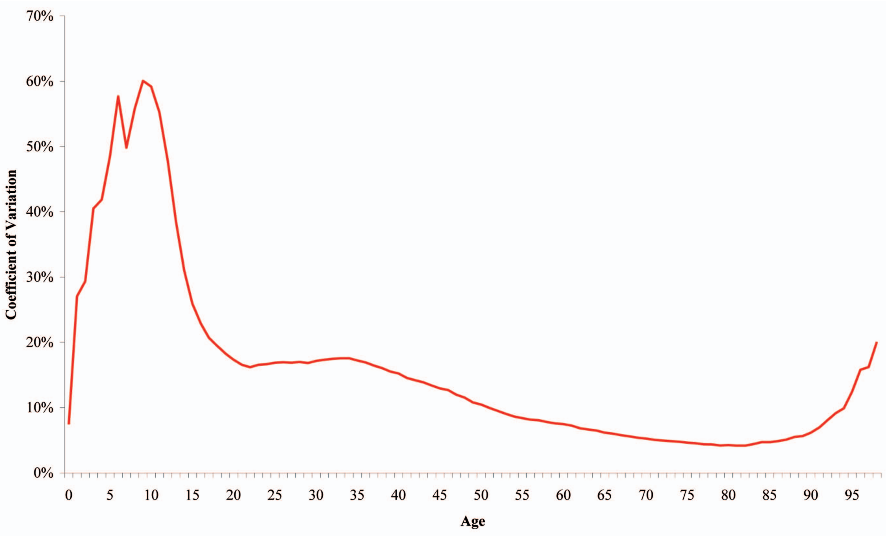

Figure 6. Coefficient of variation of estimator of mortality, based on 2002 census numbers of males, and mortality of Irish Life Table 14 males

increase with increasing age as mortality rates at later ages show a greater sensitivity to environmental conditions — such as extremes in weather conditions and outbreaks of influenza. Studies with Australian data (Pollard, 1970) suggest that increases in the standard error due to stochastic variation tend to dominate reductions due to heterogeneity, but the overall effect is marginal. If the relationship posited for Australian data (Pollard, 1970, p260, formula 9) were to hold for males in Ireland in 2002, the coefficient of variation shown in Figure 6 must be increased by no more than 1.6% even at advanced ages.

The standard error can be controlled by averaging deaths at a particular age over several calendar years, which reduces both random error and the adjustment required to take account of stochastic variation in the underlying mortality rate. This method of reducing standard error will be exploited later in the paper.

3.4 *Model Misspecification*

The method used to construct all 14 official Irish Life Tables is based on King's Method (King, 1909), a method close in both theory and outcome to cubic spline graduation. For ages 7 to 87 years, the method involves grouping deaths and population count into five-year or ten-year age groups, estimating the mortality rate for the mid-age of the group and using

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osculatory interpolation (or, with ten-year groupings, Langrangean interpolation) to estimate mortality rates at intervening ages (Geary, 1929; CSO, 1965, 1986). For the extremes of age — under 7 years and over 87 years — ad-hoc methods are employed. This method of graduation — by grouping deaths and population numbers — has been designed to remove much of the effects of age heaping, at least for ages up to 87 years.

Mortality rates at very advanced ages are typically estimated by assuming a mathematical relationship between mortality rate and age. Clearly, positing such a relationship introduces the possibility of errors from model mis-specification. In estimating mortality rates above age 87 years for the Irish Life Tables, different forms of the mortality curve have been assumed over the years. For Irish Life Table 1 (ILT 1), corresponding to the experience 1925-7, rates were obtained by fitting a Makeham curve to the (King's method) estimated values of p_{70}, p_{80} and p_{90} (Geary, 1929). In recent times, a quadratic curve has been fit passing through the King's method estimate of q_{72}, the parameters of the curve found by minimising the weighted squares of differences between King's estimates and the curve at the points $\hat{q}_{77}, \hat{q}_{82}, \hat{q}_{87}, \hat{q}_{92}$, the weights being the square of the number of deaths in the associated quinquennial group (see CSO, 1965, 1986). Figure 7 graphs the

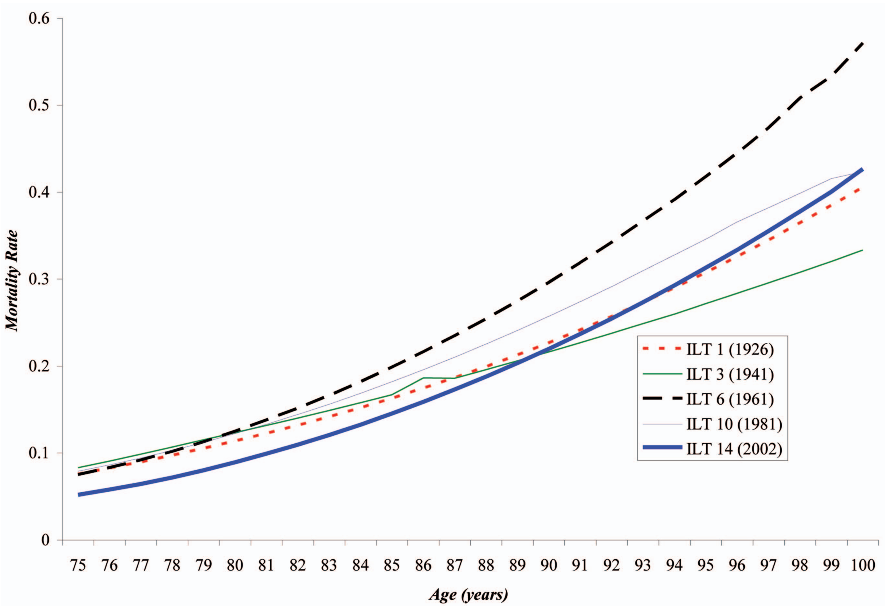

Figure 7. Mortality curves at older ages from Irish Life Tables, male, 1926-2002

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resultant mortality curves for Irish males from age 75 years, with successive curves separated by approximately two decades.

The mortality curves show mortality increasing at quite different gradients with age between the different life tables. In particular, mortality in more recent times is reported to increase with increasing age at a greater rate than in 1926 and in 1941, with the result that, though mortality at age 75 years is significantly lower now than sixty or seventy-five years ago, by age 100 years it is recorded as higher now than at those earlier times. Accordingly, identifying secular trends at advanced ages is compounded in that the curve-fitting approach used to estimate mortality rates at older ages changed with time. The difficulties of comparability over time introduced by changing methods of extrapolation at later ages is also a feature of English Life Tables of the twentieth century where finite difference methods where superseded by fitting a Gompertz curve, superseded in turn by a logistic type curve, then cubic splines with different assumed limiting ages (Gallop, 2002).

4. Alternative Method of Estimating Mortality at Advanced Ages

4.1 *Method of Extinct Generations*

Estimating mortality rates at advanced ages is challenging and, as the foregoing remarks make clear, these difficulties are compounded with Irish data. Vincent (1951) suggested an approach to estimating mortality at older ages that overcomes many of the problems identified in the last section. Vincent's approach, known as the 'method of extinct generations', has been modified and applied by Humphrey (1970) to U.K. data and updated and further developed by Thatcher (1981, 1987, 1992, 1999a), Thatcher *et al.* (1998), and Andreev *et al.* (2003). The underlying idea is simple: data from death registrations can be employed to provide a better assessment of the exposed-to-risk at advanced ages than census data. The merit of the method of extinct generations is sometimes attributed to using the more accurate age recorded on the death certificate than that declared at a census. While this is undoubtedly true for centenarians, the more significant merit of using Vincent's approach comes from achieving a closer correspondence between deaths and exposed-to-risk at ages up to the late 90s, as we shall show later.

Deaths in Ireland are reported as age last birthday at time of death. Let us denote the number of deaths aged x in calendar year y by d_x^y. Ignoring migration, the persons who die aged $x+n$ in calendar year $y+n$ comprise two groups: (i) those born in calendar year $y+n-(x+n)=y-x$ who died after reaching their birthday in calendar year $y+n$, and (ii) those born in calendar year $y-x-1$ who died before their birthday in calendar year $y+n$. If we assume that deaths are uniformly spread over the year of age then the initial exposed to risk at time y is closely approximated by

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$$E_x^y \cong \sum_{i=0}^{\infty} d_{x+i}^{y+i} \tag{1}$$

(see Humphrey, 1970, p107). Vincent's idea is to employ E_x^y and estimate the crude mortality rate at age x in calendar year y as:

$$\hat{q}_x = \frac{d_x^y}{E_x^y}. \tag{2}$$

Of course, it is assumed that there is no migration at these advanced ages. No figures are published showing migration flows for Ireland at ages above 75 years or so, but those published for persons aged 65 and over show that net migration in this broad age group totalled just 2,200 in the six years to end 2008, despite very high overall net migration at 295,400 persons in these calendar years (calculated from Table 4 in CSO, 2008). We can conclude that net migration at ages over 75 years must be negligible.

Tables 1 and 2 in Appendix A set out the number of recorded deaths at each age at or over 99 years for Irish males and females respectively over the calendar years 1950 to 2006, based on data kindly provided by the Central Statistics Office (CSO). Humphrey (1970) reports, from a study of ages at death and estimated mortality rates in England and Wales, that there appeared to be an appreciably more accurate age of death if the birth was registered. In the case of Ireland, with official registration of births introduced in 1864, deaths up to age 75 years in calendar 1939 had an associated formal registration of birth, as do deaths up to age 76 years in 1940, and so on, up to 111 years in 1975. This cut-off is marked by a line in Tables A.1 and A.2. Appendix B reconsiders the number of centenarians and records of the longest lived in Ireland.

Let ω be the highest attained age over the period studied, so that no person was alive at age $\omega + 1$. We might take $\omega = 111$ for females in Ireland (see Appendix B). Our data set is a record of deaths in Ireland from 1950 up to and including calendar year 2006, broken down by age and sex. The method of extinct generations can be used to estimate mortality rates at age up to $\omega - a$ in calendar year $2006 - a$, for $a = 0, 1, 2, \ldots$ Accordingly, we can estimate female mortality rates at age 111 years at end of calendar year 2006, at ages over 110 years in calendar year 2005, …, and at ages over 85 years in 1980. We require some other method to give estimates of mortality rates at younger ages in more recent calendar years.

4.2 *Exposed-to-Risk by Census Method and Method of Extinct Generations Compared*

It is of interest to investigate to what extent the initial exposed-to-risk, E_x^y, as determined by the method of extinct generations, differs from a

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population count of those aged x made during calendar year y, i.e. compare how close a census count is to E_x^y. The census count, occurring at the end of April, is closer to a central exposed-to-risk than the initial exposed-to-risk estimated by the method of extinct generations. The adjustments to the census count required to make it directly comparable with the initial exposed-to-risk of the method of extinct generations (which corresponds to deaths grouped by age last birthday in a calendar year) are:

(1) To the count of those aged x last birthday at the end of April in the calendar year: this population count should be given a weight of 0.722 equivalent years' exposure assuming births of the group are uniformly distributed over the calendar year.
(2) To the count of those aged $x+1$ in April of the calendar year: this population count should be given a weight of 0.056 equivalent years' exposure, again assuming births of the group are uniformly distributed over the calendar year.
(3) To the count of those aged $x-1$ in April of the calendar year: this population count should be given a weight of 0.222 equivalent years' exposure, assuming births of the group are uniformly distributed over the calendar year.
(4) Also one must add one-third of deaths aged x in the calendar year, under the assumption that deaths are spread uniformly over the calendar year.

We compare the ratio of the two initial exposed to risk counts for males in Ireland at ages up to 98 years, when the census count has been adjusted as described.

Figure 8 shows that the adjusted census count differs from the count estimated by the method of extinct generations by being materially below the latter in the age range 75 to late 90s, and thereafter significantly higher. Using such data to estimate mortality rates would tend to overstate mortality in ages up to the late 90s and, based on Figure 8, the overstatement could be of the order of 5-10% for mortality rates in the age range 85-95 years. Accordingly we can conclude that the method of extinct generations produces estimates materially closer to the true exposed-to-risk corresponding to the death count. Note that this finding is contrary to expectation: Thatcher (1987), *inter alia*, suggests that the merit of the method of extinct generations over the census method lies solely in its correction of the age exaggeration in the latter. Our analysis suggests that correcting for age overstatement is a minor merit, at least up to ages in the late 90s: the major merit in the method of extinction generations is its materially better approximation to the true exposed to risk at these advanced ages when the exposed to risk changes so rapidly with age (see Figure 5 earlier). Corroboration of this insight is found in Beatty & Rodgers (2000) who, using both the method of extinct generations and reconciliation with administrative data, also report an

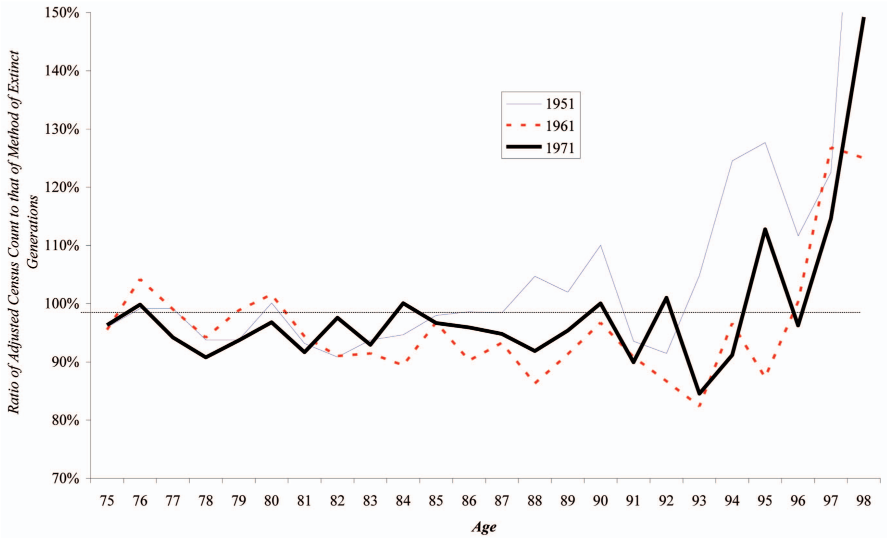

Figure 8. Ratio of adjusted population count in censuses of 1951, 1961 and 1971 to count by method of extinct generations, males, ages 75 years and over

under-enumeration of the same order of magnitude at these older ages in the Northern Ireland censuses of 1971, 1981 and 1991, reporting that the under-enumeration was zero for males aged 70 years (zero for females aged 75 years) rising smoothly to 15% for males in the group aged 95 years and over (16% for females).[1]

5. Estimating Mortality in Ireland by the Method of Extinct Generations

In this section, we apply the method of extinct generations to estimate the crude mortality rates at advanced ages. We take, as a case study, males aged

[1] The numbers found using the method of extinct generations were found to be broadly consistent with the numbers estimated from analysing the number flows on Northern Ireland's Central Health Index and also the count in the person-based database maintained by the DHSS of all claimants of benefits related to pensionable age (believed to have high coverage). However, in contrast, it should be noted that Gallop & Macdonald (2005) report the opposite: that a variant of the method of extinct generations used to estimate the population in each country of the U.K. over the years 1981, 1991 and 2001 produce numbers lower than the census count at advanced ages, with the divergence the highest for Northern Ireland in 1981 and 1991.

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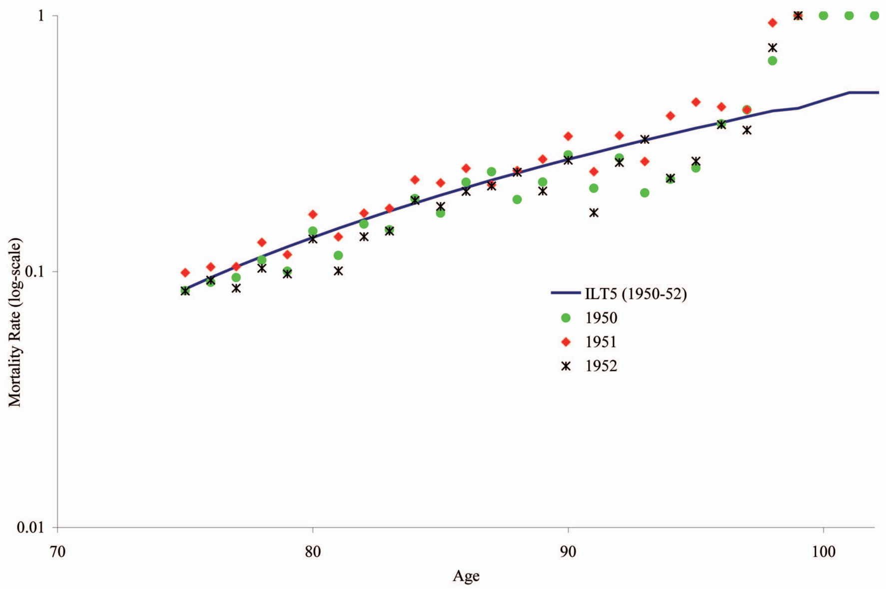

Figure 9. Crude mortality rates in years 1950, 1951 and 1952 estimated using method of extinct generations; ILT 5 (1950-52), mortality rates of males, ages above 75 years

75 years and over in the calendar years 1950-1952, corresponding to the experience that Irish Life Table 5 is based on.

Figure 9 shows that the rates in ILT 5 give a reasonable fit to the crude rates up to about age 90 years but somewhat loosely fitting thereafter, with perhaps the official rates being too high from about 87 years to the late 90s. The exposed-to-risk was under 10 for each age over 98 years, so random errors become significant. The large percentage differences are captured in Figure 10.

The life expectancy of a 75 year old male was reported as 6.8 years in ILT 5 but, based on the average crude mortality rate over 1950-52, we estimate it to have been slightly higher at 7.0 years. A similar analysis for both males and females was performed from 1951 to 1971 and, in each case, the re-estimated life expectancy using the method of extinct generations was marginally higher. Figure 11 graphs the results.

Mortality rates at older ages reported in Irish Life Tables appear to be too heavy. Figure 12 illustrates the discrepancy between rates reported in Irish Life Tables and those estimated using the method of extinct generations for a male aged 85 and 95 years using mortality rates averaged over three years centred on the year shown.

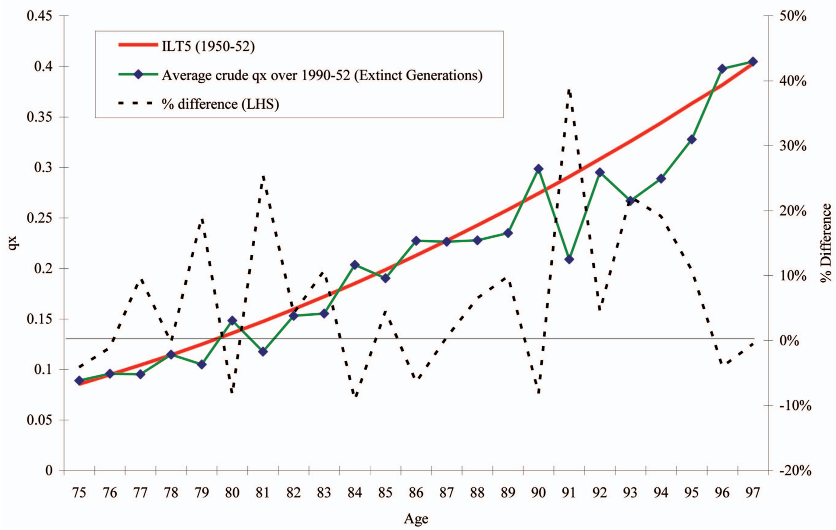

Figure 10. Average of crude mortality rates in years 1950-1952 estimated using method of extinct generations, compared with ILT 5 (1950-52), mortality rates of males, ages above 75 years

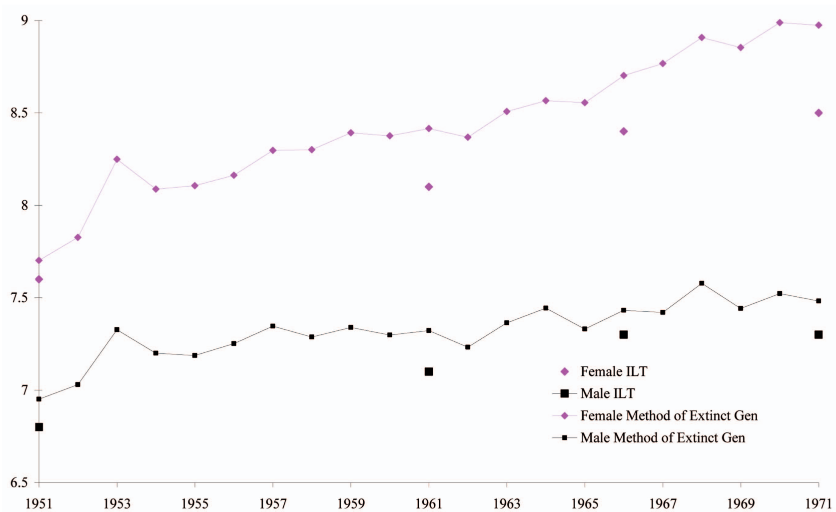

Figure 11. Life expectancy at age 75 years, by method of extinct generations compared with that reported in Irish Life Tables

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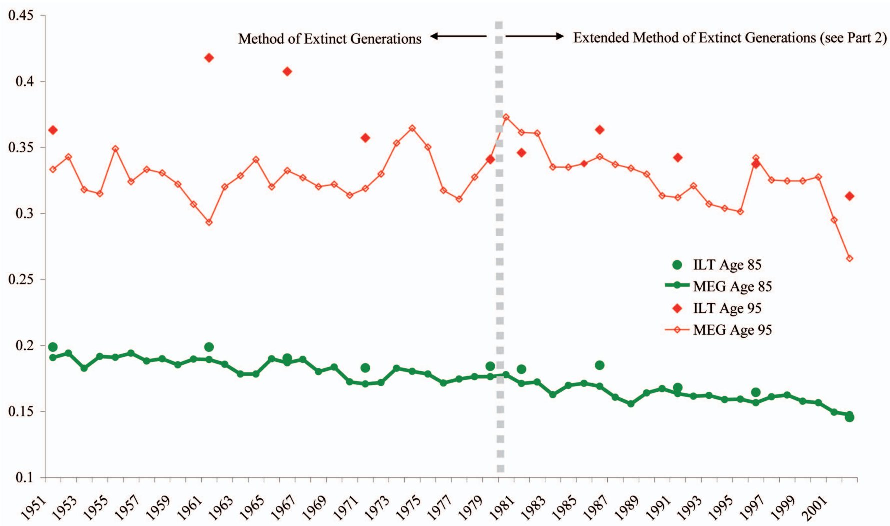

Figure 12. Mortality rates for male aged 85 and 95 years, estimated by method of extinct generations compared to that reported in Irish Life Tables, 1951-2002

The lack of correspondence between deaths and exposed-to-risk using the census method, with a resultant bias to understate the true exposed-to-risk, has led to the rates reported in the Irish Life Tables being overstated.

6. Comparison with International Trends in Mortality at the Highest Ages

Thatcher (1992) provides estimates of the mortality in England and Wales at advanced ages based on a variant of the method of extinct generations over six decades, 1930-1990. He shows that mortality rates seem to have fallen broadly uniformly over the period, with the rate of improvement tending to decline slightly with increasing age. Subsequent analysis up to 2003 shows the trend decline accelerating in more recent decades (Gallop & Macdonald (2005), see especially Figures 1-4 and Tables 7-8) but with little evidence of improvements after age 100 years. Figure 13 shows a parallel shift downward in the mortality curve at advanced ages in England and Wales and contrasts it with crude mortality rates in Ireland estimated by the method of extinct generations over the same periods. The changes in mortality in Ireland are somewhat erratic. Mortality rates in Ireland were

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Source: Mortality Rates for Males in England and Wales, Table 6 in Thatcher (1992). For Ireland as calculated by author using the method of extinct generations.

Figure 13. Comparison of mortality rates for males aged 85 to 98 years, Ireland and England and Wales over decades 1950-60 and 1980-90

lower than those in England and Wales in the 1950s but higher in the 1980s. We note that there was a slight improvement recorded in Irish rates up to age 90 years but rates disimproved marginally from 91 to 95 years, from which age the trend is obscured by random fluctuations.

Levels and trends of mortality at the highest ages have also been studied for many other countries. The Kannisto–Thatcher Oldest-Old database (within the *Odense Archive of Population Data in Aging*, Odense University Medical School, University of Odense, Denmark) and available on-line from the Max Planck Institute for Demographic Research[2]) is a highly structured database with data on all deaths at and over age 80 years in more than thirty low mortality countries, divided by sex, age at death, calendar year of death, and calendar year of birth. Thatcher *et al*. (1998) provides a detailed study of the level and trend of mortality since 1960, basing the exercise on a subset of the database, using data from just the thirteen countries (out of the thirty) countries that maintained good quality records over the period.[3] The

[2] www.demogr.mpg.de/databases/ktdb/
[3] England and Wales are included as a country as vital registration divides the U.K. into England and Wales, Northern Ireland, and Scotland.

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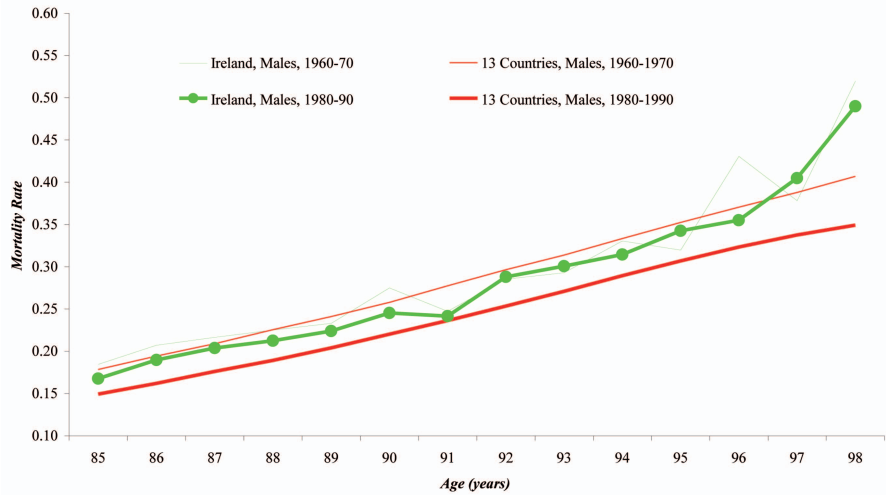

Source: Mortality Rates for 13 Developed Countries (see text), Table 6.1 in Thatcher *et al.* (1998). For Ireland as calculated by author using the method of extinct generations.

Figure 14. Comparison of mortality rates for males aged 85 to 98 years, Ireland and 13 developed country average over decades 1960-70 and 1980-90

13 countries were Austria, Denmark, England and Wales, Finland, France, Iceland, Italy, Japan, the Netherlands, Norway, Sweden, Switzerland and West Germany. In total the study included over 32 million deaths over the period 1960-1990 and included over 120,000 persons that attained a century. The exposed-to-risk was calculated using an extended version of the method of extinct generations and it was assumed that no migration occurred at these advanced ages.

Ireland is included in the Kannisto–Thatcher Oldest-Old database but was not included in the subgroup of thirteen countries studied because the data was deemed to fall below 'good quality' and even 'acceptable quality', being classed as 'conditionally acceptable quality' (Kannisto, 1994).[4] Irish data is believed to biased by an overstatement of age at death at these later ages so "these data give probably a roughly correct description of the mortality trend though at a level artificially lowered by age overstatement" (Kannisto, 1994). Figure 14 compares Irish mortality for older males over the decades 1960-70 and 1980-90 as estimated using

[4] It is classed above the 'weak quality' of the U.S., Canada and others.

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the method of extinct generations with that of the thirteen country average over the same periods.

Figure 14 shows again the parallel shift in the mortality curve with time in the 13 countries with Irish rates tending to lie between the two international curves and being significantly less smooth.

Figures 13 and 14 highlight the need to graduate the Irish crude mortality rates found by the method of extinct generations. Age heaping in the reported age of death at, say, 90 years, has created a crude mortality rate at age 90 years implausibly higher than the crude mortality rate of a 91 year old. It is also necessary to extend the method of extinct generations in some manner so mortality rates for non-extinct generations can also be estimated. The companion paper, *Mortality in Ireland at Advanced Ages, 1950-2006: Part 2: Graduated Rates* (Whelan, 2009), reports the results of these further investigations into Irish mortality at the highest ages.

7. Conclusion

We may summarise our initial findings on Irish population mortality at advanced ages over the period from the 1950s to 1980s as follows:

(1) There are significant non-random biases in the underlying data at advanced ages, with age exaggeration in Irish census data and age heaping in Irish death data.

(2) The inevitable lack of correspondence between the exposed-to-risk estimated from census data and the death count from registration data grows in significance with increasing age and is a significant source of error at advanced ages.

(3) Applying the method of extinct generations to estimate crude mortality rates at older ages, eliminates errors from (2) and reduces errors from (1). Distortion in mortality rates from age heaping in death counts remain, particularly at ages 80 and 90 years, and pose a challenge to graduation.

(4) Re-estimating Irish mortality rates using the method of extinct generations show that mortality in Ireland over the period from the 1950s to the 1980s was marginally lower than recorded in the Irish Life Tables, so life expectancies at advanced ages were higher than previously believed. In particular, mortality rates did not increase as steeply with age as reported in the official tables.

(5) The re-estimated crude rates show a very slight decrease in mortality rates up to age 90 years, with no improvement discernible at older ages.

(6) Improvements at advanced ages in Ireland have not been as great as those in England and Wales or other developed countries over the same period. Mortality for males in England in the 1950s was marginally higher than that for males in Ireland at advanced ages but by the 1980s it was lower. Similarly, the rate of improvement in Irish females mortality at higher ages lags behind those evident in England and Wales over the same period.

The companion paper, *Mortality in Ireland at Advanced Ages, 1950-2006: Part 2: Graduated Rates* (Whelan, 2009), graduates the crude rates and extrapolates patterns to very advanced ages, using several popular formulae, different calibration techniques, and different evaluation criteria. Extensions to the method of extinct generations so that mortality rates of more recent, still surviving generations, can be estimated are explored and the results reported. Part 2 shows a modest trend of improvement in male and female mortality at advanced ages accelerating in the most recent decades but still lagging behind those evident in England and Wales.

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APPENDIX A

DEATHS RECORDED IN IRELAND AT AND OVER 99 YEARS, 1950-2006

Table A.1. Number of recorded deaths at ages 99 years and over, males, 1950-2006

Year	99	100	101	102	103	104	105	106	107	108	109	110	Total deaths at age 100 and over
1950	6	5	1	1	2	–	1	–	–	–	–	–	10
1951	3	–	–	–	–	–	–	–	–	–	–	–	0
1952	1	–	–	–	–	–	–	–	–	–	–	–	0
1953	4	–	–	–	–	–	–	–	–	–	–	–	0
1954	8	–	–	–	–	–	–	–	–	–	–	–	0
1955	5	–	–	–	–	–	–	–	–	–	–	–	0
1956	8	–	–	–	–	–	–	–	–	–	–	–	0
1957	10	–	–	–	–	–	–	–	–	–	–	–	0
1958	2	–	–	–	–	–	–	–	–	–	–	–	0
1959	5	–	–	–	–	–	–	–	–	–	–	–	0
1960	8	–	–	–	–	–	–	–	–	–	–	–	0
1961	4	–	–	–	–	–	–	–	–	–	–	–	0
1962	4	–	–	–	–	–	–	–	–	–	–	–	0
1963	4	–	–	–	–	–	–	–	–	–	–	–	0
1964	7	3	5	–	–	–	1	–	–	–	–	–	9
1965	3	–	1	1	–	1	–	–	–	–	–	–	3
1966	6	4	–	–	–	–	–	1	–	–	–	–	5
1967	5	–	1	1	1	1	–	–	–	–	1	–	5
1968	4	5	1	1	–	1	–	–	–	–	–	–	8
1969	8	1	1	–	–	1	1	–	–	1	–	1	6
1970	15	3	2	1	–	–	–	–	–	–	–	–	6
1971	7	3	1	1	–	–	–	–	–	–	–	–	5
1972	6	2	4	1	–	1	–	–	–	–	–	–	8
1973	9	5	1	1	–	–	–	–	–	–	–	–	7
1974	8	5	1	1	–	–	–	–	–	–	–	–	7
1975	10	2	1	–	–	–	1	–	–	–	–	–	4
1976	9	–	2	2	–	–	–	–	–	–	–	–	4
1977	13	2	1	2	–	–	–	–	–	–	–	–	5
1978	4	2	3	–	1	–	–	–	1	–	–	–	7
1979	9	5	1	2	1	1	–	–	–	–	–	–	10
1980	10	3	3	–	2	–	1	–	–	–	–	–	9
1981	10	1	–	1	–	–	–	–	–	–	–	–	2
1982	10	1	2	3	–	–	–	–	1	–	–	–	7
1983	5	4	–	1	–	–	–	–	–	–	–	–	5
1984	7	2	4	2	2	–	–	–	–	–	–	–	10
1985	6	2	2	3	1	1	–	1	–	–	–	–	10
1986	7	2	2	2	–	1	1	–	–	–	–	–	8
1987	6	7	2	–	–	–	1	–	–	–	–	–	10
1988	7	5	3	2	–	–	–	–	–	–	–	–	10
1989	8	3	–	–	–	–	–	–	–	–	–	–	3
1990	7	8	7	1	–	–	–	–	–	–	–	–	16

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Table A.1. — continued

Year	99	100	101	102	103	104	105	106	107	108	109	110	Total deaths at age 100 and over
1991	4	3	4	2	1	–	–	–	–	–	–	–	10
1992	9	2	2	–	–	1	–	–	–	–	–	–	5
1993	7	4	4	3	–	–	–	1	–	–	–	–	12
1994	7	3	6	2	–	–	–	1	–	–	–	–	12
1995	10	2	1	4	1	1	2	–	–	–	–	–	11
1996	9	9	4	–	1	–	1	–	–	–	–	–	15
1997	9	6	7	2	1	–	1	–	–	–	–	–	17
1998	8	7	3	4	1	1	–	–	–	–	–	–	16
1999	7	13	6	1	1	–	2	–	–	–	–	–	23
2000	10	8	4	1	2	–	1	–	1	–	–	–	17
2001	5	5	6	1	2	–	–	–	–	–	–	–	14
2002	9	8	2	2	2	–	2	–	–	–	–	–	16
2003	13	10	8	–	–	–	–	–	1	–	–	–	19
2004	13	8	2	1	3	2	–	–	–	–	–	–	16
2005	9	6	6	3	2	1	–	–	–	–	–	–	18
2006	17	11	2	3	4	1	1	1	–	–	–	–	23

Sources: Based on data kindly provided by CSO. The figures for 2006 are provisional. Line through table indicates cut-off year with it being possible to verify age at death by reference to birth registration records at those ages and years lying under the cut-off line.

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Table A.2. Number of recorded deaths at ages 99 years and over, females, 1950-2006

Year	99	100	101	102	103	104	105	106	107	108	109	110	111	Total deaths at age 100 and over
1950	11	10	–	3	–	–	–	–	–	–	–	–	–	13
1951	11	–	–	–	–	–	–	–	–	–	–	–	–	0
1952	10	–	–	–	–	–	–	–	–	–	–	–	–	0
1953	13	–	–	–	–	–	–	–	–	–	–	–	–	0
1954	9	–	–	–	–	–	–	–	–	–	–	–	–	0
1955	16	–	–	–	–	–	–	–	–	–	–	–	–	0
1956	13	–	–	–	–	–	–	–	–	–	–	–	–	0
1957	10	–	–	–	–	–	–	–	–	–	–	–	–	0
1958	13	–	–	–	–	–	–	–	–	–	–	–	–	0
1959	16	–	–	–	–	–	–	–	–	–	–	–	–	0
1960	6	–	–	–	–	–	–	–	–	–	–	–	–	0
1961	14	–	–	–	–	–	–	–	–	–	–	–	–	0
1962	14	–	–	–	–	–	–	–	–	–	–	–	–	0
1963	10	–	–	–	–	–	–	–	–	–	–	–	–	0
1964	10	8	6	5	3	–	1	–	–	–	–	–	–	23
1965	17	7	–	2	1	1	–	–	–	–	–	–	–	11
1966	19	8	1	2	3	1	–	–	–	1	–	–	–	16
1967	12	4	3	4	–	–	–	1	–	–	–	–	–	12
1968	14	3	6	2	–	–	–	1	–	–	–	–	–	12
1969	22	5	5	2	1	–	–	–	–	–	–	–	–	13
1970	16	14	5	1	–	–	–	–	–	–	–	–	–	20
1971	13	5	2	3	–	1	–	–	1	–	–	–	–	12
1972	26	5	5	3	1	1	–	–	1	–	–	–	–	16
1973	21	14	4	4	2	–	1	–	–	–	–	–	–	25
1974	30	7	3	8	3	1	–	–	–	–	–	–	–	22
1975	28	4	5	6	1	2	–	–	–	–	–	–	–	18
1976	17	15	6	6	1	1	–	–	–	–	–	–	–	29
1977	26	10	14	4	–	2	–	–	–	–	–	–	–	30
1978	30	10	3	5	2	–	–	–	–	–	–	–	–	20
1979	27	8	7	4	1	–	–	–	–	1	–	–	–	21
1980	26	11	9	3	2	4	1	1	–	–	–	–	–	31
1981	15	15	9	4	2	1	4	–	–	–	–	–	–	35
1982	22	16	8	1	2	–	–	–	–	–	–	–	–	27
1983	17	18	6	8	3	1	2	2	1	–	–	–	–	41
1984	16	13	5	6	4	2	–	1	–	–	–	–	1	32
1985	22	5	8	5	1	2	1	2	–	–	–	–	–	24
1986	28	25	11	7	4	1	1	–	–	1	–	–	–	50
1987	24	11	11	5	1	3	1	–	–	–	–	–	–	32
1988	40	20	12	5	–	3	2	1	–	–	–	–	–	43
1989	32	17	16	3	4	4	–	1	–	–	–	–	–	45
1990	31	16	13	9	2	4	2	1	–	–	–	–	–	47
1991	31	16	9	4	6	3	–	1	–	1	–	–	–	40
1992	30	23	8	5	5	2	1	1	2	1	–	–	–	48
1993	35	24	10	6	7	4	3	–	2	1	–	–	–	57
1994	34	24	15	10	9	4	2	–	–	–	–	–	–	64
1995	46	18	14	10	8	2	1	1	–	–	–	–	–	54
1996	47	17	13	9	6	2	1	–	–	–	–	1	–	49

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Table A.2. — continued

Year	99	100	101	102	103	104	105	106	107	108	109	110	111	Total deaths at age 100 and over
1997	41	15	20	12	4	3	–	1	–	–	–	–	–	55
1998	46	28	13	12	9	4	–	2	–	–	–	–	–	68
1999	38	29	20	11	2	5	2	3	–	–	–	–	–	72
2000	42	29	16	12	8	6	1	–	1	–	–	–	–	73
2001	46	31	13	5	8	3	3	1	–	–	–	–	–	64
2002	39	31	24	9	6	5	2	1	–	–	–	–	–	78
2003	50	30	19	21	7	3	2	–	–	2	1	–	–	85
2004	50	43	18	14	8	8	3	1	–	1	1	–	–	97
2005	55	34	15	11	7	5	1	2	1	–	1	–	–	77
2006	52	43	27	15	9	4	4	3	–	1	1	–	–	107

Sources: Based on data kindly provided by CSO. The figures for 2006 are provisional. Line through table indicates cut-off year with it being possible to verify age at death by reference to birth registration records at those ages and years lying under the cut-off line.

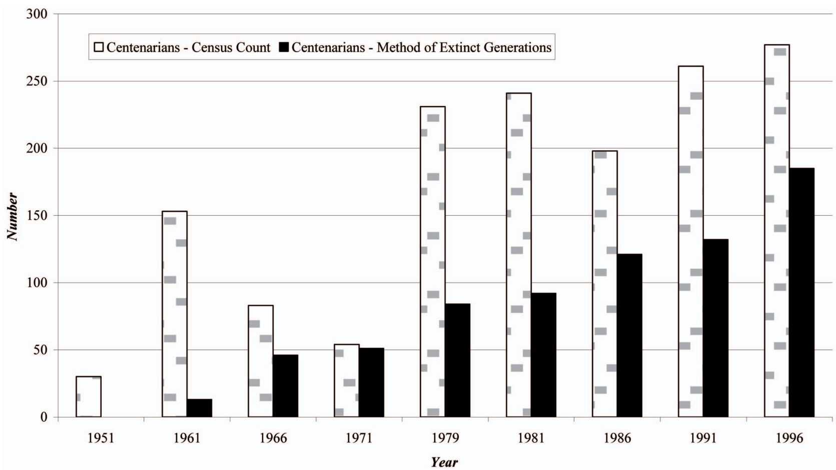
APPENDIX B

NUMBER OF CENTENARIANS AND LONGEST LIVED IN IRELAND

It is of interest to compare the number of centenarians enumerated in Irish censuses with the number of centenarians estimated by the method of extinct generations. The censuses report the number enumerated in April of the census year while the method of extinct generations estimates the number as at 1st January who will subsequently die as centenarians (see Figure B.1). One would expect this latter number to be slightly greater than the former.

The two methods provide quite different estimates with the method of extinct generations giving considerably lower numbers. This pattern of higher numbers recorded in censuses than by method of extinction generations has been a noted feature in England and Wales — Thatcher (1981) investigates the 1971 census count of centenarians and shows it to be about double the more reliable estimate of the method of extinct generations.

Aside from the census and death data, there is another source of information on the number of centenarians in Ireland. The Centenarian Bounty is a payment made by the President of Ireland to anyone in Ireland reaching their 100th birthday. The scheme started in 1940 with a 'bounty' payment of £5 but has grown so that it amounts to €2,540 in 2008, which is arranged to



Source: Based on data kindly provided by the Central Statistics Office (CSO). In estimating the number of centenarians in 1996, we took ù=110 years (or, equivalently, assumed no-one was alive aged 111 or more at the end of 2006).

Figure B.1. Number of centenarians reported in Irish censuses, compared with number estimated by method of extinct generations

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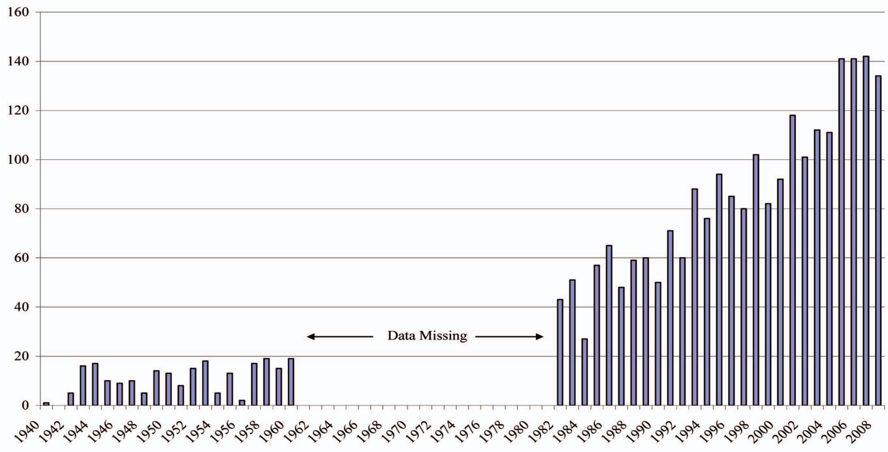

Source: From data kindly provided by the Office of the President of Ireland (Áras an Úachtaráin).

Figure B.2. Number of persons in Ireland reaching 100th birthday in calendar years 1940-1960 and 1982-2008

be presented on the recipient's 100th birthday with a congratulatory letter signed by the President. The scheme applied only to those living in Ireland (whatever their nationality) at first but was extended in March 2006 to include all Irish citizens born on the island of Ireland wherever they are now resident. A further development to the scheme was made in 2000, so that from that time a commemorative coin, especially designed each year, is given on each birthday celebrated after their 100th.

For those in receipt of a state pension the bounty is automatically awarded on their birthday but others must apply. Given the widespread knowledge of the bounty in Ireland and the materiality of the payment in recent years, it can be expected to achieve close to 100% coverage of those centenarians resident in Ireland.[5] Figure B.2 graphs the number of persons in Ireland reaching their 100th birthday by calendar year according to the records of the bounty scheme.

[5] This is in contrast with the number of Queen's messages of congratulations sent to those reaching their 100th birthday and on every birthday from their 105th in the U.K., which is believed "not to provide accurate numbers of the very elderly. However, they can provide a lower bound on numbers at the oldest ages" (Gallop, 2002, p4). Where such schemes exist in other countries to celebrate citizens' longevity, such as the President's congratulatory letter in the U.S. and even the silver cup and certificate presented in Japan to centenarians, none can expect to have the same completeness of coverage as that in Ireland.

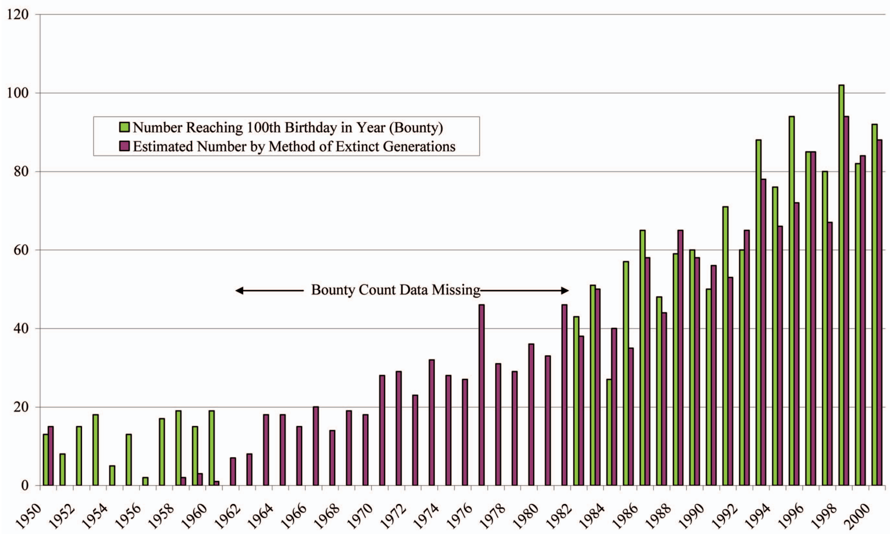

Figure B.3. Number of persons in Ireland reaching 100th birthday in each calendar year, by bounty awards and estimated by method of extinct generations

The number of centenarian bounties awarded in any year can provide an independent check on the numbers at very advanced ages. Figure B.3 compares the numbers awarded the bounty in every calendar year from 1950 for which data exists and compares it with the number of 100th birthdays in that year estimated by the method of extinct generations.

We note that the number of bounty payments appears high in the fifties and sixties when age could not be verified by birth registration. From 1982 to 2000, the numbers match reasonably well: over that period 1,290 bounty payments were made and 1,196 persons are estimated to have reached their 100th birthday by the method of extinct generations.

We note the marked trend of increasing numbers of centenarians in Ireland. The trend is primarily due to the increasing numbers of females reaching extreme ages. Figure B.4 highlights the numbers of centenarians in Ireland in 2008 by age and gender. Of the total 223 centenarians who celebrated a birthday in 2008, 194 (87%) were female.

Finally, it is of interest to record that the highest age recorded at death in Ireland over the period 1950 to 2006 was of a female aged 111 years who died in 1984 (and therefore an official record of her birth should exist). This equals the highest verified age of death of a person in Ireland ever (Katherine Plunket who died on 14th October 1932 (Thatcher, 1999b). The highest recorded age of a male death in the period 1950 to 2006 inclusive was 110

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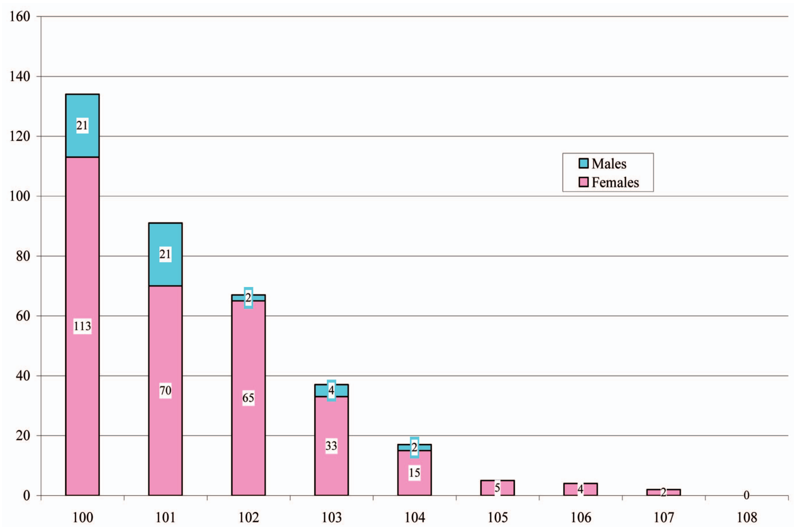
years (in 1969) but he was born before formal registrations of birth could provide an independent check. The greatest longevity in Irish males with a birth registration is 107 years, with four such cases reported — in years 1978, 1982, 2000 and 2003.[6]



Source: From data kindly provided by the Office of the President of Ireland (Áras an Úachtaráin).

Figure B.4. Number of bounty awards for 100th birthday and medals for attaining higher ages awarded to Irish residents in year 2008

[6] Up to 1992, the highest verified age at death in England and Wales was 114 years for a female (in 1987) and 112 years for a male (in 1990) (Thatcher, 1992). The highest verified age at death of a human is of the French woman Jeanne Calment who died on 4th August 1997 at the age of 122 years (Robine & Allard (1999) and Guinness Book of Records (2008)). It should be noted that the Irish have always figured prominently in league tables of centenarians and supercentenarians. Easton (1799) gives a list of supposed centenarians that ever lived numbering 1,712, of which no less than 145 were mainly resident in Ireland. The list includes St. Patrick (122 years), St Kevin of Glendalough (120 years), and the oldest reported Irish person, the Countess of Desmond (145 years) who died in 1612 and "was married in the reign of King Edward IV, was in England the same reign, and danced with the Duke of York, the King's brother. Upon the ruin of the house of Desmond, she was obliged, at the great age of one hundred and forty, to travel from Bristol to London, to solicit relief from the court, being reduced to poverty. Lord Bacon says, she renewed her teeth twice or thrice. This remarkable lady was a subject for the pens of a variety of authors. She retained her vigour to the last" (pp5-6). Of course, all of these remarkable feats of longevity must be put down to straightforward exaggeration (see, for instance, Bowerman, 1939; Laslett, 1999). In fact, early tales in many cultures tell of improbable longevity, e.g. Tír na nÓg and Oisín's several hundred year visit there, and, excepting Cain and Abel, the lifespan of the first ten men mentioned in the Bible averaged more than 850 years, with Methuseh the longest lived at 969 years (Boldsen & Paine, 1995).