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Socioeconomic Differentials in Male Mortality in Ireland: 1984-2008

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Abstract: The presence of pronounced inequalities in mortality and life expectancy across income, education and social groups is now well established. Research across a large number of developed and wealthy countries, including Ireland, has shown that those with fewer resources, less education or a lower occupational class have higher standardised mortality rates (SMRs) than more advantaged individuals. Research for Ireland for the period 1989-1991 indicated that men in the unskilled manual social class had a mortality rate 2.8 times that of men in the higher professional social class. However, serious issues with the occupational coding of mortality data for the years since 1991 have meant that there has been no subsequent analysis of trends in socio-economic inequalities in mortality. The period since then has been characterised by an unprecedented boom and bust in economic activity which may well have influenced mortality differentials between socio-economic groups. The SMR in 2008 was 37% lower than in 1984 and 30% lower than in 1995. Using annual mortality data from the CSO over the period 1984-2008, this paper examines whether the overall downward trend in mortality observed over this period was experienced equally by all socio-economic groups (SEG) whilst adjusting the SMRs to take account of the coding issues effecting data on occupation/SEG. We use three methods to deal with the coding issues in the data across time: direct adjustment; imputation and a fully Bayesian imputation. Using these approaches we find that the differential in SMRs between professional and unskilled men aged 15+ decreased between 1984 and the early 1990s but then increased significantly thereafter as the SMR for professional men continued to decrease whilst that of unskilled men stabilised and then began to increase.

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1 INTRODUCTION

The presence of pronounced inequalities in mortality and life expectancy across income, education and social groups is now well established. Research across a large number of developed and wealthy countries, including Ireland, has shown that those with fewer resources, less education or a lower occupational class have higher standardised mortality rates (SMRs) than more advantaged individuals (Mackenbach and Bakker 2002). The latest analysis of Irish adult mortality differentials across social classes, based on data for 2006 (CSO 2010), identified large differences across classes (e.g., males in the unskilled manual social class had a standardised mortality rate (SMR) that was 1.8 times higher than males in the professional social class). However, no analysis of trends over time was undertaken, and the methodological problems associated with missing information on social class were not addressed. There have been previous analyses of trends over time in socio-economic inequalities in mortality in Ireland but these only considered the period up to the mid-1990s (Barry, et al., 1997; O'Shea 2002). Analysis of trends across time were not possible due to the increasing proportion of cases where the socio-economic group (SEG) identifier was missing from the early 1980s onward. Although it has not yet been possible up to this point to identify differential trends in mortality rates between social groups, data do suggest that Ireland's overall mortality rate has fallen significantly and consistently over the last three decades. Published data from the CSO show that the average crude mortality rate per 100,000 population (all ages) between 1981 and 1990 was 922, by 1995 this had fallen to 896 and by 2010 it was 545, a fall of almost 41 per cent across the period.

There is a growing international literature on the impact of the economic cycle on morbidity and mortality (European Observatory on Health Systems and Policies 2013; Laporte 2004; McInerney and Mellor 2012; Neumayer 2004; Ruhm 2000; Ruhm 2003; Ruhm 2013; Suhrcke and Stuckler 2012; Suhrcke, et al., 2009; Svensson 2007; Tekin, et al., 2013). However, the research has tended to focus on morbidity and mortality trends at an aggregate level, with little or no discussion of experience across different social groups. Since the mid-1990s, Ireland has undergone intense social and economic change; in 1995 Irish GNP per capita was 12 per cent below the OECD average but was 22 per cent above average by 2003 (Maitre and Nolan 2007). Median household incomes (adjusted for household size) increased by 118.5 per cent between 1995 and 2007 (Calvert, et al., 2013). Levels of income inequality remained relatively stable over the period of the boom; the Gini coefficient was 0.32 in both 1994 and 2007 (although it fell to 0.30 during 2000 and 2001) (Calvert et al. 2013). From 2008, however, Ireland entered a severe and prolonged recession, resulting in the need to accept an EU-IMF bailout at the end of 2010. Unemployment rose sharply (from 4.6 per cent in Q1 2007 to

13.7 per cent in Q4 2012)[1], and household incomes have fallen year on year (CSO 2013). In the initial period of the economic crisis, the Gini coefficient fell (falling to 0.29 in 2009), but since then the Gini coefficient has increased to a level similar to that seen during the boom (Calvert et al., 2013). The Irish experience of economic change in the 1990s may well have had profound consequences for differentials in mortality patterns across social groups, yet because of difficulties with coding of occupation and social groups in the data there has not been a thorough examination of change over time.

Using annual mortality data from the CSO over the period 1984-2008, the purpose of this paper is to examine whether the general downward trend in mortality observed over the period was experienced equally by all socio-economic groups (SEGs). As already remarked upon, research on mortality differentials across SEGs in Ireland is complicated by methodological difficulties generated by incomplete data; data on the number of deaths (numerator) and the underlying population (denominator) being from different sources (leading to 'numerator/denominator' bias); and different coding systems for socio-economic position across data sources. We begin by reviewing the literature on socio-economic differentials in mortality both in Ireland and elsewhere in Section 2. Section 3 describes our data and methodological approach. Section 4 presents empirical results, while Section 5 discusses the results, and outlines a number of areas that merit further research.

2 PREVIOUS LITERATURE

A large number of research papers over the last three decades have examined socio-economic inequalities in mortality outside Ireland, with a number of comparative studies emerging in recent years (Benzeval, et al., 1995; Blane, et al., 1990; Kunst, et al., 1996; Mackenbach, et al., 2003; Mackenbach, et al., 1997; Siegrist and Marmot 2006). A large-scale comparative analysis of socio-economic differentials in mortality (and morbidity) across 12 European countries by Kunst et al. (1996) found that in each country for which data were available, mortality rates were higher among the lower occupational classes (for example, men from manual classes had about 30 to 50 per cent higher mortality rates than men from non-manual classes).

Evidence for Ireland also shows substantial inequalities across social groups. Nolan (1990) was the first study to examine male mortality differentials using national data from 1981. The results revealed substantial differences in mortality across SEGs. For example, men in the unskilled manual category had an SMR that was almost three times higher than men in the professional group. The analysis was confined to males aged 15 to 64 years of age and did not differentiate between different causes of death. O'Shea (1997) extended Nolan's work by combining mortality data from a number of years (1986-1991) and analysing mortality by cause of death. He found similar patterns of mortality by SEG and that there were gradients in mortality by SEG for all of the five major causes of death for males (for example, the ratio of SMRs for cancer between the unskilled manual category and the higher professional group was 2.2:1). Unfortunately trend analyses between 1981 and 1986-91 were hampered by the fact that the proportion of death certificates of missing or 'unknown' SEG

[1] See Table QNQ20: ILO Participation and Unemployment Rates by Sex, Quarter and Statistic (www.cso.ie/en/databases) [last accessed 9 August 2013].

had increased between the periods (even though the ratio of the 'unknown' population to the total population in the Census of Population remained constant between the two periods). The deterioration in the quality of the mortality data over the period meant that definitive statements on changes in SMRs by SEG over time could not be made. Barry et al 2001 (Barry, et al., 2001b) examined trends in SMRs for men aged 15-64 years in the census years over the period 1981-1996. For all causes and deaths from ischaemic heart disease, the socio-economic differentials in mortality declined over time but they note, like O'Shea, that the drop in the SMR for the unskilled manual group could also be due to a rise in the number of unknowns over the period.

The most recent year for which information on socio-economic inequalities in mortality in Ireland have been presented is 2006 (CSO 2010). The CSO analysed all those who died in the twelve-month period following the census date in 2006.[2] They found strong socio-economic differences in SMRs across a variety of indicators such as social class, area deprivation[3] and education. For example, males in the unskilled social class had an SMR of 798 per 100,000 population, in comparison to 449 per 100,000 population for professional males. However, the analysis was confined to a single year, and therefore no conclusions about trends over time could be inferred. In addition, no attempt was made to incorporate those with missing social class into the analysis.

It is clear that considerable socio-economic inequalities in mortality exist in Ireland, although there is no analysis of trends in socio-economic inequalities in mortality in Ireland since 1996 (with the exception of the above-mentioned study for 2006), nor any analysis of what has happened since the onset of the economic crisis in 2007. A notable exception is a recent paper on perinatal mortality in Ireland (Layte and Clyne 2010) which suggests that the pattern of socio-economic inequalities in mortality may actually have improved since the mid-1990s. This paper analysed trends in perinatal mortality between the late 1980s and early 2000s and showed that there had actually been a significant reduction in the differential between the professional class and unskilled manual/unemployed from 1.99 to 1.88 over the period.

As noted, the 1990s and early- to mid-2000s were characterised by rapid economic and social change. Research suggests that average life expectancy is influenced by per capita national income but that this relationship tends to weaken in wealthier countries when average life expectancy appears to be more closely associated with the level of inequality in the distribution of income (Lynch, et al., 2004; Wilkinson and Pickett 2006). Ireland's overall mortality rate had been falling steadily for a number of decades before 1996 (Layte, et al. 2007) but the rate of reduction accelerated significantly around 1999. Time series analysis by Layte, et al. (2011) suggests that there was a structural change in mortality rates in Ireland around 1999-2000 and that this can be explained by the pattern of cardiovascular prescribing during the period which significantly reduced mortality from circulatory diseases, particularly during the winter months. It is not known what impact this structural change in circulatory mortality patterns has had on socio-economic inequalities in mortality in Ireland but it is often the case that more advantaged population groups

[2] The overall match rate was 85 per cent, i.e., 85 per cent of the death records over the period were matched to a Census record (CSO. 2010. "Mortality Differentials in Ireland." in *Analysis based on the census characteristics of persons who died in the twelve month period after Census Day 23 April 2006*. Dublin: CSO.

[3] Each electoral division (ED) in Ireland is assigned a deprivation score, with EDs then grouped into quintiles ibid.

gain more when provision of good medical care is expanded than do less advantaged groups. The frequency with which this pattern emerged in the British National Health Service led Julian Tudor Hart to name it the 'inverse care law' (Tudor Hart 1971). Applied to Ireland, the inverse care law would predict that the expansion of free pharmaceuticals to the older population in the late 1990s should have increased differentials between social groups.

Research outside Ireland has identified a tendency toward increasing socio-economic differentials in mortality. For instance, Mackenbach et al. (2003) analysed trends in socio-economic differentials in mortality over the period 1981-1985 to 1991-1995 in six European countries (Finland, Sweden, Norway, Denmark, England/Wales and Italy (Turin)). They found a widening gap between social groups (both education and occupation), largely due to a faster proportional mortality decline among the higher social groups. This in turn was largely due to faster proportional mortality decline for cardiovascular diseases among the higher social groups. However, widening inequalities for certain causes such as lung cancer, breast cancer, respiratory disease, gastrointestinal disease and injuries were due to rising rates of mortality in the lower social groups. Kunst, et al. (1998) analysed mortality for males aged 30-64 years across 11 EU countries using data from the 1980s, although the analysis for Ireland could only be carried out for males up to the age of 59 years.[4] They found that the ratio of the manual SMR to the non-manual SMR for males aged 30-44 years ranged from approximately 1.18 to 1.60 (after adjustment for the inclusion of males with missing occupation) and for males aged 45-59 ranged from approximately 1.10 to 1.65 (also after adjustment for the inclusion of males with missing occupation). The Irish ratios were 1.31 and 1.32 respectively. Trend analysis for France and Italy suggested that the manual/non-manual rate ratios increased over a five-year period in the 1980s. A related paper also analysed inequalities in mortality using education as an alternative indicator of socio-economic status, and found consistent results (Mackenbach et al., 1997).

Data for Australia over the period 1981-2002 show that while there was little change in the ratio of manual to non-manual deaths for males aged 25-59 years up to 1998, there was some evidence of widening inequality from 1998 (Williams, et al., (2006). Khang, et al. (2004) examined mortality for males and females aged 30-59 years in Korea over the period 1990-2000 and found that relative socio-economic inequalities in mortality, using education as the indicator of socio-economic status, were unchanged over the period. Leyland (2004) examined regional inequalities in premature mortality (0-64 years) in Great Britain over the period 1979-1998, and found substantial regional disparities in premature morality over the period which they proposed were due to regional inequalities in income and living standards. Marang-van de Mheen, et al. (1998) analysed socio-economic differentials in mortality among males in England, Scotland and Wales over the period 1951-1981 and found that inequalities in mortality increased to a greater extent in Scotland over the period, driven by a faster proportionate decline in mortality among professional groups in Scotland. Leclerc, et al. (2006) found significant increases in socio-economic mortality differentials for both males and females aged 30-64 years in France over the period 1968-1996. Bos, et al., 2005 found evidence for significant differentials in mortality across ethnic groups in the Netherlands over the period 1995-2000. Kibele, et al. (2013) found that relative socio-economic differences in mortality

[4] The time period covered varied by country.

for German males aged 65+ widened over the period 1995-2008, particularly for males in Eastern Germany.

A number of studies have attempted to explain the reasons behind the existence and persistence of socio-economic inequalities in mortality. Plug, et al. (2012) examined socio-economic inequalities in mortality from conditions amenable to medical care in individuals aged 30-74 years across 14 countries (Ireland was excluded), and found that, contrary to their initial hypothesis[5], inequalities in mortality from amenable causes were not more strongly associated with inequalities in health care use than conditions that were not. Education was used as the indicator of socio-economic status. Kindig, et al. (2002) examined geographical variation in mortality in the US in the period 1990-1992 as a function of area characteristics and population composition; they found that while almost one third of the variance in area mortality was unexplained, the strongest predictor of mortality was the ethnic composition of the area. Cutler, et al. (2011) analysed the extent to which behavioural differences explained the increases in educational mortality differences that were observed in the US over the period 1971-2000, and found that these factors did not explain the differences. Yang, et al. (2012) found that income inequality was significantly and positively associated with mortality at the county-level in the US over the period 1998-2002, but only until the 80th percentile of mortality. However, they found that while socio-economic status (derived from a principal components analysis of eight socio-economic status variables such as per capita income, education, poverty rate, *etc*.) was positively and significantly associated with mortality, the relationship was the same over all of the mortality distribution. On the other hand, Leigh and Jencks (2007) found that changes in economic inequality (as proxied by the share of pretax income going to the richest 10 per cent of the population) were not significantly associated with mortality in 12 rich countries over the period 1903-2003 (mortality was measured in a variety of ways, including life expectancy at birth, infant mortality, homicide and suicide). Hemström (1999) focussed on differential trends in male and female mortality in Sweden over the period 1945-1992 and found that excess male mortality was positively associated with GDP per capita and cigarette and alcohol consumption, and negatively associated with lagged unemployment, the male/female wage ratio and butter consumption.

3 DATA AND METHODS

The review of the literature has demonstrated that socio-economic inequalities in mortality and life expectancy across income, education and social groups are a feature of all countries, although there is considerable debate over the extent to which these inequalities are widening or narrowing over time, and over the precise mechanisms that give rise to these inequalities. The main objective of this paper is to examine whether different SEGs experienced different trends in mortality over the period 1984-2008 in Ireland. There are a number of ways in which mortality may be analysed empirically. The standard approach is to calculate mortality or death rates. The crude mortality rate (CMR) is simply the number of deaths divided by the population, and is typically expressed per 100,000

[5] One factor that may contribute to health inequalities is that lower income individuals may be more likely to face barriers to accessing health care. On the other hand, inequalities in mortality from amenable conditions might also reflect inequalities in the background risk of disease among socio-economic groups.

population. However, mortality rates are strongly age-related, so it is necessary to adjust mortality rates for the age distribution of the group in question. We therefore calculate an age-adjusted standardised mortality rate (SMR) for each group, using the direct standardisation approach:

$$SMR_i = \Sigma_i w_{si} * m_i$$

Where the SMR for each group is the sum of the mortality rate in each age group i weighted by the proportion of reference population in each age group.

Population Denominators

Calculation of CDRs and SMRs requires data on the numerator (deaths) and denominator (population). Denominator information, i.e., population counts, are taken from the 1986, 1991, 1996, 2002 and 2006 Census of Population. As the Irish Census occurs every five years[6], we replace population counts for non-Census years with those of the nearest Census year (for example, the relevant population count for 1988 is 1986, while for 1989 it is 1991).[7] Quite apart from the issue of 'numerator-denominator' bias, discussed in greater detail below, the main complication with the denominator data is the change in occupational coding at the CSO in 1996.[8] From 1996 onward occupational codes, SEGs and social class groups for the Census all moved to new codings whereas occupation in death registrations continued to be coded in the previous manner. Coding to social class groups using both the new or old CSO schemas requires detailed information on employment which is not requested at death registration. For this reason we, in this project, like those previously, use SEGs as the basis of our comparisons. The CSO provided us with a contingency table of the new and old SEGs for Census 1991 and this was used to develop a new 7 group schema that could be used in a consistent fashion across years (details are available from the authors on request). The new schema and its relationship to the existing SEGs is given in Table 1.

INSERT TABLE 1 HERE

Population Numerators

Information on the numerator, i.e., death counts, is available from the death certificate records administered by the CSO. Information on date of death, age (in years), sex, principal economic status (i.e., at work, retired, *etc*.), SEG, area of registration and cause of death for every death that occurred in Ireland over the period 1 January 1984 – 31 December 2008 were made available to the authors. SEG refers to the 12-category 1996 SEG schema employed by the CSO. SEG is derived from information on occupation. Children under 15 years of age are classified under the occupation of

6 The exception was 2001, in which the Census was delayed for a year due to the outbreak of foot and mouth disease in 2001.

7 An alternative approach would be to estimate population counts for non-Census years (e.g., by assuming a constant rate of population growth between Census years). See for example, Williams, G., J. Najman, and A. Clavarino. 2006. "Correcting for numerator/denominator bias when assessing changing inequalities in occupational class mortality, Australia 1981-2002." *Bulletin of the World Health Organization* 84:198-203..

8 See Appendix 1.

their parent or guardian, retired individuals are classified under their former occupation and married or widowed women may be classified under their husband's occupation (if their own occupation is missing). Registration area refers to the 88 areas in which deaths are registered, i.e., it does not necessarily equate to place of death. Cause of death is coded to ICD-9 for the period 1984-2006 and ICD-10 from 2007.

The main complication with the numerator data is the large proportion of deaths that are classified as having an 'unknown' or missing SEG. The proportions, for males and females, over the period 1984-2008 are presented in Figure 1. The proportion of 'unknowns' is much higher for females than for males in every year. In 2008, approximately 20 per cent of male deaths had an 'unknown' SEG, in comparison with 30 per cent of female deaths (and in some years in the early 2000s, the discrepancy was even greater). For both males and females, the proportion of missing observations was relatively steady up to 1996, and then increased to a peak in 2002 before declining thereafter, particularly in 2006. We have no information on whether the increase in missing SEGs from 1996 stemmed from worse reporting of occupations in Registration Offices by relatives of the dead, or a decline in the effectiveness of coding within the CSO Vital Statistics Unit or some combination of the two. CSO sources confirmed that coding procedures did change in that year with deaths being coded straight to an SEG rather than being allocated an occupational code and then aggregated into SEGs. This could suggest that reporting in offices was the main reason for unknowns before 1996 with the addition post-1996 due to the change in office procedures. However, the steep fall in unknowns in 2006 would not be consistent with this explanation. Irrespective of the source of the change, it is clear that proportion of 'unknown' or missing SEGs varied significantly and that this presents a problem for analysis. The level of incomplete data is significantly larger for women compared to men so in this paper we focus on male mortality differentials alone and a future paper will examine female differentials.

Previous analyses of Irish mortality trends noted the difficulty in examining socio-economic differentials in mortality in Ireland in the presence of missing observations on SEG (Barry et al. 2001b; Nolan 1990; O'Shea 1997; O'Shea 2002). This problem is not unique to Ireland; many international analyses have discussed the problem of how to incorporate those with missing information on socio-economic status (in most cases, women are excluded from the analysis for this reason) (Kunst et al., 1996; Kunst, et al., 1998; Martikainen and Valkonen 1999; O'Shea 1997; O'Shea 2002). However, as those with missing information on SEG are more likely to have higher mortality rates, their exclusion from the analysis results in the underestimation of mortality rates. In addition, as those with missing information on SEG are more likely to originate in lower SEGs, their exclusion results in an underestimation of mortality differentials across SEGs (Kunst et al., 1996). A number of solutions to this problem have been proposed. In this paper, we employ three methods in an attempt to incorporate those with missing information on SEG into the analysis:

- indirect adjustment of the observed mortality rates within SEGs to account for differential levels of missing SEGs
- Multiple imputation of missing SEGs
- A Baysian approach to imputation (which results in five different outcomes).

Full details of each approach are provided in the Appendix.

Numerator/Denominator Bias

As noted, numerator and denominator data in this study come from different sources. The use of such unlinked data gives rise to the problem of possible 'numerator-denominator' bias, in which different criteria may be used to record occupation on census and death certificate records. Generally, census records refer to 'current' occupation, while death certificate records refer to 'last known' or 'usual' occupation. Comparisons of time trends for different groups may be affected by this discrepancy; for example, in periods of high unemployment, there may be a decrease in the numbers in particular occupations, but no commensurate decrease in the deaths of persons previously employed in those occupations, thereby potentially inflating the mortality rate of the economically disadvantaged in periods of high unemployment (Williams, et al., 2006). A further problem arises from the greater potential for errors in the death certification registration of occupation; occupation is often recorded by next of kin, who may be unsure of the exact occupation of the deceased, or 'promote the dead' by inflating the occupation of the deceased (Nolan 1990). Kunst, et al. (1998) estimated the extent of the bias from using unlinked death registration and Census data for Ireland at approximately 20 per cent, with the bias possible in either direction (i.e., either an under- or over-estimation of the non-manual/manual rate ratio). Martikainen and Valkonen (1999) estimated that the exclusion of the economically inactive population underestimated social class differences in mortality in Finnish males and females by approximately 25 per cent and 60 per cent respectively.[9] Future work will investigate the extent of this problem in the Irish context using linked death register and Census data for 2006.

After adjusting the numerator for missing information on occupation, and ensuring that the same SEG schema is used for all denominator observations over the period, we calculate SMRs. Several summary measures are available to assess the magnitude of mortality differences by SEG. We first provide a descriptive analysis of SMRs across SEGs, before and after adjustment for missing observations on SEG. Then, we compare the rate ratio of those in higher and lower SEGs, i.e., the ratio of the SMRs of the unskilled manual and professional SEGs. Finally, to examine whether there are statistically significant differences in SMRs across time for *all* SEGs, we estimate statistical models of SMRs.

The SMR of each group defined by year and SEG is the combination of count data for the number of deaths divided by the population (expressed in terms of per 100,000 population). This quantity is continuous and can be zero or positive but never negative. The form of the data is not suitable for model estimation using standard linear methodologies such as ordinary least squares of the form $\mu=\alpha+\beta x$ since this can yield $\mu<0$. Instead we use a general linear model with log link function and poisson error distribution, often referred to as the poisson log-linear model where $\log(\mu)=\alpha+\beta x$. As this model is estimated on grouped data (defined by year and SEG) where the underlying population size may vary significantly, frequency weights representing the population count in that cell are applied so that more weight is given to cells based on a larger absolute population.

[9] Blakely, T. and J. Fawcett. 2005. "Bias measuring mortality gradients by occupational class in New Zealand." *The New Zealand Medical Journal* 118:1-13. also discuss the bias associated with the use of unlinked mortality and Census data in New Zealand.

Our model is fitted with a term for SEG group (relative to the professional SEG). As there was a downward trend in mortality rates throughout our period of interest (1984-2008) with some acceleration in the rate of decline in some periods, our model contains a linear term for year plus a quadratic term. Our primary interest is in testing whether the rate of decline in mortality rates was uniform across all SEG groups; thus we also specific an interaction between SEG and year and SEG and the year quadratic term. We estimate eight models, that is, one for each of the methods for dealing with the missing data problem plus one for the unadjusted data. As the analysis is of SMRs, these are already standardized for variation across years and SEGs by age and so age is not entered into the model:

$$\text{Log(Y)}=\alpha+\beta\text{Year}+\beta\text{Year}^2+\beta\text{SEG}+\beta\text{SEG*Year}+\beta\text{Year}^2$$

4 EMPIRICAL RESULTS

As noted, mortality rates in Ireland have been falling steadily over recent decades. Figure 2 presents SMRs for men and women aged 15+ in Ireland over the period 1984 to 2008. As is evident from the data, while the SMRs of both sexes have been falling over the period, the gap between men and women SMRs has declined over time. While the general trend is downward there are a number of periods in which mortality increased from one year to the next, although the SMRs have been relatively steady since 2003/2004 (the period in which the 'Celtic Tiger' was entering its height). The larger proportion of SEGs defined as 'unknown' or missing among women compared to men means that all analyses must be carried out separately by sex and as noted, the analysis of female differentials is a task beyond the confines of a single paper. A future paper will present analyses for women. In the following analyses we focus on male mortality alone.

INSERT FIGURE 2 HERE

Overall trends in mortality can disguise considerable variation among more disaggregated population groups. Figure 3 presents SMRs for men by three broad age groups (15-44 years, 45-64 years and 65+ years). For all age groupings, SMRs have been falling since 1984, with the greatest percentage decline in SMRs experienced by those aged 45-64. The marked acceleration in the rate of decline in 1999 as identified in previous research by Layte (2011) is evident, with the structural break most pronounced for men aged 65+.

INSERT FIGURE 3 HERE

Next, we focus on the core issue of this paper, namely, the trends in SMRs for different SEGs over the period 1984-2008. Figure 4 presents SMRs for men including those classified as having an 'unknown' SEG. There are substantial declines in mortality rates for some groups over the period 1984-2008, particularly the 'employers and managers' and professional groups. Falls are less pronounced among the skilled, unskilled manual and farming groups. The decline in the rate for 'unknown' SEGs is very pronounced across the observation period with a particularly sharp fall in 1999. Figure 5 gives the unadjusted SMRs for professional and unskilled manual groups alone (i.e. only standardised for age) plus the rate ratio of the SMRs from 1984 to 2008. This shows that the ratio of the SMRs averaged 1.82 over the period, although there is a pronounced rise in 1999 which peaks in 2004, before falling back again to the post 1998 average by 2008.

INSERT FIGURE 4 HERE

The high SMRs for the ‘unknown’ SEG, particularly in the earlier years, are notable. Simply excluding these individuals from the analysis potentially biases any conclusions regarding trends over time in mortality across SEGs, particularly if those with ‘unknown’ SEG are those whose true SEG is in the lower SEGs. If so, then excluding them from the analysis would underestimate socio-economic differences in mortality, particularly in the years up to and including 1998.

INSERT FIGURE 5 HERE

Figure 6 presents the predicted SMRs for professional men both unadjusted and after adjustment using the seven methods previously described (i.e., adjusting the data for the inclusion of observations with missing information on SEG using direct adjustment, imputation and five kinds of Full Baysian methods (FBM)). Full details of the adjustment methods are provided in the Appendix. Figure 6 shows that the direct adjustment method yields the highest estimate of professional SMRs followed by direct imputation and then the FBM approaches. As would be expected, the higher the proportion of ‘unknown’ SEGs reclassified into a known SEG group using the FBM, the closer is the estimate is to that using standard imputation techniques (which allocates all ‘unknown’ SEGs). However, the extent of the downward trend in SMRs varies little by method.

INSERT FIGURE 6 HERE

Figure 7 provides similar estimates for the unskilled manual SEG group. The vertical patterning of the lines is similar to that found for the professional group but there is clear positive curvature in all the lines with SMRs increasing from 1999 onwards suggesting that the SMR of unskilled manual men was actually increasing after the late 1990s after falling for the preceding decades. If we combine the predictions for the professional and unskilled manual groups we can calculate a predicted rate ratio using the different adjustment methods and these are shown in Figure 8. This suggests that there has been a pronounced increase in mortality differentials for men of the unskilled manual SEG group relative to their professional peers since the early 1990s.

INSERT FIGURES 7 AND 8 HERE

Descriptive patterns such as these cannot tell us anything about the significance of any changes over time, nor whether changes over time are significantly different between SEGs (up to now, we have presented data on the ratio of SMRs for the unskilled manual and professional SEGs only). To do this, we estimate generalised linear models of mortality rates. SMRs are calculated for the various year and SEGs cells, resulting in 150 observations for analysis. Various models were tested, and the models with a time trend, quadratic time trend and interactions between the time trends and the various SEGs were preferred.[10]

Table 2 presents the results of the preferred GLM model of SMRs for males aged 15+ over the period 1984-2008, based on the unadjusted SMRs (in column 1), and for the SMRs calculated from the seven adjustment methods (in columns 2-8). The model results confirm the significant downward trend in mortality rates for males aged 15+ years over the period 1984-2008 (consistent with the descriptive patterns presented in Figure 2). The significance of the quadratic time trend term indicates that mortality declined over the period, but at a declining rate over time, although the significance of this curvature varies by method. In comparison with those in the professional SEG, all other SEGs had significantly higher mortality rates, with the effect of for the unskilled manual group particularly large and significant. The interaction term of SEG with year indicate that in comparison to professional men, those in the unskilled manual group experienced a significantly larger reduction in mortality over the period. However, the deceleration in mortality decline among the unskilled manual group was larger than that experienced by the professional group, as shown by the SEG5*Year2 interaction in Table 2. In contrast, most other SEGs experienced a significantly smaller fall in mortality than the professional SEG over the period 1984-2008, but a relative acceleration in the rate of decline over the period. The exception is the employers and managers group, who experienced a significantly greater fall in mortality over the period (relative to the professional group), and a relative acceleration in this trend over this period.

INSERT TABLE 2 HERE

5 DISCUSSION/CONCLUSIONS

The presence of pronounced inequalities in mortality and life expectancy across income, education and social groups is now well established. Research across a large number of developed and wealthy countries, including Ireland, has shown that those with fewer resources, less education or a lower occupational class have higher standardised mortality rates (SMRs) than more advantaged individuals. The most recent analysis of Irish adult mortality differentials across social classes, carried out by the CSO and based on data for 2006, found that males in the unskilled manual social class had a standardised mortality rate (SMR) that was 1.8 times higher than males in the professional social class. However, little is known about how socio-economic inequalities in mortality in Ireland have changed since the mid-1990s, a period characterised by an unprecedented boom and bust in economic activity. In addition, previous analyses have made no attempt to adjust the SMRs to take account of those reporting ‘unknown’ SEG. This is a major omission that potentially has important policy implications. For example, in 2002, the then Department of Social, Community and Family Affairs published the social inclusion strategy entitled “Building an Inclusive Society”. This undertook to reduce the gap in premature mortality for circulatory, cancer, injuries and poisoning between the

[10] Model selection results are available from the authors.

lowest and highest socio-economic groups by 10% by 2007 (DSCFA 2002), p12) yet at the time it was impossible to measure SMRs for any social group in a reliable fashion.

Using annual mortality data from the CSO over the period 1984-2008, this paper examined whether the general downward trend in mortality observed over this period was experienced equally by all SEGs. After adjusting the data for the inclusion of observations with missing information on SEG, we found that in comparison to men in the professional group, those in the unskilled manual group experienced a significantly larger reduction in mortality over the period, but that the subsequent deceleration in mortality decline among the unskilled manual group was larger than that experienced by the professional group. In contrast, most other SEGs experienced a significantly smaller fall in mortality than the professional SEG over the period 1984-2008, but a relative acceleration in the rate of decline over that period. Analysis suggests that the rate of decline in SMR among the unskilled had already slowed down by the mid-1990s and actually began to rise again in the early 2000's leading to an increasing differential between this group and professional men whose SMR continued to fall across the period. There appears to have been no decrease in the SMRs of unskilled men associated with the structural change in mortality in 1999 identified by Layte et al (2011).

With analyses of this kind, there are inevitably data limitations. First, a common problem in many international studies is 'numerator-denominator' bias, which arises from the use of unlinked death record and Census of Population data. While there have been some attempts to quantify the possible extent of this problem in international analyses of mortality rates, future work will examine this issue in greater detail in the Irish context using the micro-data from the 2006 linked mortality-Census data file. Second, there are substantial proportions of observations with missing information on our main variable of interest, SEG. Again, this is a common problem in international analyses. As the exclusion of these observations from the analysis would result in the underestimation of socio-economic differentials in mortality, we adjusted the observed mortality rates to account for the presence of observations with missing information on SEG. To our knowledge, this is the first time that Bayesian methods have been used to re-allocate observations with missing information on SEG to alternative SEGs, and our analysis also allows us to compare the results using the various methods. With the exception of the imputation method, results were very similar across the various methods.

While the results provide initial evidence on socio-economic differentials in mortality for males aged 15+ years in Ireland over the period 1984-2008, the use of SEG (derived from information on occupation) to analyse socio-economic differences in mortality raises the issue of whether the same results would be observed with alternative socio-economic indicators. A number of studies have checked the robustness of their results using occupation with alternative measures of socio-economic position and have found largely consistent results (see for example, Kunst, et al., (1998)). Unfortunately, we cannot replicate our analysis with alternative indicators of socio-economic status as SEG is the only indicator collected during the death registration process in Ireland. However, when the linked 2006 mortality-Census micro-data become available, we will be able to test the robustness of our results (by examining socio-economic differentials in mortality using alternative indicators of socio-economic status such as education and social class that are available on the Census file). We can also extend this analysis to consider possible explanations for the trends in socio-economic differentials in mortality that we have observed. To inform this work, future analyses will consider the extent to which these trends differ by age, cause of death and household location. In this context, future work will attempt to unpick the mechanisms underlying these changes over time, e.g., change in prescribing behaviour (as suggested by Layte, et al., 2011).

FIGURES AND TABLES

Table 1: Socio-economic group (SEG) schema

Aggregated SEG	SEG Prior to 1996	SEG Post-1996
SEG1: Professional	Higher professional Lower professional	Higher professional Lower professional
SEG2: Employers and Managers	Self-employed (with employees) and managers	Employers and Managers
SEG3: Clerical and Administrative	Salaried employees Intermediate non-manual workers	Non-Manual Workers
SEG4: Skilled Manual	Other non-manual workers Skilled manual workers Semi-skilled manual workers	Manual Skilled Workers Semi-Skilled Workers Own Account Workers
SEG5: Unskilled	Unskilled manual workers	Unskilled Manual Workers
SEG6: Farming	Farmers, farmers' relatives, farm managers Other agricultural occupations and fishermen	Farmers Agricultural Workers
SEG7: Unknown	Unknown	All Others Gainfully Occupied and Unknown

Source: Adapted from CSO (1993).

Figure 1: Proportion of Deaths with 'Unknown' Socio-Economic Group By Sex

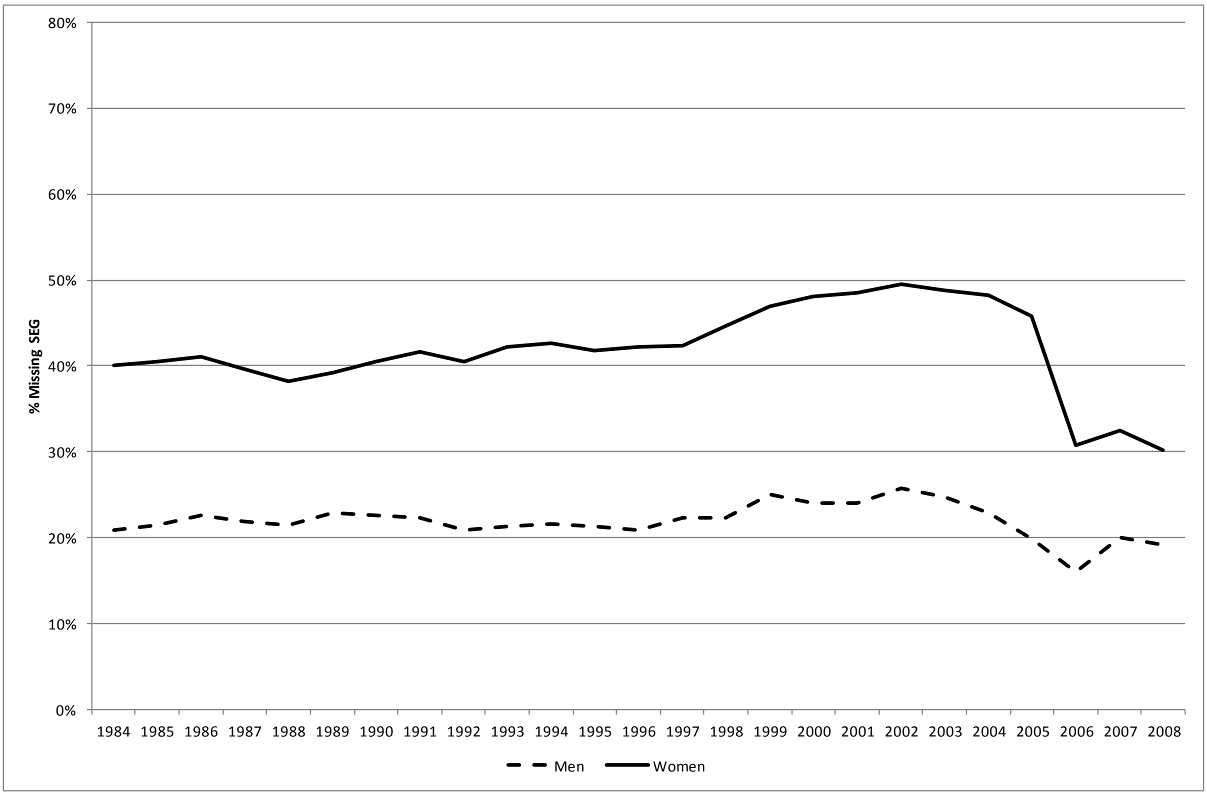

Figure 2: SMR 1984-2008 by Sex

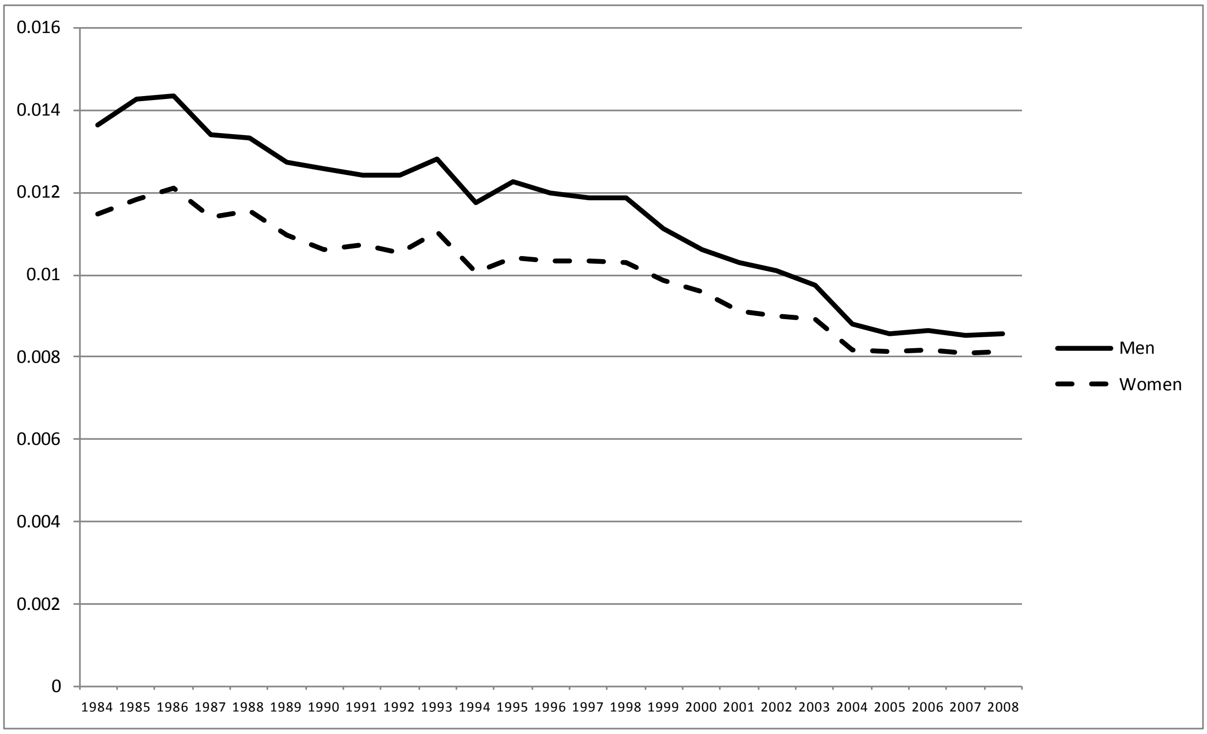

Figure 3: SMR for Men by Age Group 1984-2008

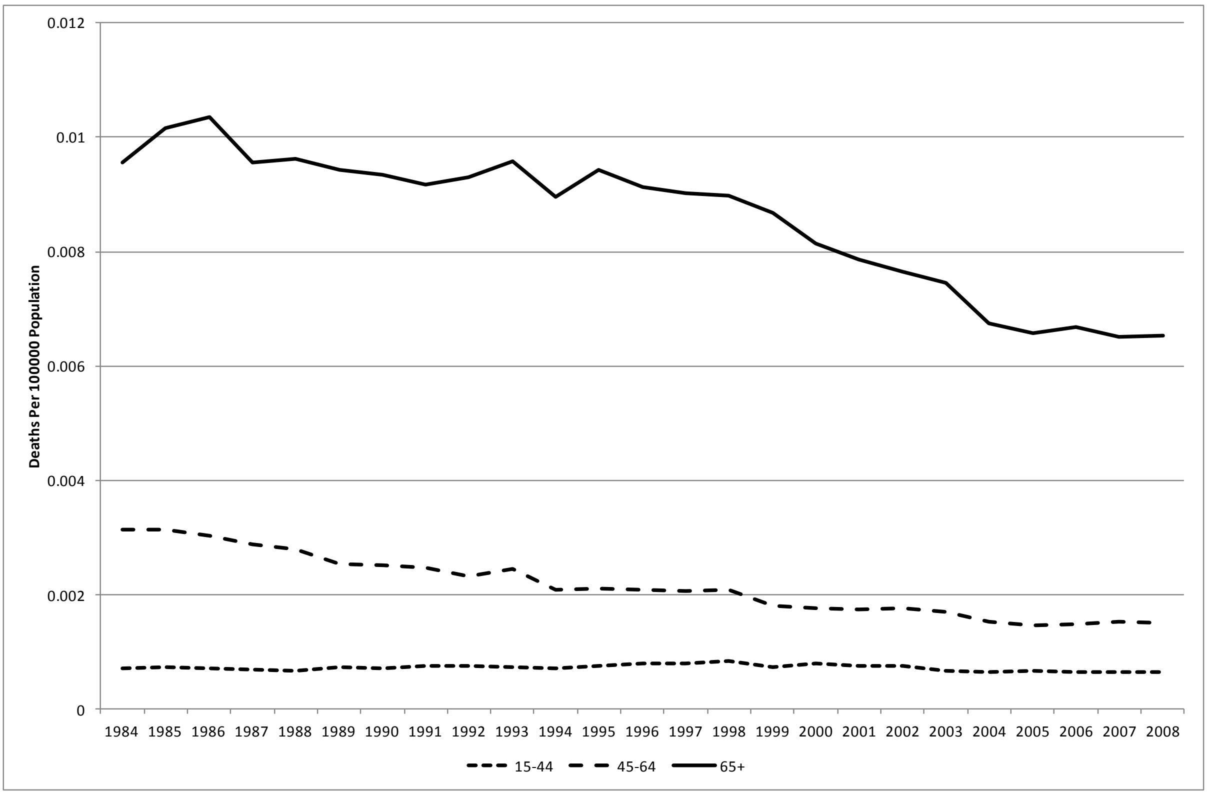

Figure 4: SMR for Men by Socio-Economic Group 1984-2008

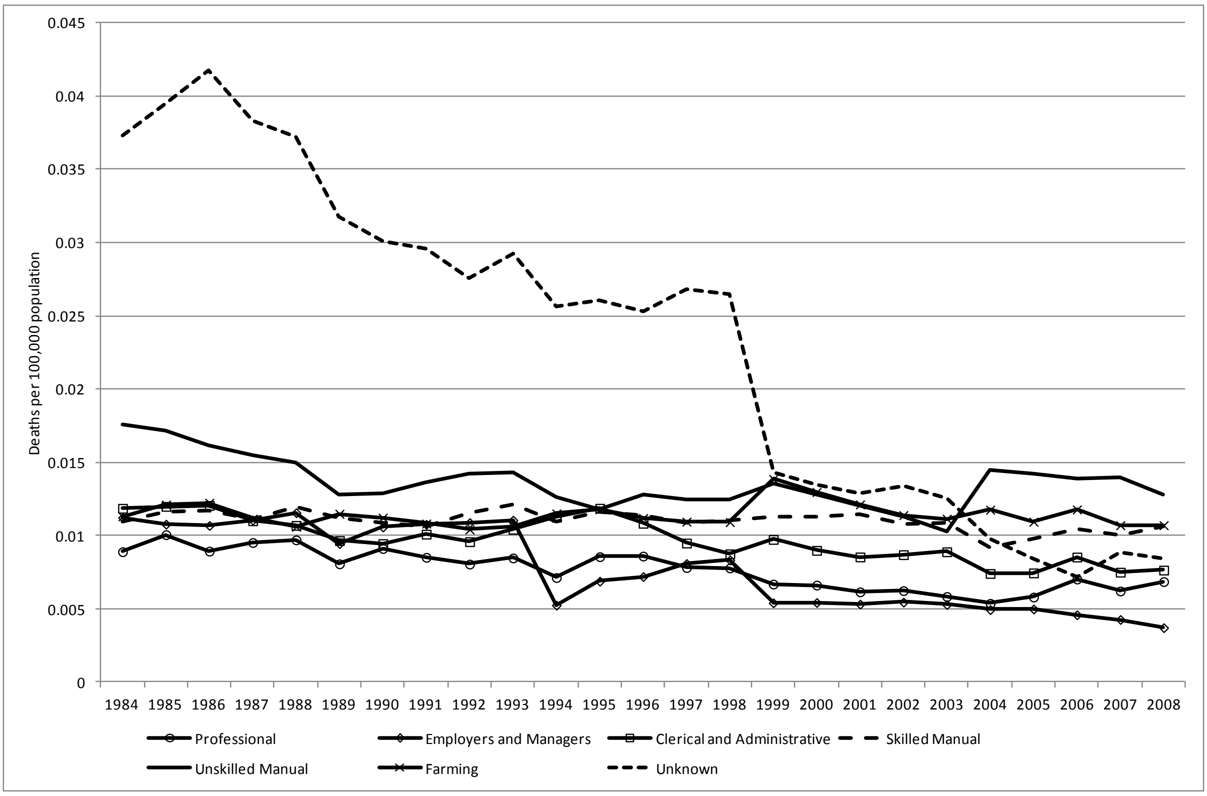

Figure 5: Observed Unadjusted SMR of Professional and Unskilled Manual Workers and Ratio of the Rates

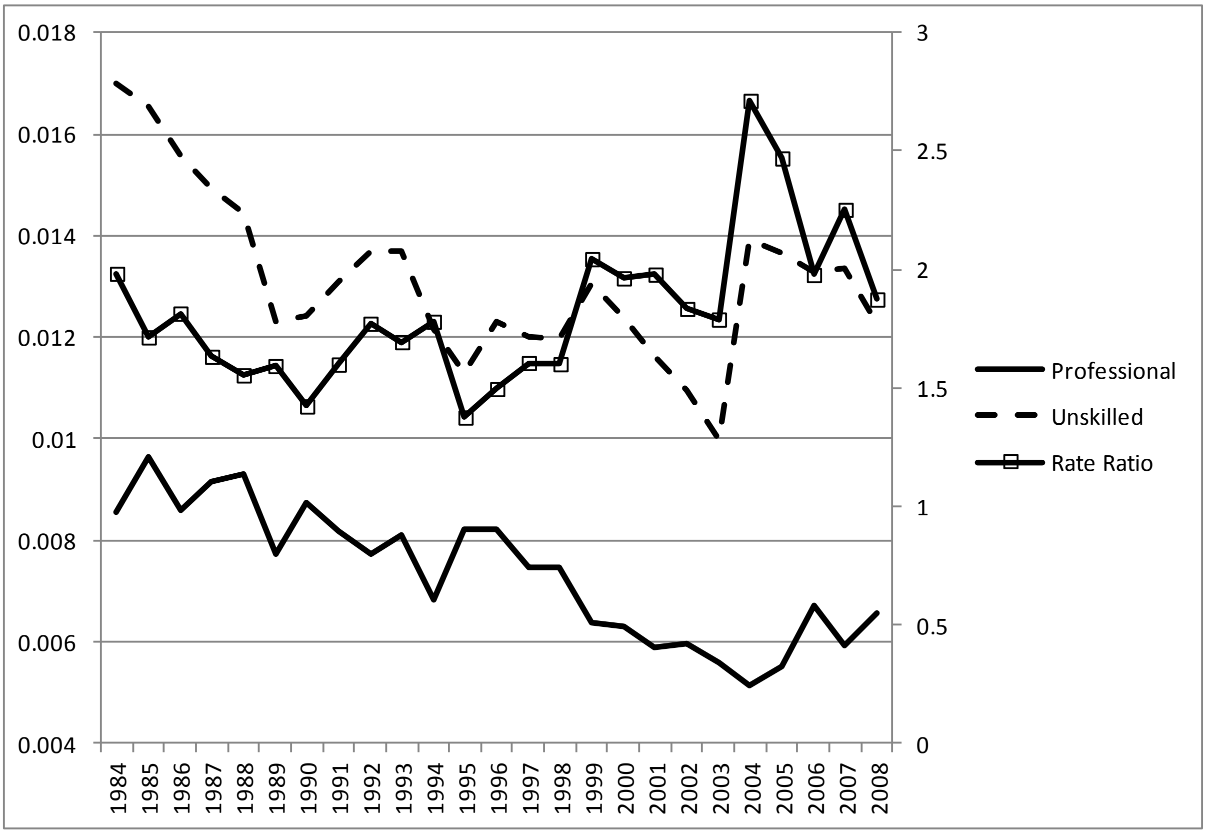

Figure 6: Predicted SMR of Professional Men 1984-2008

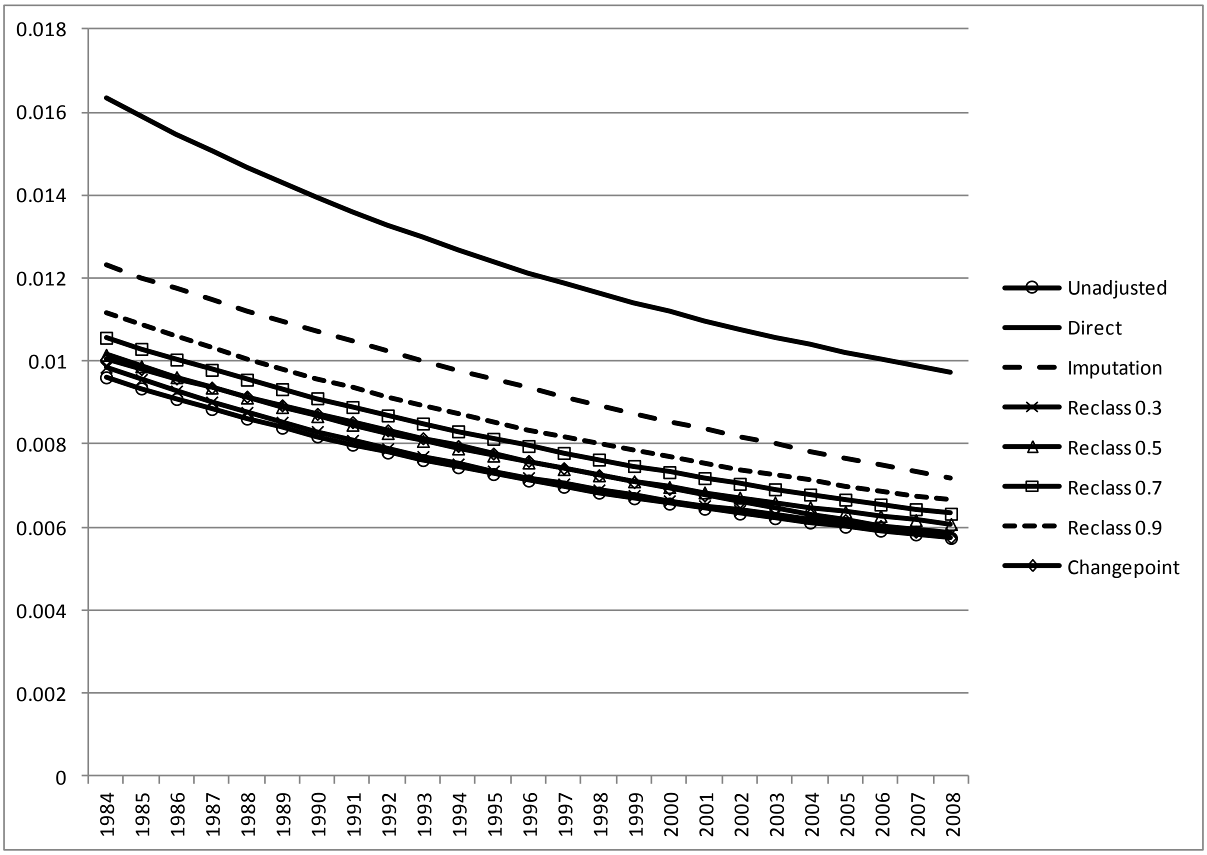

Figure 7: Predicted SRM of Unskilled Manual Men 1984-2008

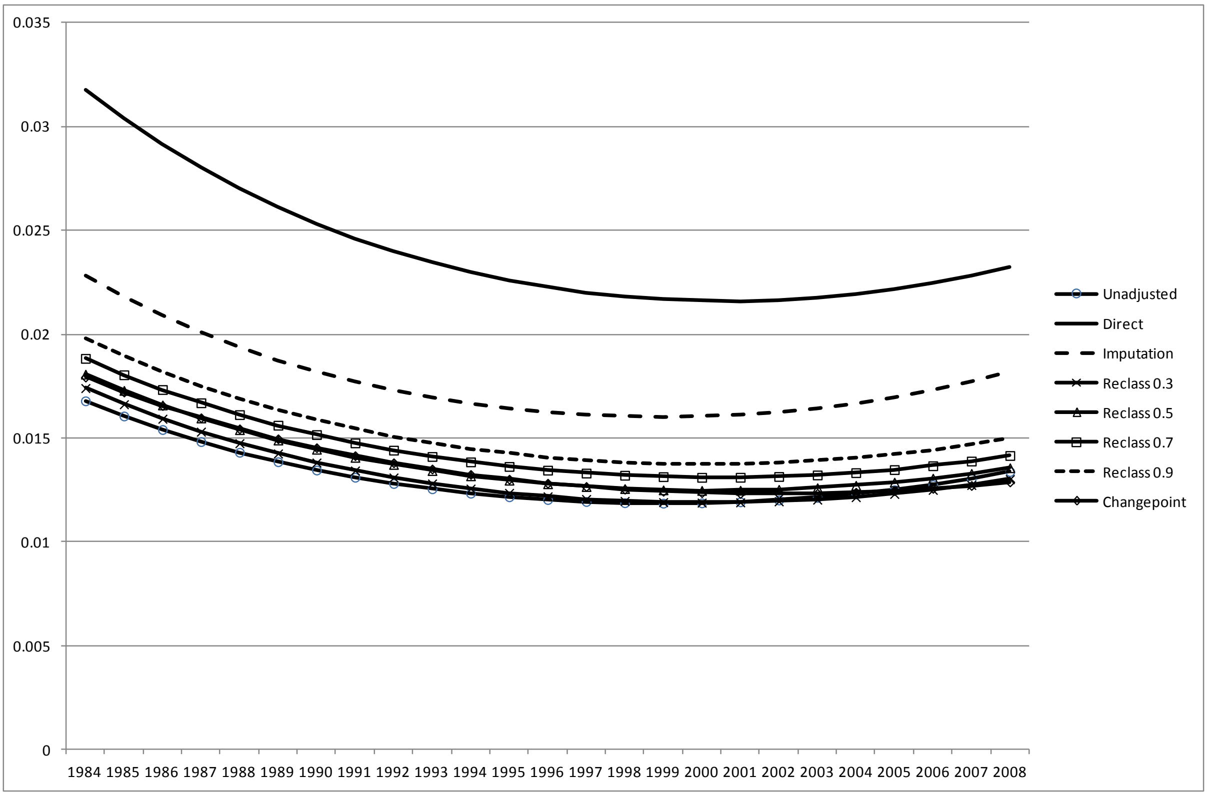

Figure 8: Predicted Rate Ratio of SMRs for Men (unskilled manual/professional) 1984-2008

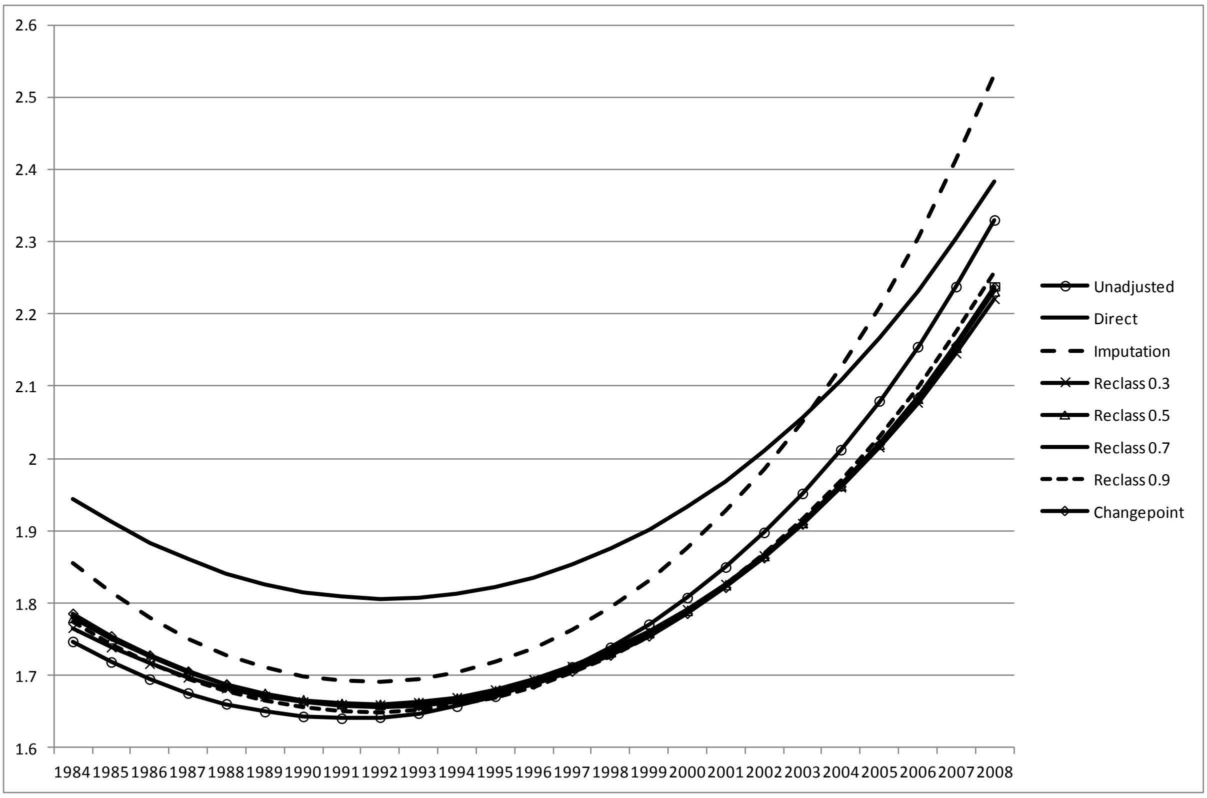

Table 2: Parameters, Significance and Standard Errors for Eight General Linear Models of Standardised Mortality 1984 to 2008 – Men Aged 15+

	Unadjust.	Direct Adjust.	FBA Reclass. 0.9	FBA Reclass. 0.7	FBA Reclass. 0.5	FBA Reclass. 0.3	FBA Change-point	Imputation
year	-0.029***	-0.029***	-0.027***	-0.026***	-0.028***	-0.032***	-0.023***	-0.023***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
$year^2$	0.000**	0.000***	0.000*	0.000	0.000**	0.000***	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SEG2	0.181***	0.184***	0.268***	0.248***	0.249***	0.246***	0.251***	0.164***
	(0.030)	(0.023)	(0.027)	(0.028)	(0.029)	(0.029)	(0.029)	(0.026)
SEG3	0.124***	0.144***	0.080***	0.083***	0.082***	0.070***	0.086***	0.149***
	(0.026)	(0.020)	(0.024)	(0.025)	(0.025)	(0.026)	(0.025)	(0.023)
SEG4	0.092***	0.151***	0.146***	0.166***	0.167***	0.156***	0.169***	0.115***
	(0.023)	(0.017)	(0.021)	(0.022)	(0.022)	(0.022)	(0.022)	(0.020)
SEG5	0.577***	0.684***	0.593***	0.597***	0.595***	0.586***	0.600***	0.643***
	(0.027)	(0.020)	(0.025)	(0.025)	(0.026)	(0.026)	(0.026)	(0.023)
SEG6	0.104***	0.117***	0.089***	0.111***	0.110***	0.100***	0.115***	0.005
	(0.025)	(0.019)	(0.023)	(0.024)	(0.024)	(0.024)	(0.024)	(0.022)
SEG2 * Year	-0.003	-0.003	-0.012**	-0.010**	-0.010**	-0.009*	-0.010**	0.001
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
SEG3 * Year	0.020***	0.020***	0.022***	0.022***	0.022***	0.024***	0.021***	0.021***
	(0.005)	(0.003)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
SEG4 * Year	0.033***	0.032***	0.026***	0.027***	0.027***	0.028***	0.026***	0.032***
	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
SEG5 * Year	-0.020***	-0.020***	-0.021***	-0.021***	-0.020***	-0.019***	-0.021***	-0.027***
	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.004)
SEG6 * Year	0.028***	0.028***	0.022***	0.022***	0.023***	0.025***	0.022***	0.028***
	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
SEG2 * $Year^2$	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SEG3 * $Year^2$	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***

	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SEG4 * Year^2	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SEG5 * Year^2	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SEG6 * Year^2	-0.000	-0.000**	0.000	0.000	0.000	0.000	0.000	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-4.616***	-4.085***	-4.469***	-4.524***	-4.562***	-4.588***	-4.577***	-4.375***
	(0.021)	(0.016)	(0.019)	(0.020)	(0.020)	(0.021)	(0.020)	(0.018)
Observations	31.478m	31.478m	31.478m	31.478m	31.478m	31.478m	31.478m	31.478m

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1 SEG1=Professional; SEG2=Employer and Manager; SEG3=Clerical and Administrative; SEG4=Skilled Manual; SEG5=Unskilled Manual; SEG6=Farming.

See Appendix for full description of the various adjustment methods.

APPENDIX 1: Change in Coding of Socio-Economic Group in CSO Census Data

Beginning in 1996, the population was classified to one of ten specific SEGs (introduced in 1996). In addition a residual group entitled "All others gainfully occupied and unknown" was used where sufficient details were not provided. The groups are as follows:

- A Employers and managers
- B Higher professional
- C Lower professional
- D Non-manual
- E Manual skilled
- F Semi-skilled
- G Unskilled
- H Own account workers
- I Farmers
- J Agricultural workers
- Z All others gainfully occupied and unknown

The classification aims to bring together persons with similar social and economic statuses on the basis of the level of skill or educational attainment required. Prior to 1996, the population was classified into 11 SEGs, plus a residual 'unknown' group. The groups were as follows:

- 0 Farmers, farmers' relatives and farm managers
- 1 Other agricultural occupations and fishermen
- 2 Higher professional
- 3 Lower professional
- 4 Self-employed (with employees) and managers
- 5 Salaried employees
- 6 Intermediate non-manual workers
- 7 Other non-manual workers
- 8 Skilled manual workers
- 9 Semi-skilled manual workers
- X Unskilled manual workers
- Y Unknown (CSO 1993; CSO 2012)

APPENDIX 2: Incorporating observations with missing socio-economic group into the analysis

Rubin 1987 (Rubin 1987) has identified three potential patterns of missing data:

- Missing completely at random (MCAR)
- Missing at random (MAR)
- Missing not at random (MNAR)

Data are said to be MCAR if the probability that the case is missing is unrelated to its value or that of any other of the variables in the analysis. Here, MCAR would entail that the value of missing SEGs do not depend on the true value of the SEG (i.e. unskilled manual SEGs are no more likely to be missing than professional SEGs) or other variables such as the year of death. If MCAR could be assumed we would be able to delete the missing cases from the analysis and the results would not be biased. As shown by Figure 1, this assumption does not seem tenable since the extent of missing varies by sex and year at least.

MAR defines a situation where the probability of 'missingness' does not depend on the true value of the missing variable but may depend on the values of other variables in the model. For example, MAR in our data would imply that the probability of missing does not depend on the true value of SEG but may depend on the value of other variables such as age and year. If the assumption held, we would be able to correct for this missing information using several possible methods. One approach is the reweighting of the observed distribution of SEGs to match a distribution in the true population. A second approach would be to use an indirect adjustment approach where distribution of observed independent variables is used to adjust the mortality rates of the non-missing SEGs. Kunst et al (1998) have described such a process based on the proportion of 'inactive' individuals (see below). A third approach would be the imputation of missing SEGs based upon the observed relationship between non-missing SEG groups and other variables in the data. A model of these relationships would provide a set of parameters from which the true value of missing SEGs could be estimated.

Examination of the incidence of missing male SEGs by year (see Figure 1a) suggests that there is an increase in the proportion of deaths among some SEG groups after 2002 that may be related to the fall in the proportion of 'unknown' or missing SEGs (this is particularly pronounced among the skilled manual) but the relationship is unclear and statistical tests suggest that it is weak. Given this it is not possible to reject MAR.

MNAR occurs where neither MCAR or MAR holds, that is, that the true value of the missing value itself may be associated with the probability of being missing. In this situation it is not possible to use other information in the data to predict the value of the missing SEG and thus the missing data mechanism itself becomes informative and must be modelled. This can be achieved using a 'fully-Baysian' approach to modelling the missing data process.

Our inability to reject the MAR assumption means that any of the three approaches above could be used. However, no data are available on the true distribution of SEGs for Irish death records which rules out a simple reweighting approach. Given this, we adopt the indirect adjustment approach of Kunst and colleagues (Kunst 1998) and a multiple imputation approach. The likely possibility of MNAR means that we also adopt a fully Baysian approach. Detail on all three approaches is given below.

The Indirect Adjustment of Mortality Rates

First, following Kunst 1998 (Kunst, et al., 1998), we calculate adjustment factors for the SMRs of those with complete information on SEG to take account of differential missing information. Analysis of the pattern of missing SEGs shows that those records with a missing SEG are significantly more likely to be economically inactive and that inactive groups also tend to have higher SMRs. Kunst et al 1998 developed a method which combines information on the proportion of each group inactive from external sources with information from within the data on SMRs among the inactive to create an adjustment factor. The adjustment factor for SEG x is calculated thus:

$$=1 + P_x^{inactive} *(RRx^{inactive/active} -1)$$

Where $P_x^{inactive}$ represents the proportion of the population in each SEG who are inactive and $RR_x^{inactive/active}$ represents the mortality rate ratio of active and inactive groups ($rate_x^{inactive}/rate_x^{active}$).

Multiple Imputation of Missing SEGs

Second, using regression analysis, we directly impute SEG for those that are missing such information (see Williams, et al., 2006, for example). In other words, we re-allocate those with missing information on SEG to one of the six SEGs, using the information within the death registration data to carry out the imputation. To impute the missing SEG information we model the relationship between a polytomous dependent variable with categories *q* and a set of *k* predictor variables (*x*1, *x*2,….*x*k), which are either categorical or continuous:

$$\log\left(\frac{\mathrm{Prob(cat\ j)}}{\mathrm{Prob(cat\ q)}}\right) = \beta_0^{(j)} + \sum_{i=1}^{k} \beta_i^{(j)} x_i, j = 1, \dots, q-1$$

Here, the logit of q - 1 categories of SEG is estimated as a linear function of an intercept, β_0 plus a set of predictor variables, *X*i. The model is estimated using maximum likelihood and produces a set of predicted probabilities for q – 1 categories for each case, the highest of which represents the most probable value of SEG given the other observed characteristics of the case.

A Fully Baysian Approach

Bayesian methodology naturally provides a framework for dealing with a missing data problem where the probability of being missing is associated with the true value of the variable. In analysis of data with missing values a joint model is built comprising a model of interest and one or more models to describe the 'missingness' mechanism. Estimation of the joint model is made through use of Markov-Chain Monte-Carlo (MCMC) methods to sample from the posterior distribution. If the data is partitioned into observed and missing data the joint model can be represented as follows:

$f(z(obs), z(mis), m \mid \beta, \theta) = f(m \mid z(obs), z(mis), \theta)\, f(z(obs), z(mis) \mid \beta)$

- Here $f(m \mid z(obs), z(mis), \theta)$ is the model of the missing data mechanism.
- While $f(z(obs), z(mis) \mid \beta)$ is the analysis model.
- β and θ are vectors of unknown parameters for which priors are provided.

With this approach, realistic (informed) assumptions about the mechanism of missingness (or equivalently mislabelling) can be incorporated into the model and the sensitivity of the results of the analysis on assumptions made can be examined. Also uncertainty about imputed values is fully propagated through the model and is reflected in estimates for parameters, whereas results from other approaches fail to reflect this inherent uncertainty.

We estimate five different Baysian models, each of which represents an assumption about the nature of the missing data mechanism. Each combines a multinomial logit model which estimates parameters for the effect of year, sex and age group on the probability of the case being in one of five SEGs (one being the reference category) with a different model of the missingness mechanism. An initial model assuming that discrepancies between the numbers of deaths in each group and the population counts proved a poor fit. Given this, four models assumed that the distribution of deaths should approximate that of the census data (conditional on year, sex, age group and SEG). The model then reallocated different proportions (0.9, 0.7, 0.5, 0.3) of the 'unknown' SEGs across the six known SEGs using the estimated probabilities of the underlying model. These models are referred to as reclassification models.

A fifth model assumed that the pattern of 'unknown' SEGs was a function of time. Here the model for the missingness mechanism assumed that the pronounced fall in known cases after 2004 (see Figure 1) means that this period has little or no mislabeling problem. Based on this assumption a probability of reallocation of 0.4 using the parameter estimates from the model is used prior to 2005 and zero thereafter.

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