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Socio-economic 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 has long been a "stylized fact" of demography. 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 last analysis of Irish adult mortality differentials across social classes, carried out by the Central Statistics Office (CSO) and based on data for 2006, found that men in the unskilled manual social class had an 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 missing or "unknown" occupation/socio-economic group (SEG). Using annual mortality data from the CSO over the period 1984-2008, a period of economic recovery and boom, this paper examines whether the general downward trend in mortality observed over this period was experienced equally by all SEGs. We find that the SMR for all groups fell between the 1980s and 2000s but that the extent of this fall was largest for Employer and Manager and Professional SEGs leading to a growing differential between these groups and all others.

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I INTRODUCTION

The presence of pronounced inequalities in mortality and life expectancy across income, education and social groups has been long accepted as an important demographic "stylized fact". 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 last 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.*, 2001; O'Shea, 1997; O'Shea, 2002). Analyses of trends across time were not possible due to the increasing proportion of cases where socio-economic group was missing from the early 1980s onward. Although it has not yet been possible to identify differential trends in mortality rates between social groups, data show that Ireland's overall mortality rate has fallen significantly and consistently over the last three decades. Published data from the CSO show that the standardised mortality rate per 1,000 population (all ages) between 1981 and 1990 was 10.01 for men and 8.42 for women; by 1995 this had fallen to 9.55 and 8.38 and by 2010 it was 6.34 and 5.94, a fall of almost 37 per cent for men and 30 per cent for women across the period. In particular there appears to been a structural change in death rates after the mid-1990s resulting from a number of factors including increased spending and efficiency in health care (Layte *et al*., 2011), improved environmental conditions (such as air pollution and quality of housing) and the dramatic reduction in the incidence of poverty and unemployment (Walsh, 2008).

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), although 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 GDP per capita was 12 per cent below the OECD average but was

22 per cent above average by 2003 (Maître 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 acceptance of 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). However, the impact of this crisis on public health would not be reflected in the data used in the present paper, which end in 2008. In the initial period of the economic crisis, the Gini coefficient fell (falling to 0.29 in 2009). However, the Gini coefficient has since increased to a level similar to that seen during the boom (Calvert *et al.*, 2013). The Irish experience of economic change in the 1990s and early twenty-first century may well have had 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 yet been an examination of the behaviour of these differentials 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). Our analysis covers a period of strong economic recovery from the recession of the 1980s and the supercharged "Celtic Tiger" period of the early twenty-first century. It ends before any impact of the crash and subsequent Great Recession could be apparent in the mortality data. As already noted, research on mortality differentials across SEGs in Ireland is complicated by methodological difficulties generated by incomplete occupational classification of the data on deaths which are not linked to the underlying population (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 II. Section III describes our data and methodological approach. Section IV presents empirical results, while Section V discusses the results and outlines a number of areas that merit further research.

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

II PREVIOUS LITERATURE

A large number of research papers over the last three decades have examined socio-economic inequalities in mortality outside Ireland (Benzeval *et al.*, 1995; Blane *et al.*, 1990; Kunst *et al.*, 1996; Mackenbach *et al.*, 2003; Mackenbach *et al.*, 1997; Marmot *et al.*, 1991; 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) based on data from the 1980s 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 and more recent papers have confirmed that this general pattern has not changed (Mackenbach *et al.*, 2014).

Evidence for Ireland also shows substantial inequalities across social groups. Nolan (1990) examined male mortality differentials using national data from 1981. The results revealed substantial differences in mortality across SEGs. For example, men in the unskilled manual SEG 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 were hampered by the fact that the proportion of death certificates of missing or "unknown" SEG had increased between 1981 and 1991 from 13 per cent to 19 per cent (even though the ratio of the "unknown" population to the total population in the Census 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 examined trends in SMRs for men aged 15-64 years in the census years over the period 1981-1996. For all causes and for deaths from ischaemic heart disease, the socio-economic differentials in mortality declined over time but the authors 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 no conclusions about trends over time could be inferred except by comparison with earlier studies. In addition, no attempt was made to incorporate those with missing social class into the analysis.

As noted, the 1990s and early- to mid-2000s in Ireland were characterised by rapid economic growth in average incomes (Maître and Nolan, 2007; Calvert *et al.*, 2013). Research suggests that 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 in the 1990s (Walsh, 2008). 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 may 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 has had on socio-economic inequalities in mortality in Ireland but it is often the case that more advantaged population groups gain more when provision of 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" (Asthana and Gibson, 2008; Tudor Hart, 1971; Watt, 2002). Applied to Ireland, the inverse care law would predict that the expansion of free pharmaceuticals to the older population in the late 1990s might have increased differentials between social groups as the more affluent gained free access whilst the position of the less affluent remained the same.

Research outside Ireland has shown that socio-economic differentials in mortality have increased over time. 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 only]). They found a widening gap between social groups (classified by both education and occupation), largely due to a faster proportional mortality decline among the higher social 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).

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

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 across countries from approximately 1.18 to 1.60 and for males aged 45-59 from approximately 1.10 to 1.65. 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.

In addition, individual country studies have also found widening socio-economic inequalities in mortality over time. In France, Leclerc *et al.* (2006) found a significant increase in socio-economic mortality differentials for both men and women aged 30-64 over the period 1968-1996. 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. 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. Data for Australia over the period 1981-2002 show that while there was little change in the ratio of manual to non-manual death rates for males aged 25-59 years up to 1998, there was some evidence of widening inequality from 1998 (Williams *et al.*, 2006). Similarly in Germany, Kibele *et al.* (2013) found that relative socio-economic differences in mortality 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 not included). They found that, contrary to their initial hypothesis,[5] inequalities in mortality from amenable causes were not strongly

[4] The time period covered varied by country.

[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.

associated with inequalities in health care use. Education was used as the indicator of socio-economic status. 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. 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.

III 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 found in many 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 compare SEG mortality differentials among males over time from the 1980s to the 2000s. 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 population. However, mortality rates are strongly age-related, so when comparing trends over time 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.

3.1 *Population Denominators*

Calculation of CDRs and SMRs requires data on the numerator (deaths) and denominator (population). Here, 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

[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.

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. Denominator information on socio-economic group was coded to a different coding scheme from 1996 onwards 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. In the absence of the information required for a social class scheme, this project uses SEGs as the basis of our comparisons. The CSO could provide us with a contingency table of the new and old SEGs for Census 1991 and this was used to develop a new six group schema that could be used in a consistent fashion across years. By collapsing SEG groups it was possible both to ensure consistency across years whilst also producing larger groups for whom SMRs would be more stable. The new schema and its relationship to the existing SEGs is given in Table 1 and includes professionals, employers and managers, clerical and administrative, manual and farming SEGs. To aid the comparison of death rates across decades and achieve more stable estimates, year of death was also grouped into three categories; 1980s (1984-1989), 1990s (1990-1999) and 2000s (2000-2008). There is a legitimate concern that the change in denominator coding in the 1990s may have produced a discontinuity in the data series. Figure 1 gives the proportion in each collapsed SEG group for men between 1984 and 2008 and shows that there is no abrupt change after 1996.

3.2 *Population Numerators*

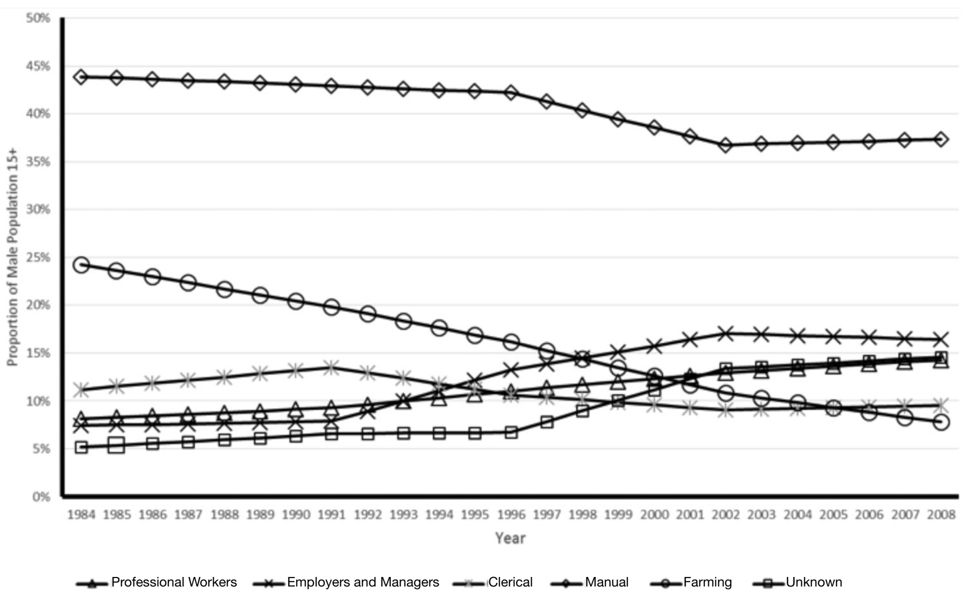
Information on the numerator, i.e., death counts, is available from the death certificate records administered by the CSO. Information on date of death, age (in years), sex, principal economic status (i.e., at work, retired, *etc*.), SEG, area of registration and cause of death for every death that occurred in Ireland over the period 1 January 1984–31 December 2008 were made available to the authors. SEG refers to the 12-category 1986 SEG schema employed by the CSO, based on occupation. Children under 15 years of age are classified under the occupation of their parent or guardian, retired individuals are classified under their former occupation and married or widowed women may be classified under

[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 *et al.*, 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.

Table 1: *Socio-economic Group (SEG) Schema*

SEG Groups Used for Analysis	*SEG Prior to 1996*	*SEG Post-1996*
Professional	Higher Professional Lower Professional	Higher Professional Lower Professional
Employers and Managers	Self-employed (with Employees) and Managers	Employers and Managers
Clerical and Administrative	Salaried Employees Intermediate Non-manual Workers	Non-Manual Workers
Manual	Unskilled Manual Workers	Manual Skilled Workers Semi-Skilled Workers Own Account Workers Unskilled Manual Workers
Farming	Farmers, Farmers' Relatives, Farm Managers Other Agricultural Occupations and Fishermen	Farmers Agricultural Workers
Unknown	Unknown	All Others Gainfully Occupied and Unknown

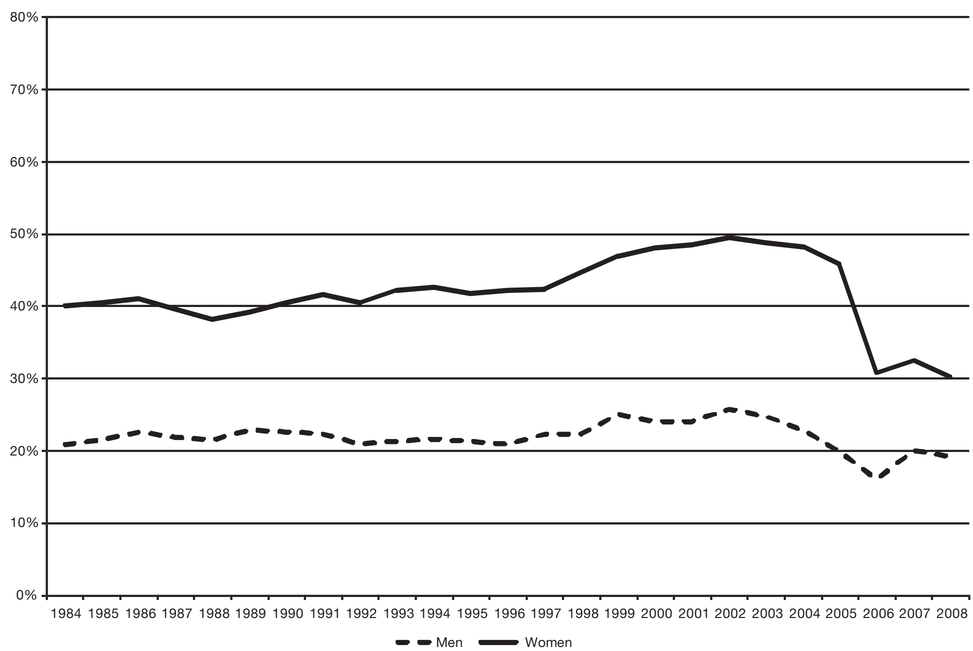
Figure 1: *Distribution of Collapsed SEG Groups from 1984 to 2008*



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 International Classification of Diseases (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 2. The proportion of "unknowns" is much higher for women than for men in every year, due perhaps to the larger proportion of women who were not in paid work at death and for whom a previous occupation could not be given. 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 men and women, 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 (see Figure 2). We have little information on whether the increase in missing SEGs from 1996 stemmed from a deterioration in the 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. Analysis shows that coding performance across registry offices varied

Figure 2: *Proportion of Deaths with "Unknown" Socio-Economic Group By Sex*



significantly which would suggest that worse coding in registry offices was partly to blame. However, it also appears that coding procedures did change at the CSO in 1996 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 the proportion of "unknown" or missing SEGs varied significantly and that this presents a potentially very serious 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.*, 2001; Nolan, 1990; O'Shea, 1997; O'Shea, 2002). This problem is not unique to Ireland although the scale of problem is greater for 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 approaches 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:

- Direct 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.

3.3 *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 reported 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 *et al.*, (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.[8] Future work will investigate the extent of this problem in the Irish context using linked death register and Census data for 2006.[9]

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 calculated SMRs. Several summary measures are available to assess the magnitude of mortality differences by SEG. We provide analyses 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, e.g. the ratio of the SMRs of the different SEGs.

To examine whether the rate ratios in death rates between groups are significant and whether there are trends in these over time we employ grouped logit models which estimate the log of the number dying in a given (age, year, SEG) group divided by the proportion not dying in that group. We estimate models for each of our adjustment methods and fit terms for the decade of the death, the SEG of the person and the interaction of the two. The sign and size of the interaction terms are a test of whether the rate ratio between SEGs is stable or increasing/decreasing over time. To adjust for the differential

[8] 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 discusses the bias associated with the use of unlinked mortality and Census data in New Zealand.

[9] The authors have a pending request for access to the micro-data from the linked Census – mortality file for 2006. (CSO, 2010).

distribution of age across SEG and how this may change over time, terms for age group and the interaction of age group with decade are fitted to the models but not shown in the results.

IV EMPIRICAL RESULTS

As noted, overall mortality rates in Ireland fell over the period of this study. Figure 3 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 beyond the confines of the present paper.

Overall trends in mortality can disguise considerable variation among more disaggregated population groups. Figure 4 presents SMRs for men by three broad age groups (15-44 years, 45-64 years and 65+ years). For all age groups, 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

Figure 3: *Standardised Mortality Rate by Sex 1984-2008*

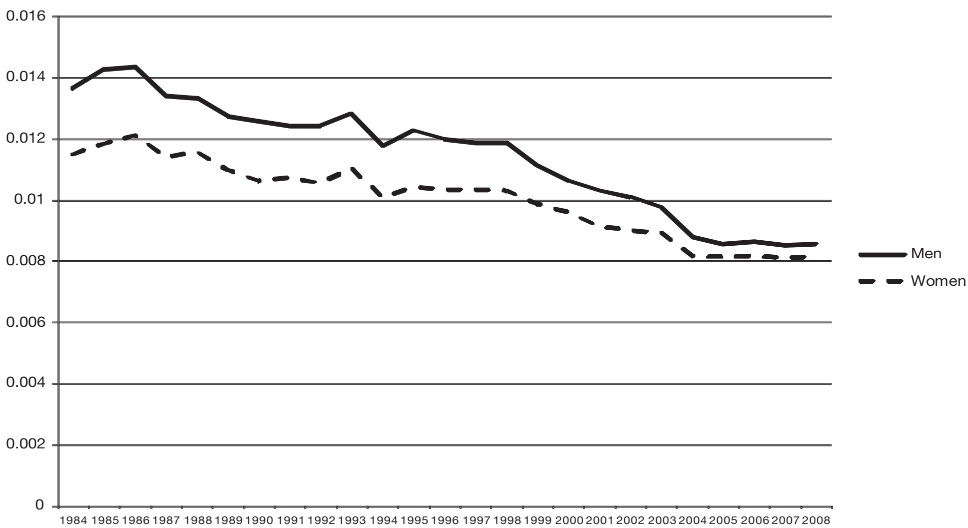
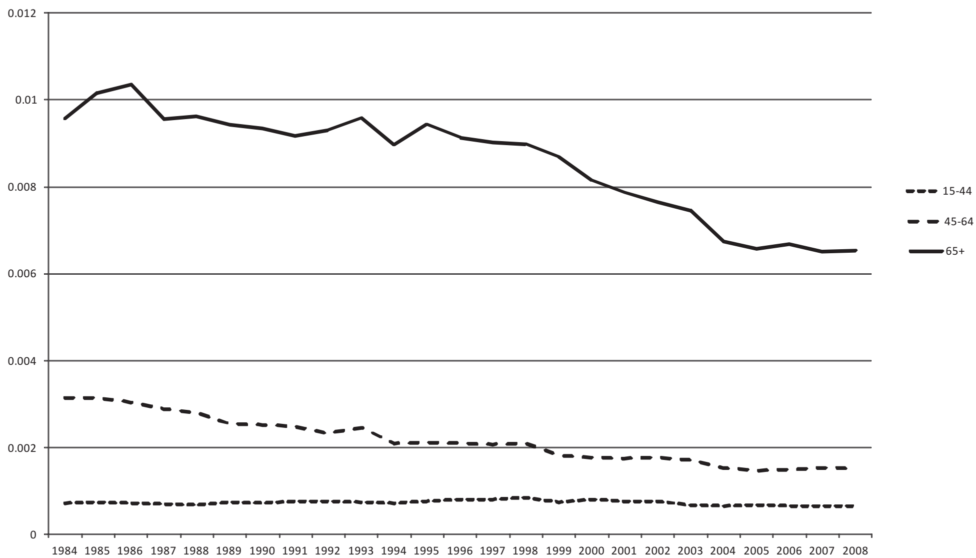


Figure 4: *SMR for Men by Age Group 1984-2008*



decline after 1999 identified in previous research (Layte, 2011) is evident, with the structural break most pronounced for men aged 65+.

Table 2 gives the standardised mortality rate (SMR) (i.e. standardised for distribution across the age groups) and the standardised rate ratio (SRR) (i.e. the ratio of the standardised mortality rate for manual groups relative to professional) by adjustment method for men aged 15+ over the decades 1980s, 1990s and 2000s. This shows that there is a gradient in death rate across SEGs for each of the adjustment methods with professionals generally having the lowest rate and manual workers the highest rate. On closer inspection, however, Professionals have lower mortality rates than Employers and Managers for all adjustment methods but only in the 1980s, as shown by the rate ratio larger than unity. In the 1990s and 2000s Employers and Managers have lower mortality rates than Professionals except when using the direct adjustment methods where the reversal in position does not occur until the 2000s.

Across SEGs and adjustment methods we see absolute falls in the SMR in the 1990s and 2000s compared to the 1980s. The absolute decrease in SMR (proportionate fall) is largest in both time periods for the Employer and Manager SEG followed by that for the Professional SEG. The average fall in absolute SMR across time periods is smallest among the Farming SEG followed by the manual SEG. These relative differences in absolute mortality trends mean that the rate ratio relative to the Professional SEG increases for all groups except for Employers and Managers in both the 1990s and 2000s.

Table 2: *Standardised Mortality Rate and Rate Ratio (with Professional) of Men Aged 15+ by Adjustment Method and Period*

	Standardised Mortality Rate			*Standardised Rate Ratio*		
	1980s	*1990s*	*2000s*	*1980s*	*1990s*	*2000s*
			Unadjusted			
Professional	878.4	754.4	595.4	1.00	1.00	1.00
Employer and Managers	1026.2	726.9	464.2	1.17	0.96	0.78
Clerical	1050.8	978.4	779.1	1.20	1.30	1.31
Manual	1196.2	1127.6	1042.8	1.36	1.49	1.75
Farming	1101.6	1080.4	1103.5	1.25	1.43	1.85
			Direct Adjustment			
Professional	899.9	775.6	604.7	1.00	1.00	1.00
Employer and Managers	1095.5	777.2	479.3	1.22	1.00	0.79
Clerical	1236.8	1136.9	827.1	1.37	1.47	1.37
Manual	1594.1	1439.9	1164.1	1.77	1.86	1.93
Farming	1153.4	1129.7	1131.5	1.28	1.46	1.87
			Imputed			
Professional	1137.7	978.1	767.3	1.00	1.00	1.00
Employer and Managers	1317.7	943.8	599.3	1.16	0.96	0.78
Clerical	1405.1	1308.6	1060.0	1.24	1.34	1.38
Manual	1586.5	1478.6	1378.3	1.39	1.51	1.80
Farming	1309.0	1281.9	1275.9	1.15	1.31	1.66
			Bayesian Estimate with 30% Reclassification			
Professional	952.5	830.3	674.1	1.00	1.00	1.00
Employer and Managers	1099.4	802.4	542.7	1.15	0.97	0.81
Clerical	1127.9	1055.6	855.8	1.18	1.27	1.27
Manual	1275.3	1206.8	1122.1	1.34	1.45	1.66
Farming	1180.5	1158.3	1178.1	1.24	1.40	1.75
			Bayesian Estimate with 50% Reclassification			
Professional	1007.3	884.8	728.0	1.00	1.00	1.00
Employer and Managers	1152.9	858.2	597.3	1.14	0.97	0.82
Clerical	1183.4	1110.5	910.0	1.17	1.26	1.25
Manual	1330.1	1261.3	1176.7	1.32	1.43	1.62
Farming	1234.9	1213.5	1233.1	1.23	1.37	1.69
			Bayesian Estimate with 70% Reclassification			
Professional	1062.1	939.4	782.3	1.00	1.00	1.00
Employer and Managers	1208.0	912.5	651.9	1.14	0.97	0.83
Clerical	1236.5	1164.4	965.8	1.02	1.28	1.48
Manual	1384.0	1315.3	1230.9	1.12	1.13	1.27
Farming	1288.6	1267.1	1288.4	0.93	0.96	1.05

Table 2: *Standardised Mortality Rate and Rate Ratio (with Professional) of Men Aged 15+ by Adjustment Method and Period (Contd.)*

	Standardised Mortality Rate			*Standardised Rate Ratio*		
	1980s	*1990s*	*2000s*	*1980s*	*1990s*	*2000s*
	Bayesian Estimate with 90% Reclassification					
Professional	1116.1	994.1	836.6	1.00	1.00	1.00
Employer and Managers	1260.7	966.7	706.3	1.13	0.97	0.84
Clerical	1291.0	1218.6	1019.4	1.16	1.23	1.22
Manual	1438.7	1370.2	1285.4	1.29	1.38	1.54
Farming	1343.7	1321.6	1341.6	1.20	1.33	1.60
	Bayesian Estimate with Period Change & 40% Reclassification					
Professional	878.4	754.4	645.2	1.00	1.00	1.00
Employer and Managers	1026.2	726.9	512.0	1.17	0.96	0.79
Clerical	1050.8	978.4	828.5	1.20	1.30	1.28
Manual	1196.2	1127.6	1092.0	1.36	1.49	1.69
Farming	1101.6	1080.4	1144.8	1.25	1.43	1.77

Figure 5 presents the SMRs for Professional men using the different adjustment processes. This shows that making no adjustment for the missing SEGs yields the lowest estimate of Professional SMRs followed by direct imputation method and the fully Baysian methods (FBM) using a temporal breakpoint. On the other hand, the FBM method reclassifying 90 per cent of cases produces the highest estimate of Professional SEG mortality although there is substantial cross-over with the imputed line. The extent of the downward trend in SMRs varies little by method however, except that the imputed estimate decreases more strongly in the 1990s and 2000s whilst the FBM estimate with temporal breakpoint takes a shallower trajectory in the 2000s.

Figure 6 provides similar estimates for the manual SEG group. It too shows that the unadjusted method yields the lowest estimate of SMR followed by the fully FBM with temporal changepoint. Again, as found for the professional group the imputed method and FBM with 90 per cent reclassification produce the highest estimates. However, unlike the estimates for professionals, where the direct adjustment approach yielded a lower estimate, here that method produces one of the highest, for the 1980s and 1990s at least.

In the 2000s, the directly adjusted estimate falls more steeply than those using other adjustment processes. Apart from the method using direct adjustment, what is clear is that the downward trajectory of lines for the Manual SEG is shallower than that found for the Professional SEG. The

Figure 5: *SMR of Professional Men by Adjustment Method and Period*

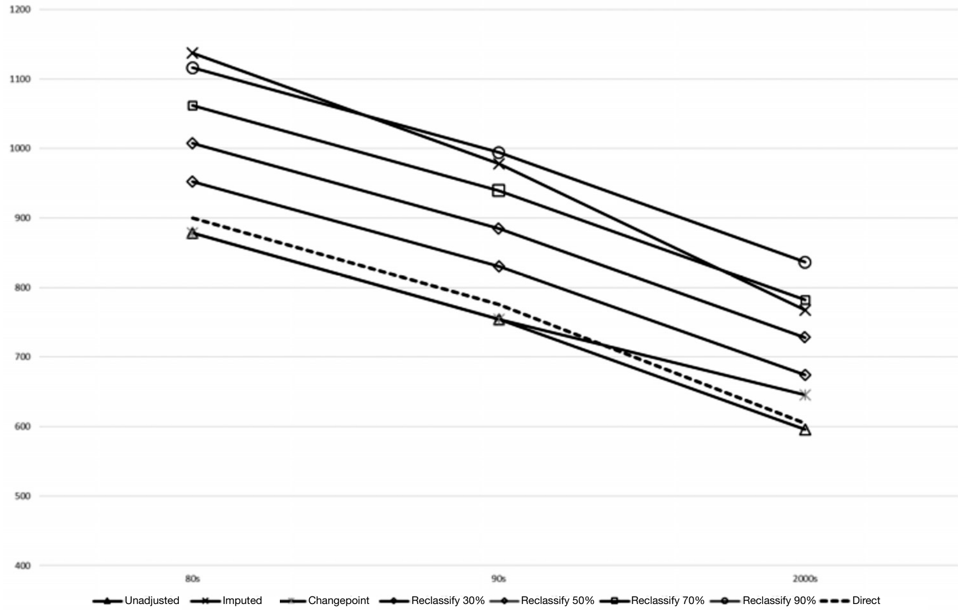
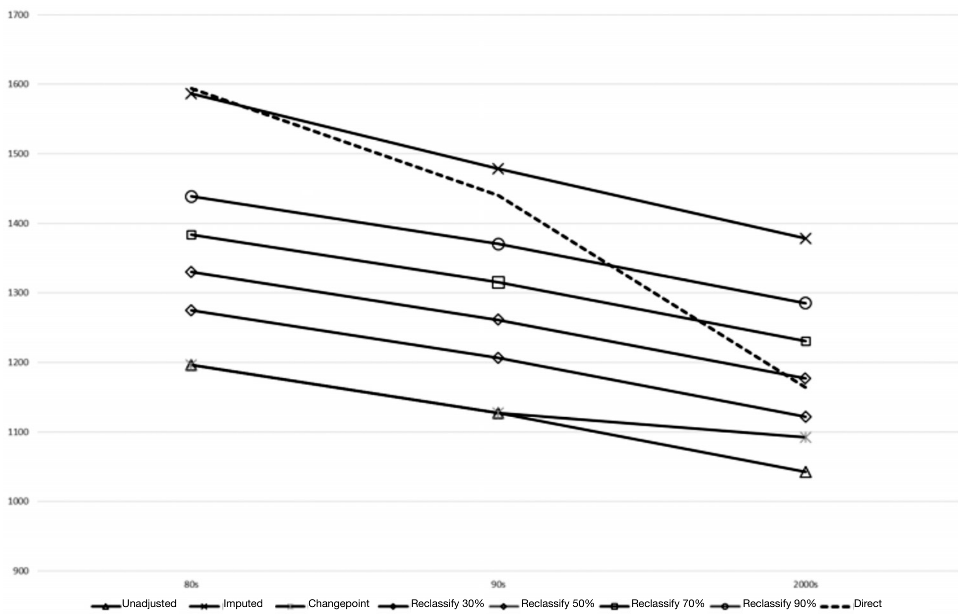
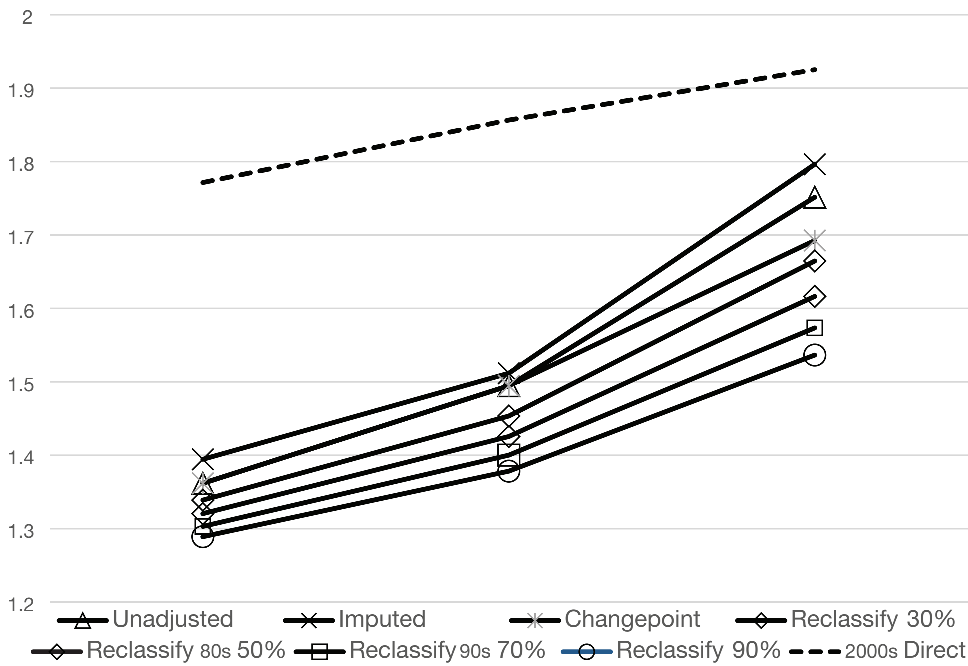


Figure 6: *SMR of Manual Men by Adjustment Method and Period*



differential in downward trajectories means that the rate ratio of the two SEG groups gets larger over the decades as shown in Figure 7 (except for the ratio based on direct adjustment) with rate ratios varying from 1.53 (using the FBM with 90 per cent reclassification) to 1.93 (using direct adjustment) in the 1990s.

Figure 7: *Ratio of the Rates Professional and Unskilled Manual Workers by Adjustment Method*



We test for the significance of the difference in death rates between groups using a grouped logit model which models the log-odds of death for groups defined by decade, age group, SEG and the interaction of decade with age group and decade with SEG. Table 3 gives the results for this model (for brevity the main terms of age and the interaction of age with decade have been omitted). Table 3 shows that across all adjustment methods there was a fall in death rates for professionals across the 1990s and 2000s as evidenced by the negative log-odds for the 1990s and 2000s. Similarly, the main terms for SEG show that all other SEG groups have higher log-odds of death in the 1980s compared to the professional SEGs with the manual group having the highest coefficient.

Our main interest is in whether the differential between the SEGs increased over the decades as evidenced by the interaction terms between SEG and decade. Table 3 shows that whereas the interaction terms for Employers

Table 3: *Grouped Logit Model* of Log-odds of Mortality Among Men Aged 15+*

	Unadj.	*Imputed*	*Direct*	*FBD 30%*	*FBD 50%*	*FBD 70%*	*FBD 90%*	*FBD with Break*
1980s	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
1990s	–0.17	–0.17	–0.17	–0.15	–0.14	–0.13	–0.12	–0.17
2000s	–0.43	–0.44	–0.44	–0.37	–0.34	–0.31	–0.29	–0.31
Professional	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Employer and Managers	7.65	6.90	7.66	4.82	4.31	3.96	3.70	5.95
Clerical	7.61	6.89	7.66	4.83	4.35	4.03	3.79	5.94
Manual	7.67	6.93	7.76	4.90	4.43	4.11	3.87	6.01
Farming	7.64	6.82	7.64	4.88	4.41	4.09	3.86	5.99
Employer and Managers * 1990s	–0.19	–0.19	–0.20	–0.17	–0.15	–0.14	–0.13	–0.19
Clerical * 1990s	0.09	0.09	0.07	0.07	0.06	0.06	0.05	0.08
Manual * 1990s	0.11	0.10	0.05	0.09	0.08	0.07	0.07	0.11
Farming * 1990s	0.16	0.15	0.16	0.14	0.13	0.12	0.11	0.16
Employer and Managers * 2000s	–0.42	–0.41	–0.45	–0.36	–0.33	–0.30	–0.28	–0.40
Clerical * 2000s	0.10	0.12	–0.02*	0.07	0.06	0.05	0.05	0.07
Manual * 2000s	0.28	0.29	0.08	0.23	0.20	0.18	0.17	0.22
Farming * 2000s	0.47	0.44	0.47	0.41	0.38	0.35	0.32	0.37
Constant	–9.64	–8.60	–9.64	–6.87	–6.39	–6.07	–5.83	–8.00**

Note: distribution of age groups and the interaction of age with decade were fitted to the model but are omitted from the table.
*All coefficients are significant at <0.05 except for the interaction of clerical SEG with the third time period (Clerical * 2000s) for the Direct adjustment method.

and Managers by decade are negative for both the 90s and 2000s (evidence of falling differentials), those for every other SEG are positive and significant across all adjustment methods, suggesting growing differentials, with differentials largest for manual and farming groups. The coefficients from the interaction terms between decade and SEG are larger for the 2000s than the 1990s, suggesting growing differentials between the professional SEG and all others except for the Employers and Managers.

V 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 last 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 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 in our knowledge that 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 lowest and highest socio-economic groups by 10 per cent 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. Our analyses show that all SEG groups experienced an absolute fall in death rates between the 1980s and the 1990s/2000s, but that the size of the fall was significantly larger for the Professional SEG and the Employer and Manager SEG. Thus, the relative risk of mortality for all SEGs relative to those groups increased over the period, irrespective of the adjustment method employed to account for the missing information on SEG. The increase in relative risk was largest for Farmers followed by men in the Manual SEG.

These findings are important since they suggest that the positive developments in health and mortality risk experienced over an important 25-year period in Irish history were not shared equally across social groups. More research is required to identify the why this increasing differential has occurred. For example, research needs to examine whether there were increasing differentials across different causes of death as this will provide an indication of the types of processes that may have been at work. It is known that the fall in mortality rate for cardiovascular and respiratory causes steepened in the late 1990s/early 2000s and this may have contributed to the patterns observed (although only for the latter period) if the availability of free GP care and access to cardiovascular medications among Professional and Employer and Manager SEGs increased after 1999 relative to men in other SEGs.

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 differentials 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 shall also be able to 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).

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APPENDIX A

INCORPORATING OBSERVATIONS WITH MISSING SOCIO-ECONOMIC GROUP INTO THE ANALYSIS

Rubin (1987) has identified 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 Direct Adjustment of Mortality Rates

First, following 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:

$$= 1 + P_x^{\text{inactive}} *(RR_x^{\text{inactive/active}} - 1)$$

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

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 ($x1$, $x2$,….xk), which are either categorical or continuous:

$$\log\left(\frac{\text{Prob(cat } j)}{\text{Prob(cat } q)}\right) = \beta_0^{(j)} + \sum^{k} \beta_i^{(j)} x_i, j = 1, \ldots, q-1$$

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 2) means that this period has little or no mislabelling 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.

APPENDIX B

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) "Census 86". In *Central Statistics Office 1993*, *Volume 7 – Occupations*. Dublin: Stationery Office. CSO (2012) "Profile 3 – At work". In *Central Statistics Office 2012, Highlights from Census 2011 – Part 2*. Dublin: Central Statistics Office