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Working Paper

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QUCEH Working Paper Series, No. 2020-04

Provided in Cooperation with:
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Suggested Citation: Colvin, Christopher L.; McLaughlin, Eoin (2020) : Death, Demography and the Denominator: New Influenza-18 Mortality Estimates for Ireland, QUCEH Working Paper Series, No. 2020-04, Queen's University Centre for Economic History (QUCEH), Belfast

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https://hdl.handle.net/10419/218827

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DEATH, DEMOGRAPHY AND THE DENOMINATOR: NEW INFLUENZA-18 MORTALITY ESTIMATES FOR IRELAND

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Working Paper 2020-04

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May 2020

Death, Demography and the Denominator: New Influenza-18 Mortality Estimates for Ireland*

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26 May 2020

Abstract:

Using the Irish experience of the Spanish flu, we demonstrate that pandemic mortality statistics are sensitive to the demographic composition of a country. We build a new demographic database for Ireland's 32 counties with vital statistics on births, ageing, migration and deaths. We then show how age-at-death statistics in 1918 and 1919 should be reinterpreted in light of these data. Our new estimates suggest the very young were most impacted by the flu. New studies of the economic impact of Influenza-18 must better control for demographic factors if they are to yield useful policy-relevant results. Covid-19 mortality statistics must go through a similar procedure so policymakers can better target their public health interventions.

Keywords: demographic economics, pandemics, age-adjusted mortality, Spanish flu, Ireland.

JEL Codes: N34, I18, Q54.

* We thank Kyle Richmond for excellent research assistance, and Graham Brownlow and Matthias Blum for helpful feedback on an early draft.

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1. Introduction

Lessons from the Great Depression were widely employed by economists and policymakers to understand and respond to the Great Recession (Eichengreen 2012). As the world's last truly global pandemic before Covid-19, the influenza pandemic of 1918-1919 ("Influenza-18") is now being used in much the same way. A plethora of new studies has already emerged which use this historical pandemic to discuss the potential social, economic and political impacts of Covid-19 (see, e.g., Barro et al. 2020; Carillo and Jappelli 2020; Correia et al. 2020; Dahl et al. 2020; Lilley et al. 2020; Lin and Meissner 2020; Velde 2020).

But learning lessons from history is hard and the history profession has long shied away from doing so out of fear that practically anything can be justified by appealing to one or other interpretation of past events (Colvin and Winfree 2019). The advantage economists had in the last crisis was that we knew a lot about the Great Depression; indeed, the field of macroeconomics originated in that very crisis. Economists do not have this same advantage when they look to Influenza-18 to draw their lessons; we are relatively new to this topic and run the risk of making rookie errors which distort our findings and may lead to bad policy choices. We highlight one such error in this paper and then prescribe a solution from the field of demography.

Influenza-18 was a high-mortality virus with significant social repercussions. The Spanish flu, as it is still commonly known, infected approximately one-third of the world's population and had a death toll between 50 and 100 million (Jordan et al. 2018), with 2.64 million deaths in Europe alone – 1.1 per cent of the continent's population (Ansart et al. 2009). Like Covid-19 (WHO 2020), the influenza A virus subtype H1N1 responsible for the 1918-1919 pandemic was so deadly because it led to secondary bacterial pneumonia infections and respiratory failure (Taubenberger 2006). Figure 1 plots the crude mortality rate of the constituent polities of the UK, alongside other countries, between 1900 and 1920. It reveals the severity of the pandemic, but it also highlights the fact that Influenza-18 took place within a high disease environment where epidemics were more commonplace than today.

Influenza-18 originated from an unknown source (Taubenberger et al. 2001), and typically arrived in countries in major trading ports – carried, among others, by military personnel returning from the battlefields of World War I. It diffused through populations in a process of spatial contagion in three waves, the second being the deadliest (Smallman-Raynor et

al. 2002). While all areas of the world saw excess mortality, rates differed significantly across countries; the disease proved particularly deadly in developing countries (Chandra et al. 2012). There was also significant heterogeneity in the flu's health impact within countries, an outcome driven by local differences in demography, density, economy, environment and policy (Patterson and Pyle 1991; Hatchett et al. 2007; Clay et al., 2018).

Age mattered. Indeed, worldwide the conventional wisdom is Spanish flu was particularly fatal to those aged between 20 and 40 years (Johnson and Mueller 2002). One hypothesis is these young adults were immunologically naïve, with older age groups benefitting from inbuilt immunity due to expose to previous influenza outbreaks (Palese 2004; Taubenberger 2006).[1] Sex also mattered; men tended to be affected more by the disease than women (Noymer and Garenne 2000). However, this immediate female advantage was somewhat attenuated by a subsequent decade-long convergence of female with lower male life expectancy, possibly a result of selection.[2]

Although we know about these, and other, demographic factors, much of the discussion about age- and sex-related mortality during the Spanish flu tends to rely on fragile population estimates, raw death counts and crude mortality rates when it should be using age-adjusted mortality rates based on vital statistics. Many scholars appear unaware that their chosen population statistics are arithmetic interpolations (e.g., Correia et al. 2020). Studies that do incorporate population growth in turn do not acknowledge the limitation of the underlying estimation methodology (e.g., Lilley et al. 2020). A closer reading of their data sources would have highlighted the problem; contemporaneously it was acknowledged that 'owing to recent unusual migrations of the population and the fact that 1916 [1917, 1918, 1919] is far away from the last census year, the estimates are probably too high in some cases and too low in others' (Census Bureau 1918b, p. 62; 1919, p. 77; 1920, pp. 118-119; 1921, pp. 118-119).[3]

Some of this year's new crop of pandemic economics studies make no acknowledgement of, let alone an adjustment for, the demographic composition of countries and regions, either for 1918 or today (e.g., Lin and Meissner 2020). But if one location has a higher mortality rate than

[1] Given what we know about disease contagion in societies which fail to shut down their economies to preserve life (Hatchett 2007), we can also speculate the working-age population was inherently more at risk of catching the disease.
[2] Male flu victims represented a group which would have been more at risk of contracting and dying from tuberculosis, a disease which consequently disproportionately affected females (Noymer 2012).
[3] After the 1920 US census, estimated growth by state was re-estimated as 'the populations are estimated by the arithmetical method based on the 1910 and 1920 censuses' (Census Bureau 1922, p.74).

another, and also has a higher share of the population over 65 years of age, or a greater proportion of women, then we need to adjust for these differences before any inferences can be drawn about the efficacy of public health policy, the speed of economic recovery or the electoral consequences of lockdown measures. Even those studies which do take note of the differential demographic impact fail to consider its consequences.[4]

Why has the existing literature focusing on the "wrong" demographic groups during Influenza-18, or ignored demography altogether? We think this is because scholars tend to make use of "convenient" data, typically derived from the closest previous census. We demonstrate this choice distorts the denominator in mortality statistics. We measure the consequence of this methodological mistake using the case of Ireland, then a developing region of one of the world's most advanced economies. We show that choosing the convenient denominator means scholars fail to take full account of demographic change during World War I, a war in which large numbers of Irish men were sent to their deaths on the battlefields of Etreux, Gallipoli, Ypres, Hulluch, Passchendaele and the Somme.

Using what demographers call the "component method" (Long 1993), we construct a new spatially-disaggregated demographic dataset for the case for Ireland. Our analysis of this dataset suggests the very youngest in society, those under the age of five, had the highest mortality rates during the Spanish flu. We think this finding has potentially significant implications for economic analysis linking mortality rates with other datasets, in this and other settings, historical or present day. Policymakers are currently making difficult choices about non-pharmaceutical public health interventions, or weighing up the costs and benefits of financial support to firms, industries or regions. Our 100-year-old historical analogue demonstrates that carefully-constructed population data and sensible demographic adjustments are necessary for our economic analyses to be useful to them.[5]

[4] Correia et al. (2020), for example, exploit regional variation in Spanish flu mortality to look at the pandemic's subsequent economic impact, but do not control for regional heterogeneity in population structure.

[5] See Dowd et al. (2020) and Kulu and Dorey (2020) for recent applications of demographic adjustment to Covid-19 death rates.

2. The Irish Case

The impact of the Spanish flu on Ireland was first quantified by Ireland's then-Registrar-General, Sir William John Thompson, in an article published just after the pandemic concluded (Thompson 1919). Thompson's methodology was simpler than that used by his counterparts in London, limiting his scope to influenza and pneumonia as the two causes of death associated with the pandemic. He estimated an influenza mortality rate of 243 per 100,000 in 1918, with urban areas experiencing a rate of 370 per 100,000. He ascribed to the Spanish flu 45 of the 140 per 100,000 who died of pneumonia. He calculated this excess mortality rate by comparing pneumonia deaths in 1918 with 1917. This brought Ireland's total N1H1-related mortality rate to 288 per 100,000 for 1918.

The Irish experience of the Spanish flu was recently brought back to life by the archival work of Ida Milne in a 2018 monograph, based on her 2011 PhD dissertation. Milne's book is a rich description of life during the pandemic, including details on the public policy response, particularly in the province of Leinster. Her analysis of Ireland's medical infrastructure highlights how the country's local funding model for healthcare provisioning was incapable of dealing with a national health crisis. She describes how Irish officials had recently adopted international conventions on the collection and classification of health statistics, making Ireland's official statistics comparable with other countries. However, as elsewhere in the world, she notes how doctors struggled to define cause of death; many individuals recorded as dying of tuberculosis, bronchitis, heart failure and other maladies probably died of the Spanish flu. Official statistics therefore likely underestimate the pandemic's true impact. Milne conservatively estimates that 20,000 people died in the pandemic in Ireland, from which she infers one-fifth of the island's population must have contracted the disease (Milne 2018, chap. 3).

Another important contribution to the Irish historiography is the PhD dissertation of Caitríona Foley, published as a monograph in 2011. Foley's social history focuses on how "ordinary people" reacted to the pandemic. She recounts how Ireland's medical professionals understood the science of infection and catalogues the various treatments they used. An interesting feature of her work is that she puts the Spanish flu into its long run historical context, highlighting the fact that Ireland regularly suffered epidemics, including the so-called Russian flu in the early 1890s (Foley, 2010).

Most relevant to our own research is an unpublished PhD dissertation by Patricia Marsh, completed in 2010. She describes how the public responded to the pandemic in Ireland's northern province: businesses were shut while their employees fell ill; sporting events and public meetings were cancelled; and libraries, primary (national) schools and the university (Queen's) were closed as a public health measure. She carries out an in-depth demographic analysis for the entire island (chap. 2), uncovering the precise timing of each of the three waves of the pandemic. Exploiting the same official government sources we use in this current paper, and adopting the more sophisticated methodology of the then-Registrar General of England and Wales, she re-calculates excess mortality statistics for Ireland using a broader list of causes of death than Thompson. She estimates there may have been up to 14,000 additional deaths than previously ascribed to the flu, taking the total pandemic death toll to 34,000, and yielding a mortality rate of 782 per 100,000 population.

A recent work of quantitative history to make use of Irish influenza statistics is de Bromhead et al. (2020). The article is an analysis of the 1918 general election, which took place on 28 December and gave the previously-obscure Sinn Féin party the majority of Ireland's 105 Westminster MPs. Using the same official sources we use, de Bromhead et al. calculate crude mortality rates at the Poor Law Union level, the lowest administrative division at which health statistics were reported. They then use GIS software to allocate these to electoral constituencies – not an easy task since there were fewer such districts and the two sets of boundaries do not line up. They find higher Spanish flu mortality is associated with a lower turnout on election day, but they argue this did not affect the overall electoral outcome.

To calculate the mortality rate, a demographic researcher requires a denominator: the relevant population, the average population exposed to risk of death during the defined time period. Up-to-date population estimates are necessary for a variety of administrative indicators, such as vital statistics and disease incidence (Long 1993). For their denominators, Thompson, Milne, Marsh and de Bromhead et al. all use the population taken from a census of Ireland conducted on 24 April 1911 (BPP 1913a). This choice is understandable as the most

comprehensive sources for demographic data are censuses, and 1911 was the most recent census year.[6]

But populations can change suddenly. Relying solely on the 1911 census means Thompson and the others fail to take account of changes in population due to births, ageing, migration and deaths since 1911; their population estimates are not sufficiently up to date. Notably the 1911 census fails to take account of the falling birth rates, the ageing population and changes in the composition of deaths due to warfare. Irish scholars of the Spanish flu are not alone in their choice to use the closest census. Around the world the most recent census year to the 1918-1919 pandemic were typically around 1910 (ex ante/pre-pandemic) or 1920 (ex post/post-pandemic), and so this same "error" is being repeated across the entirety of this literature.

3. Methodology

In order to measure the demographic impact of the Spanish flu, we need to estimate a denominator for our mortality statistics; the closest pre- or post-pandemic census years 1911 or 1926 will distort the true effects of the pandemic. At the most basic level the population has changed in terms of births, ageing, migration and deaths in the intervening period. This was a very turbulent era, with the outbreak of a global war in August 1914 which lasted until November 1918, and a rebellion in Dublin City in April 1916; the 1926 census is therefore not an appropriate choice because it bookends a revolutionary period and Ireland's partition.

To more comprehensively understand the impact of the pandemic, we need to make postcensal estimates of the population in 1918 and 1919 to calculate influenza-related mortality rates in 1918 and 1919:

$$M_t = \frac{D_t}{P_t} \times 100{,}000 \tag{1}$$

where M_t is the mortality rate per 100,000 population in year t; D_t is the number of deaths in year t; and P_t the base population in year t, typically measured mid-year. Because the nature of the disease means men and women were impacted differently, we need to calculate this separately

[6] This census was based on a house-to-house collection of data and was considered by census officials to be their best-yet.

by sex. After sex, age is the single most crucial variable when studying mortality (McGehee 2004); we need an accurate picture of the age structure of the population. Only once we have population by sex at each age are we able to calculate age-specific mortality rates:

$$M_{sat} = \frac{D_{sat}}{P_{sat}} \times 100{,}000 \tag{2}$$

where M_{sat} is the mortality rate per 100,000 population for sex s at a specific age or age-range a in year t; D_t is the number of deaths for sex s at that age or age-range a in year t; and P_{sat} the base population for sex s in that age or age-range a in year t, typically measured mid-year.

Demographers have long observed that comparisons of mortality using crude death rates alone can be misleading as the demographic (sex, age) composition of a population will affect the level of the observed death rate (Linder and Grove 1947, p. 60). Although the crude mortality rate is a weighted average mortality based on the age composition of a given population, we need to take account of age differences in order to make meaningful comparisons across populations with different age distributions. For example, if geographic location X has a higher mortality rate than location Y, but X also has a higher share of the population under five years of age than Y, we need to adjust for this difference. We can do this by imposing group weightings from a "standard" population. Doing this creates a hypothetical death rate which assumes the demographic composition of the population under study equals that of the standard population.

We report several estimates of a standard population. In order to make meaningful contemporary comparisons we calculate a weighted average standard population for 1911 using data on OECD age structures that were reported in the 1911 Census of England and Wales (BPP 1917a, p. 63).[7] We also compare these with three modern standard populations: 1940 (US Standard Million), 1960 (World Standard Million) and 2000 (WHO Standard Population) (NCI 2012; Ahmad et al. 2001).[8] We report these standard population weights in Table 1, alongside our own estimates for Ireland.[9] The latter standard populations are most relevant for Covid-19; the earlier age structures are more relevant for Influenza-18.

[7] For OECD countries, we take: Australia, Austria, Belgium, Canada, Denmark, England and Wales, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Scotland, South Africa, Sweden, United States.

[8] World Standard Population data are available from the WHO website (https://apps.who.int/healthinfo/statistics/mortality/whodpms/definitions/pop.htm).

[9] Spatially disaggregated population weights are available for 1911 from the authors. See NCI (2012) for other years.

Here we adopt a direct age standardisation approach using:

$$m_{1st} = \frac{\sum m_{sat} P_a}{P} \times 100{,}000 \quad (3)$$

where lower-case m_{1st} refers to the mortality rate of the specific population under study; P_a is the standard population at each age; and P is the total standard population. Effectively this means we calculate a weighted average age-specific mortality rate.

Ireland's system of registration of births, marriages and deaths commenced in 1864. Annual reports collated registration statistics from various districts (Poor Law Unions) throughout the country and aggregated these to county, province and national level. We rely on these data as our sources for D_t. The data were collated by age of death, sex, and cause of death. Age-specific cause of death was only recorded for influenza and pneumonia in 1918 and 1919. We digitised all *Registrar General Reports* between 1911 and 1920 to estimate our postcensal populations to use as the denominator in our mortality statistics (BPP 1912b, 1913c, 1914b, 1915b, 1916c, 1917c, 1918b, 1919b, 1920b, 1921b). The base population for our age structure estimates comes from the 1911 census (BPP 1913a), which was digitised by Clarkson et al. (1997). To estimate the population in 1918 and 1919, we then use the component method from demography, which takes account of vital statistics in the intervening years (1911-1918). Essentially, we update the census with data on population flows. We use the following equation:

$$P_{sact} = P_{sac(t-1)} + (B_{sact} - D_{sact} + I_{sact} - E_{sact}) \quad (4)$$

where P_{sact} is the population for sex s at age or age-range a in county c at time t; and B, D, I and E are within-year births, deaths, immigration and emigration, respectively.

The component method of estimating population change has been carried out by census bureaus throughout the world since at least the start of the 1900s (Long 1993). Annual population estimates at a national level were reported in the *Registrar General Reports*, and their methodology is straightforward: 'by adding the births registered in each year to the estimated population for the previous year, deducting the deaths and the number of emigrants' (BPP 1921b, p. 40). Essentially, we follow this same procedure at a district level for Ireland's 32 counties, while also adjusting for ageing and immigration.

We use direct measurement of births, deaths, immigrants and emigrants using annual immigration figures from Social Welfare (1955, p. 326).[10] We focus here on international rather than internal migration.[11] Deaths are recorded by age range in Ireland's vital statistics, and so we can account for deaths within defined five-year age bins. Emigration age profiles are available from contemporary records (BPP 1912a, 1913b, 1914a, 1915a, 1916a, 1917b, 1918a, 1919a, 1920a). Immigration was considerably smaller than emigration, so effectively this is a net migration story.

To estimate and annually update the age structure of the population, we move a share of each age bin forward one year, assuming a survival rate for the last year in the cohort. We explain the procedure for the age bin covering 25-29 year-olds as an example of our methodology. First we account for all deaths and migration flows. Then we bring a share of the population forward to the next bin; the 29-year-olds are moved to the 30-34 bin and are replaced in the 25-29 bin by 24-year-olds from the 20-24 bin. We adjust for the 24- and 29-year-old survival rates using weights calculated from the same age band in the 1926 census, the next census of Ireland following the 1911 census.[12]

We collapse all ages over 65 into one single age band as there are perceived discrepancies with age statements in the 1911 censuses of Ireland. Ireland's census commissioners believed the 1911 was more accurate than previous census in terms of age statements as there was less heaping (reporting of rounded ages at 0 or 5) in the final report.[13] The commissioners believed older people had in the past under-stated their age, but because of the recent introduction of the 1908 Old Age Pension for over-70s, they had for the first time 'ascertained their correct age' (BPP 1913a, p. 25). Ireland's long history of youth emigration had left the country with an older population (Akenson 1993; Fitzpatrick 1980, 1984). It is likely that over-65s were therefore

[10] These are mostly return migrants from emigrant destination (see Fernihough and Ó Gráda 2019). Pre-war immigration was 20% of the emigration total. We assume immigration follows a similar spatial pattern as emigration.
[11] Census figures provide details of location of birth of the population. We can estimate internal migration by comparing the 1901 and 1911 censuses (BPP 1901; 1913a). In 1901, 11.38% of the population of counties were born outwith the county; in 1911, this figure rose to 13.20%. This equates to a growth of 0.18% per annum. The outliers in this were the major urban centres (Belfast and Dublin), with the lowest rate of internal migration seen in the west of the island (Kerry, with 3.85% in 1901 and 3.96% in 1911). Internal migration tended to be to the nearest urban centre, so province- rather than county-level statistics essentially already incorporate internal migration.
[12] This census was conducted separately for the by then jurisdictionally partitioned island (Government of Northern Ireland 1929; Roinn Tionscail agus Tráchtála 1928, 1929).
[13] See Blum et al. (2017) for a discussion of age heaping in Irish census data.

already a disproportionate share of the population, for demographic rather than nefarious reasons. However, Budd and Guinnane (1991) fear there was a deliberate overstatement of age to qualify for the pension. Collapsing the age bins over 65 years of age is our way to circumvent the possibility of overstatement of ages, while not trying to manipulate the underlying census.

Military enlistment during World War I is effectively treated as emigration in the Registrar General's population estimates as it was a sizeable population movement to the battlefields of Europe. Subsequent demobilisation was treated as return migration (immigration). For example, in the population estimates for 1914, the male population decreases by 49,881, and in 1919 it increases by 63,000 (BPP 1921b). We follow a similar procedure. To adjust for military enlistment during World War I, we estimate the total enlistment in Ireland (134,202) from contemporary military sources (BPP 1921a, p. 9; WO 1922, p. 363).[14]

We detect the county composition of Irish enlistment from a further parliamentary source which covers 97 per cent of the total Irish recruits (BPP 1916b). The age of military service was between 19 and 41, but government statisticians noted 'the male population of Ireland is composed chiefly of young men up to 18 years of age and of men over 50, as a large proportion of the remainder emigrates to the United States and Colonies' (BPP 1921a, p. 9). Estimated military mortality is derived from War Office statistics, which imply a mortality rate of 14.13 per cent for all military personnel. Our war-related mortality estimate is lower than Bowman's (2014) estimated 20 per cent mortality.[15] We have chosen the more conservative death rate of 14 per cent to keep Irish mortality in line with British Isle mortality figures.[16]

For cause-specific death rates in the influenza pandemic, we report data on deaths attributed to influenza in addition to those attributed to all forms of pneumonia. While the inclusion of pneumonia with influenza deaths was common internationally, such as in the US (see Census Bureau 1920, pp. 29-32; and used, e.g., in Brainerd and Siegler 2003), there are limitations of the data due to mistakenly attributing deaths to other causes; notably, to other

[14] Our enlistment figure is considerably lower than Bowman's (2014) recent estimates, who believes 210,000 Irish served in the British Army. This discrepancy is because the Army figures of enlistment for Ireland explicitly exclude 'Irishmen enlisted in Great Britain who came over for the purpose' (BPP 1921a, p. 6).

[15] Bowman's (2014) estimated mortality is 5.7% of all reported British Isle casualties, although his enlistment estimates suggest Irish comprised 4% of the British Army, implying Irish soldiers were over-represented in mortality figures.

[16] The average difference between the sum of our county population estimates and those estimated by the Registrar General is -0.26%. We attribute this difference to our treatment of troop movements. Further research could improve population estimates by incorporating more detailed information from more disaggregated registration districts.

respiratory illnesses. However, a no-pandemic counterfactual would also have seen deaths due to influenza and pneumonia; Ireland was a high-disease environment with a poor public health infrastructure and so counting all who died of these two maladies may result in an over-estimate.

To overcome these problems, we also report excess mortality: deaths from *all* causes relative to what would "normally" have been expected across a given year. Our estimates are based on a comparison of the mean death rate from 1910-1914 with those in 1918 and 1919, calculated by sex and age. The selection of a pre-war mean death rate is an attempt to not distort estimates with wartime spillovers. Moreover, 1915 saw a severe tuberculosis epidemic so including this year would distort the comparison. We report age-adjusted excess mortality using the estimated populations in 1918 and 1919 to account for changes in the composition of the population in the intervening period.

There exist various alternative methodologies for estimating population that are used to make population projections. One such alternative is linear interpolation. This method was used by US census officials in order to ensure timely estimates could be computed; 'the method of arithmetical progression was adopted for computing the estimates of population […] based on the assumption that the increase each year since the enumeration is equal to the annual increase from 1900 to 1910' (Census Bureau 1918a, p. 5).[17] Adopting the interpolation methodology, given the data we now have available, would be rather crude and would hide variation within Ireland.[18] Especially important in our case is that linear interpolation would yield misleading age compositions as it assumes trends from the previous decade are constant.[19]

4. Findings

Our starting point is a comparison of crude death rates across time and across a selection of countries, in Table 2 and Figure 1. Ireland's crude death rate increased from 16.52 per 1,000 in

[17] Indeed, it is these linear interpretations of population that are used in recent economic studies of the Spanish flu (e.g., Correira et al. 2020).

[18] At a national level the linear interpolation using the 1901-1911 population growth is close 0.15% per annum, versus 0.18% for 1911-1918 using the component method.

[19] Take two examples: Leitrim's growth rate between 1901-1911 was -0.86% per annum, while the population growth was effectively 0 between 1901-1918 owing to a reduction in emigration. Galway also experienced negative growth between 1901 and 1911 (-0.55%), but experienced growth between 1911 and 1918 (0.15%) owing to falling emigration.

1911, to a peak of 18.15 in 1918. But here we see a distinction between Influenza-18 and Covid-19: the prevailing levels of mortality are higher as the Spanish flu pandemic occurs in an era of epidemiologic transition when infectious (exogenous) diseases were a greater cause of death than chronic lifestyle (endogenous) causes of death (Omran 1971; Dyson 2010).[20]

Another discernible aspect of Figure 1 is the differences in the heights of the mortality spikes in 1918. One of the key distinctions between Ireland and these comparator countries is its unusual history of population decline from the 1850s onwards. The main driver of this decline was emigration; Ireland had the highest emigration rates in the world (Hatton and Williamson 1994, Tab. 1.1). These emigrants were young and the residual population was therefore older. The inverse is true for immigrant receiving countries such as Australia or the US.

Moreover, within Ireland there are demographic difference in terms of migration and age structure. These are illustrated in the various population pyramids reported in Figure 2. Notably, urban centres in the east of the island grew, drawing internal migrants, while the countryside was depleted of youth. Comparing countries by age distribution – as done by contemporary census officials in BPP (1917a) – Ireland is one of the older populations; the share of over-55s was 16 per cent in Ireland versus an average of 12 per cent across other countries listed.[21]

The population of Ireland decreased by 1.32 per cent in the seven years from the 1911 census (see Table 2). This fall in population was driven by a number of factors: a significant fall in birth rates, increasing mortality driven by an outbreak of pandemic tuberculosis in 1915, falling migration during the War, and military enlistment. If we ignore these demographic changes and use the 1911 population as our denominator for 1918 – the methodological choice made by Thompson (1919) and the others – then this implicitly, and incorrectly, assumes no change in the demographic composition of the population.

The changes in the composition are best illustrated through a visualisation of population pyramids. Firstly, as an aggregated national picture, Figure 2 illustrates the compositional changes wrought by this declining population. There were noticeable falls in all age cohorts

[20] Comparison of crude death rates in the 1910s with modern data shows regions that have undergone the second demographic transition (Lesthaeghe 2014) are 50-60% of those in the 1910s. Such comparisons are somewhat misleading given the changing demographic composition of many countries; in the US, for example, age-adjusted death rates are considerably lower than crude death rates suggest and there are age adjusted disparities between ethnic groups (see, e.g., Kochanek et al. 2019).

[21] The over-55 share of the population was 10% in the US and 12% in England and Wales (BPP 1917a).

except the 5-9 and 55-64 cohorts (Panel A and Panel B). There is a distinct difference between male and female population change, as males made up the bulk of military recruits. Disaggregating to Ireland's four historic provinces, we begin to see distinct regional patterns distinguishing the east and west of the island (Panel C). Further focusing in on the population in urban versus rural districts illustrates a disproportionate impact of military enlistment on cities (Panel D).

The raw data on influenza and pneumonia deaths in 1918 and 1919 are reported in Table 3. If we only look at the age distribution of deaths, we can confirm the view that those aged 20-40 were disproportionately affected by the influenza pandemic, with approximately 30 per cent of deaths hailing from this age group. However, this does not make allowance for the demographic weighting of these groups. Table 4 calculates cause-specific death rates using both the 1911 census weights (Panel A) and our 1918/1919 estimated weights (Panel B). Across the board, the 1911 weights understate the impact of the pandemic. Adjusting for demographic changes, the Influenza-18 story is more nuanced, and, if anything, it aligns more with conventional mortality statistics, where the youngest and oldest display highest levels of mortality. This pattern is more clearly evident by comparing Figure 3, Panel A with Panel B.

Table 5 reports distinct regional patterns in terms of age-specific and age-standardised mortality rates. Leinster and Ulster, located in the east of the island, show considerably higher age-standardised mortality than the rest of the island (Munster and Connaught) and are also high compared to the national average (see Table 4, Panel B). Focus on the main urban centres also shows much higher mortality across age groups, especially in the younger cohorts (under-5s), and age-standardised mortality rates in urban centres are more than double that of rural populations. This highlights the consequence of urban density for the spread of the disease. Disaggregated county maps of age-adjusted influenza-related mortality are presented in Figure 4, highlighting the considerable variation across the island.

Age-specific excess mortality, reported in Figure 5, show a similar pattern to age-specific influenza and pneumonia; with the exception that the oldest cohorts recorded fewer deaths in 1918 than they had recorded (on average) between 1911 and 1914, thus giving them a negative excess mortality (see Figure 6 for a map of age-adjusted excess mortality). Excess mortality more explicitly highlights the consequence of using the 1911 census rather than our estimated

1918/1919 denominators. All cohorts display higher excess mortality using 1918 population weights. The 1911 denominator records much lower expected excess mortality in the oldest cohorts than the 1918 denominator.

In contrast to the cause-specific figures shown in Figure 3, Panel B, the excess mortality of the prime working aged (25-34) is highest in Figure 5. This, in turn, reflects the fact that the pandemic operated in a competitive disease environment; whether the pandemic killed more children than usual is moot. Excess mortality and age-adjusted excess mortality show a strong positive correlation with age-adjusted influenza and pneumonia mortality (Figure 7), with the outlier being Dublin County. This may be explained by the registration of deaths from Dublin County in Dublin City, where many of the region's hospitals were located.

Age of death-specific mortality rates suggest a possible mechanism of infection may have been family units. Across provinces, apart from Connaught, the ratio of the mortality rates of under-5s and 25-34s are of a similar magnitude. This trend is most pronounced for males as the female under-5 cohort has significantly higher mortality than the 25-34 cohort.[22] This pattern suggests a possible cofounder related to the economic activity of males. During the War, part of Ireland's labour force was deemed essential for both the war effort and for domestic morale. Reserved occupations in rural Ireland included farmers; the pastoral nature of the agricultural economy meant little social interaction. Reserved occupations in urban centres related to transport and factory work (railway and transport workers, food processing, shipbuilding and repairs), where what we would now call "social distancing" was near-impossible.[23]

The major puzzle is why those over 45 had lower than expected mortality (i.e., lower excess mortality compared to the 20-40 cohort). One explanation in the literature is they enjoyed some immunity thanks to previous exposure to influenza strains, such as that in 1900, which was particularly virulent (see Taubenberger 2006). These earlier influenza pandemics may also have selected the population in this age group, leaving only healthier individuals behind. An alternative explanation is these older cohorts were less economically active and so less likely to catch influenza, or less likely to work while recovering from influenza (cf. Milne 2018).

[22] This is disproportionately driven by infant mortality (those under the age of one).

[23] Another property of the male population is that men deemed physically unfit for military service are among those left behind. It is feasible this selected population was more at risk of dying in the pandemic.

We have uncovered marked differences in demographic composition between 1911 and 1918. The most prominent divers of this change were war-related. Most immediately was army enlistment from urban centres, which reduced the male population in the military-active age groups (20-40), the exact population identified in the epidemiology literature as being particularly susceptible to 1918's N1H1 strain. Indirectly this led to a drop in birth rates during the war years. We also show rural centres are older owing to emigration trends – the specific population group traditionally identified as being less affected by the Spanish flu.

5. Conclusion

As with the Great Recession referencing the Great Depression for influence in developing policy responses (Eichengreen 2012), the Great Virus of today sees continued reference to historical pandemics. The major analogue for Covid-19 is Influenza-18. The Spanish flu is now widely studied again and referred to both in academic and popular writing, including our own (Colvin and McLaughlin 2020). The Spanish flu was notably even referenced, albeit incorrectly, by the US president (Rupar 2020). However, to fully extrapolate relevant policy lessons, we must first develop a more nuanced understanding of the population-at-risk in 1918. This means employing off-the-shelf methods from the demography literature to take account of the changing demographic composition of populations during the 1910s, a turbulent decade across the globe.

The existing literature on the 1918-1919 pandemic has stressed the importance of age and sex, with males aged 20-40 constituting the population which succumbed most to the virus. Surprisingly, economic studies of the pandemic mostly fail to address this fundamental issue of demography. They simply do not carry out age standardisation. The pandemic occurs late in the census cycle and starts during a world war which resulted in a global population upheaval. Using ex ante population estimates in mortality statistics implicitly assumes the prevailing decade had few demographic implications; adopting ex post population estimates overstates the burden of the pandemic as the dead are no longer counted in the population. Notably, the contemporaneous US influenza rates used in recent economic scholarship suffer from this denominator error; pre-1920 annual population is estimated using arithmetical interpolation from the 1901-1910 census and post-1920 census using arithmetical interpolation from the 1910-1920

census. Scholars should instead spend time to estimate their own denominators for 1918 and 1919 mortality statistics, pieced together from readily-available vital statistics.

Quantitative demographic histories of Ireland end with World War I (see, e.g., Guinnane 1997) and therefore do not address demographic change across the specific period necessary to analyse the 1918-1919 pandemic. We must, therefore, carry out this analysis ourselves. Ireland's experience of Influenza-18 has recently seen important contributions from social and medical historians (most notably: Marsh 2010; Milne 2018). We complement their analysis by updating their figures with a more robust methodology which takes age-at-death into account. While we provide a more nuanced picture of the demographic impact of the flu, our total death toll attributed directly to influenza is not far off their estimates; we use the same sources after all.[24]

However, looking at excess mortality figures tells a different story. Mean annual deaths were 72,706 between 1911 and 1914; 1918 saw 78,695 die and in 1919 this was 78,612. Total excess deaths over both years was 11,895, considerably lower than the raw total influenza and pneunomia death counts. The prevailing high mortality environment in which the pandemic occurred may account for this surprising finding. Influenza crowded out other causes of death; people would likely have died from something else were instead killed by Influenza-18, a phenomenon known in epidemiology as the "harvesting effect" (Noymer 2012). The excess mortality per capita was 163 per 100,000 in 1918 and 115 per 100,000 in 1919. Adjusted for age, the figures are 223 and 123 per 100,000, respectively.

Recent research has found little impact of the 1918-1919 pandemic on economic activity (e.g., Velde 2020; Benmelech and Frydman 2020), but these studies do not account for the different disease environment of the early twentieth century. The 1918 outbreak occurred early in the epidemiological transition, when infectious diseases were still rampant. High mortality rates across what are today's developed countries (Figure 1) means that epidemics and pandemics were almost expected. The Spanish flu had wide-reaching global impacts but it occurred only three years after a major tuberculosis epidemic, and 18 years after a particularly bad influenza outbreak. In this sense, Ireland's experience of Influenza-18 is perhaps more akin

[24] Using influenza-related cause of death statistics yields an estimated death toll between 20,000 and 31,000 individuals, similar in magnitude to those of Marsh (2010, chap. 2). This represents about 0.7 per cent of Ireland's population – considerably lower than the European total of 1.1 per cent reported by Ansart et al. (2009).

to the experience of Asian countries that suffered SARS epidemics in recent memory and thus were probably better prepared for Covid-19.

A quantitative study of the causes, anatomy and consequences of Ireland's experience of Influenza-18 has yet to be conducted. We now have the means to carry out such an analysis, and Figure 8 represents a first step. It depicts a series of scatter plots placing counties and urban districts on axes of estimated age-adjusted influenza-related mortality rates in 1918, and economic and social indicators from the 1911 census. Together they suggest strong economic drivers of influenza mortality. More disaggregated data will allow us to address policy-relevant questions, including on the efficacy of Ireland's funding model for medical infrastructure.

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Tables

Table 1: Distribution of the population in Ireland in 1911, 1918, 1919 and in standard population weights

Age (years)	Ireland						Standard population weights			
	Male			Female			US	World		
	1911	1918	1919	1911	1918	1919	1940	1911	1960	2000
0 – 4	0.10	0.10	0.09	0.10	0.09	0.09	0.08	0.11	0.12	0.09
5 – 9	0.10	0.11	0.11	0.10	0.10	0.10	0.08	0.11	0.1	0.09
10 – 14	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.1	0.09	0.09
15 – 19	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.08
20 – 24	0.09	0.09	0.10	0.08	0.09	0.09	0.09	0.09	0.08	0.08
25 – 34	0.14	0.13	0.15	0.15	0.15	0.16	0.16	0.16	0.14	0.16
35 – 44	0.12	0.11	0.12	0.12	0.12	0.13	0.14	0.12	0.12	0.14
45 – 54	0.09	0.09	0.09	0.09	0.09	0.09	0.12	0.1	0.11	0.11
55 – 64	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.08	0.08
Over 65	0.09	0.08	0.08	0.11	0.09	0.09	0.07	0.06	0.07	0.08

Source: 1911 census from the Census of Ireland conducted on April 1911 (BPP 1913a); 1918 and 1919 estimates are our calculation using method outlined in text with data from *Marriages, Births and Deaths Registered in Ireland* (BPP 1911-1919); source for standard population weights are referenced in-text.

Table 2: Demographic statistics for Ireland (1911 census versus 1918 estimate)

	1911 census	1918 estimate	Difference (1918 – 1911)
Mid-year population			
Ireland	4,394,075	4,336,292	-57,783
Leinster	1,154,486	1,136,270	-18,216
Munster	1,044,506	1,044,167	-339
Ulster	1,583,995	1,539,092	-44,903
Connaught	611,088	616,762	5,674
Deaths			
Ireland	72,598	78,695	6,097
Leinster	21,450	23,518	2,068
Munster	15,990	16,432	442
Ulster	26,496	30,637	4,141
Connaught	8,662	8,108	-554
Crude mortality rate (per 1,000)			
Ireland	16.52	18.15	1.63
Leinster	18.58	20.70	2.12
Munster	15.31	15.74	0.43
Ulster	16.73	19.91	3.18
Connaught	14.17	13.15	-1.03
Births			
Ireland	101,306	87,304	-14,002
Leinster	27,301	22,542	-4,759
Munster	23,066	19,844	-3,222
Ulster	37,342	32,421	-4,921
Connaught	13,597	11,314	-2,283
Birth rate (per 1,000)			
Ireland	23.06	20.13	-2.92
Leinster	23.65	19.84	-3.81
Munster	22.08	19.00	-3.08
Ulster	23.57	21.07	-2.51
Connaught	22.25	18.34	-3.91

Source: See Table 1. Mid-year population in 1911 adjusts the April census returns by adding second quarter births, and subtracting second quarter deaths and net migration.

Table 3: Raw influenza-related death counts, by age and sex (1918 and 1919)

Age (years)	1918						1919					
	Influenza			Influenza and pneumonia			Influenza			Influenza and pneumonia		
	Male	Female	*Total*	Male	Female	*Total*	Male	Female	*Total*	Male	Female	*Total*
0 – 4	615	621	*1,236*	1,585	1,416	*3,001*	653	624	*1,277*	1,468	1,320	*2,788*
5 – 9	224	300	*524*	349	443	*792*	166	215	*381*	250	338	*588*
10 – 14	207	233	*440*	283	326	*609*	136	190	*326*	186	259	*445*
15 – 19	524	441	*965*	685	573	*1,258*	398	362	*760*	492	444	*936*
20 – 24	681	556	*1,237*	912	743	*1,655*	545	388	*933*	684	508	*1,192*
25 – 34	1,390	1,032	*2,422*	1,866	1,351	*3,217*	1,008	775	*1,783*	1,314	1,001	*2,315*
35 – 44	706	579	*1,285*	1,005	810	*1,815*	628	517	*1,145*	929	719	*1,648*
45 – 54	448	427	*875*	765	620	*1,385*	473	419	*892*	781	605	*1,386*
55 – 64	317	321	*638*	610	521	*1,131*	363	379	*742*	667	584	*1,251*
Over 65	469	550	*1,019*	924	971	*1,895*	551	616	*1,167*	1,067	1,056	*2,123*
Total	5,581	5,060	*10,641*	8,984	7,774	*16,758*	4,921	4,485	*9,406*	7,838	6,834	*14,672*

Source: See Table 1.

Table 4: Influenza-related mortality, by age and sex (using both 1911 census and 1918/1919 estimated weights)

Panel A: Mortality rates per 100,000 population (1911 census weights)

Age (years)	1918						1919					
	Influenza			Influenza and pneumonia			Influenza			Influenza and pneumonia		
	Male	Female	*Total*	Male	Female	*Total*	Male	Female	*Total*	Male	Female	*Total*
0 – 4	279	289	*284*	718	658	*689*	296	290	*293*	665	614	*640*
5 – 9	101	139	*120*	157	205	*181*	75	100	*87*	113	157	*134*
10 – 14	95	111	*103*	130	155	*143*	63	91	*76*	86	123	*104*
15 – 19	244	212	*228*	319	275	*298*	186	174	*180*	229	213	*221*
20 – 24	356	302	*329*	477	403	*440*	285	210	*248*	357	276	*317*
25 – 34	445	319	*381*	598	417	*506*	323	239	*280*	421	309	*364*
35 – 44	258	220	*239*	368	307	*338*	230	196	*213*	340	273	*307*
45 – 54	226	217	*222*	386	316	*351*	239	213	*226*	394	308	*351*
55 – 64	230	221	*225*	442	359	*399*	263	261	*262*	483	402	*442*
Over 65	229	232	*230*	451	409	*429*	269	260	*264*	521	445	*480*
Crude rate	255	230	*242*	410	353	*382*	224	204	*214*	357	311	*334*
Age standardised mortality rates												
1911 global	257	231	*244*	414	354	*383*	225	201	*213*	356	306	*331*
1940 USA	262	232	*247*	414	349	*381*	230	204	*217*	359	304	*332*
1960 WHO	255	231	*243*	418	358	*387*	227	205	*216*	366	315	*340*
2000 WHO	260	232	*246*	416	352	*384*	230	206	*218*	365	310	*337*

Panel B: Mortality rates per 100,000 estimated population (1918/1919 estimated weights)

Age (years)	1918						1919					
	Influenza			Influenza and pneumonia			Influenza			Influenza and pneumonia		
	Male	Female	*Total*	Male	Female	*Total*	Male	Female	*Total*	Male	Female	*Total*
0 – 4	286	298	*292*	738	679	*709*	312	307	*310*	702	650	*676*
5 – 9	94	129	*112*	147	191	*169*	71	94	*82*	106	148	*127*
10 – 14	95	110	*103*	130	154	*142*	63	90	*76*	86	123	*104*
15 – 19	242	212	*228*	317	276	*297*	184	173	*178*	227	212	*220*
20 – 24	380	290	*333*	509	387	*446*	256	200	*229*	321	261	*293*
25 – 34	493	298	*386*	662	391	*512*	302	222	*261*	393	286	*339*
35 – 44	308	208	*254*	439	292	*358*	234	185	*209*	346	257	*300*
45 – 54	230	210	*220*	392	304	*347*	246	205	*225*	406	296	*349*
55 – 64	206	203	*205*	397	330	*363*	234	238	*236*	431	366	*398*
Over 65	269	274	*272*	530	483	*505*	324	315	*319*	626	540	*580*
Crude rate	266	226	*245*	428	347	*386*	223	201	*211*	702	306	*330*
Age standardised mortality rates												
1911 global	274	225	*248*	438	348	*390*	222	198	*210*	356	304	*329*
1940 USA	280	227	*251*	440	343	*388*	227	200	*214*	359	301	*330*
1960 WHO	271	226	*247*	442	354	*394*	226	203	*214*	368	314	*341*
2000 WHO	278	227	*250*	442	348	*391*	229	203	*216*	366	309	*337*

Source: See Table 1.

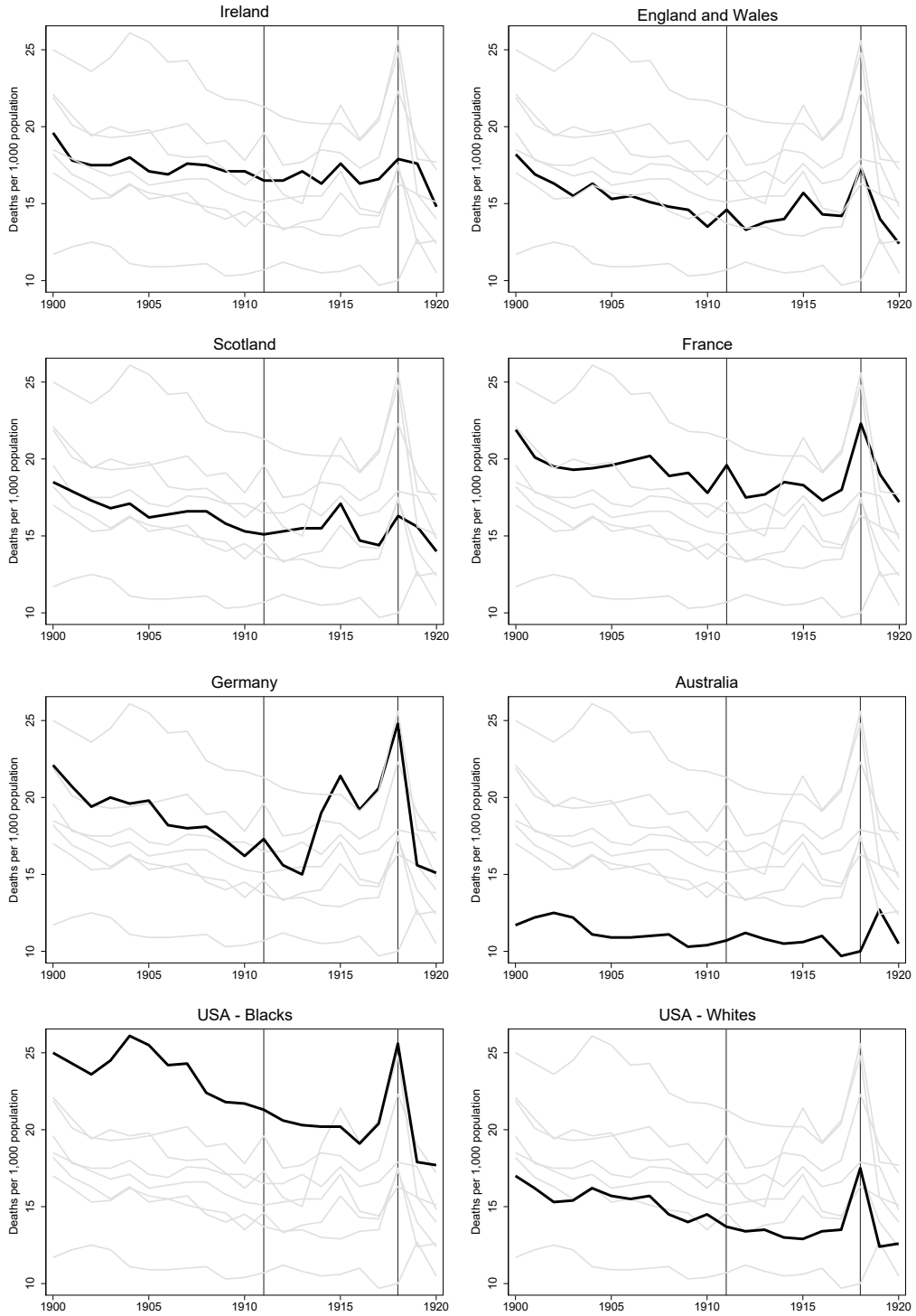
Table 5: Influenza-related mortality rates per 100,000 in 1918, by region and urbanisation level (using 1918 estimated weights)

Age (years)	Males						Females					
	Leinster	Munster	Ulster	Connaught	*Urban*	*Rural*	Leinster	Munster	Ulster	Connaught	*Urban*	*Rural*
0 – 4	922	488	962	251	*1,901*	*517*	892	447	846	240	*1,674*	*484*
5 – 9	178	130	163	80	*250*	*127*	260	139	221	76	*370*	*155*
10 – 14	184	68	160	67	*243*	*109*	233	110	173	46	*257*	*134*
15 – 19	379	204	417	150	*501*	*282*	345	184	347	130	*516*	*228*
20 – 24	589	422	602	304	*828*	*460*	485	248	498	154	*723*	*315*
25 – 34	900	441	787	318	*1,424*	*561*	481	228	502	152	*650*	*329*
35 – 44	633	318	492	165	*1,087*	*362*	360	202	343	138	*493*	*245*
45 – 54	496	257	455	275	*751*	*336*	344	201	403	108	*547*	*253*
55 – 64	461	324	460	244	*718*	*350*	358	229	420	200	*588*	*285*
Over 65	674	376	702	246	*954*	*492*	535	315	696	225	*695*	*459*
Crude rate	556	304	514	208	*848*	*362*	429	228	441	147	*639*	*289*
Age standardised mortality rates												
1911 global	564	308	532	211	*917*	*365*	434	229	440	143	*661*	*285*
1940 USA	568	310	531	217	*908*	*371*	422	225	435	143	*632*	*284*
1960 WHO	567	310	537	213	*923*	*368*	438	233	448	146	*671*	*290*
2000 WHO	570	312	535	217	*915*	*372*	428	228	442	145	*643*	*288*

Source: See Table 1.

Figures

Figure 1: Mortality rate in Ireland and other countries (1900-1920)

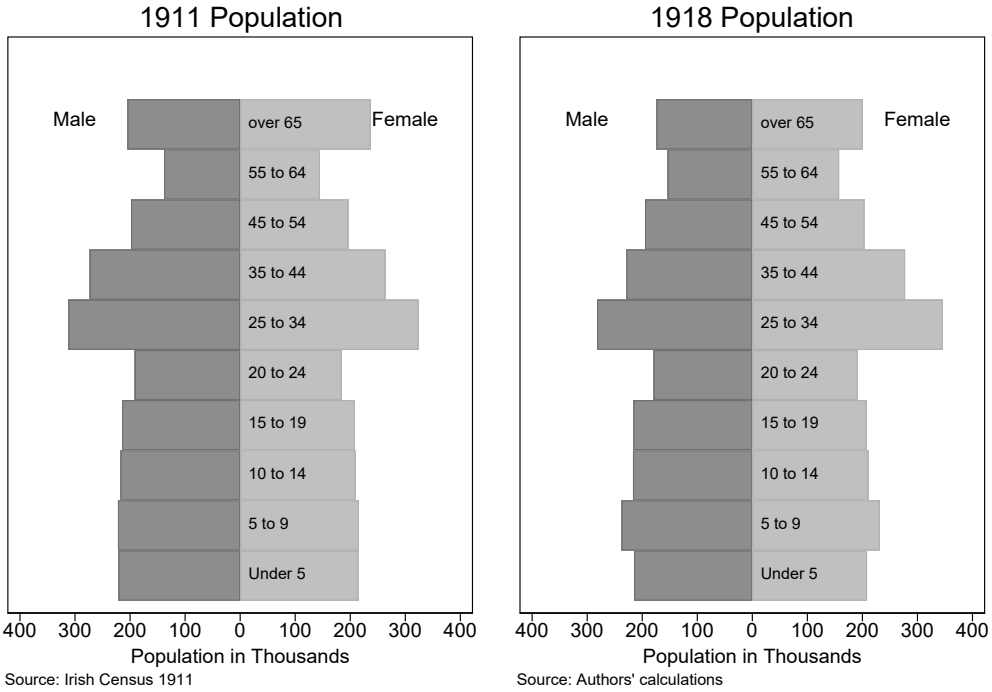


Note: 1911 and 1918 are indicated with vertical lines. US data are reported by ethnicity only.

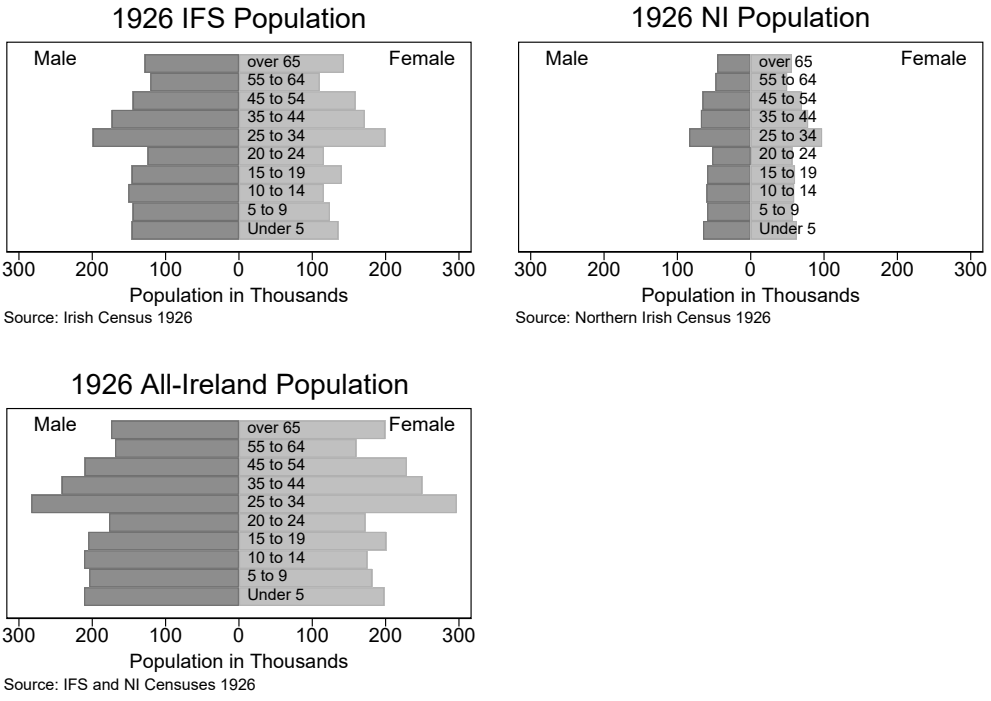
Source: Mitchell (2013).

Figure 2: Population pyramids for Ireland

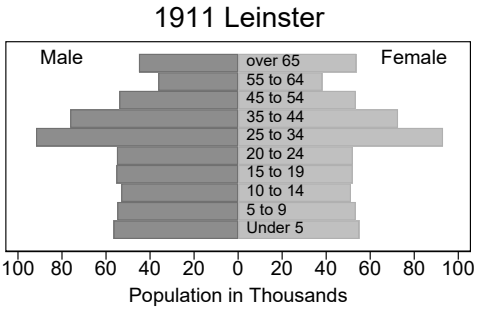
Panel A: National level (1911 census versus 1918 estimated)



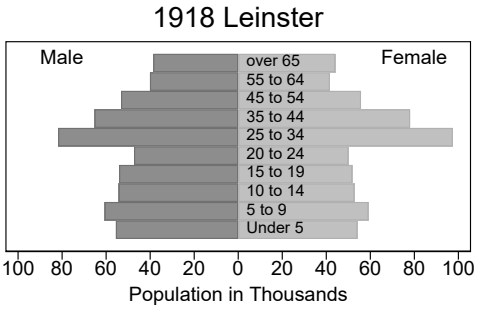
Panel B: National level (1926 census)



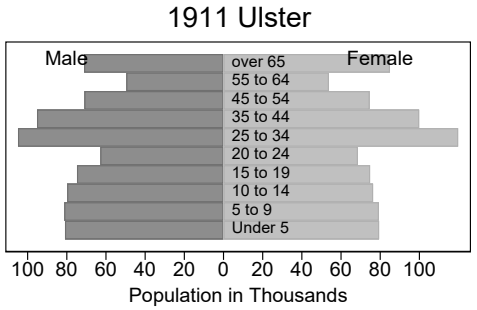
Panel C: Regional (provincial) level (1911 census versus 1918 estimated)



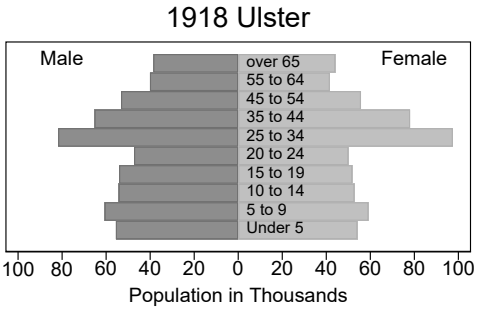
Source: Irish Census 1911



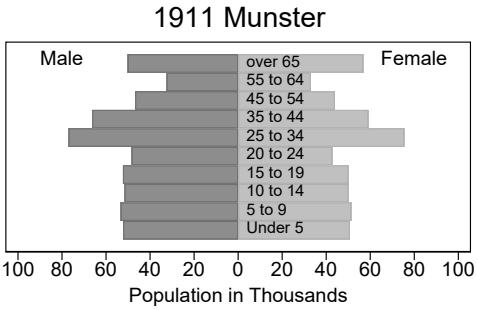
Source: Authors' calculations



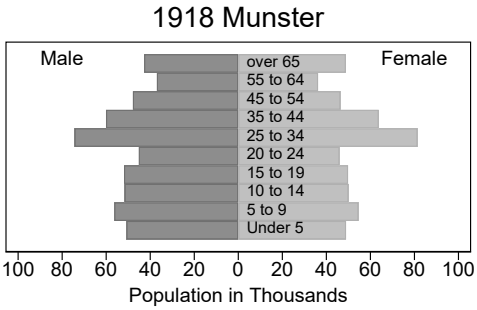
Source: Irish Census 1911



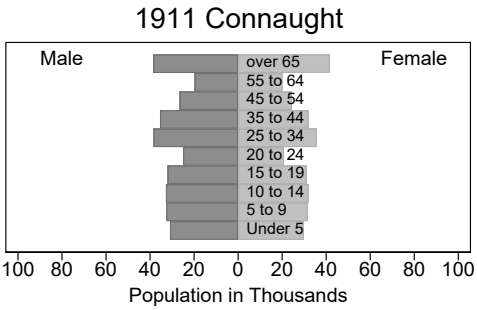
Source: Authors' calculations



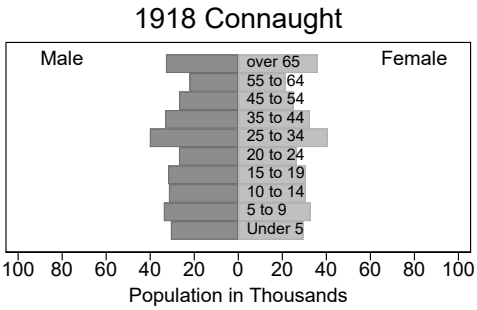
Source: Irish Census 1911



Source: Authors' calculations

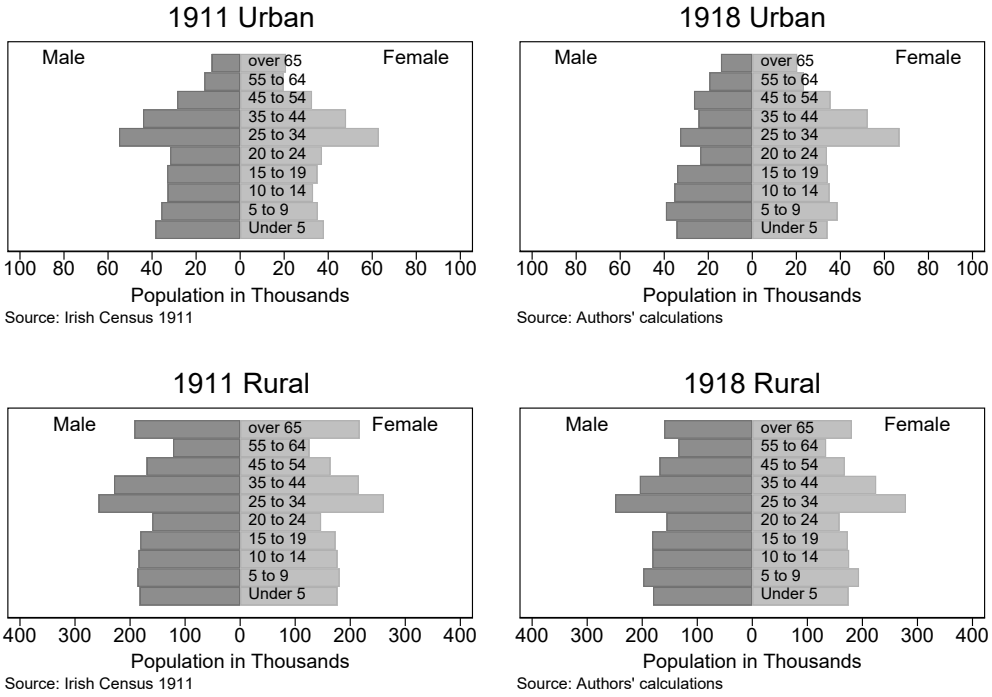


Source: Irish Census 1911



Source: Authors' calculations

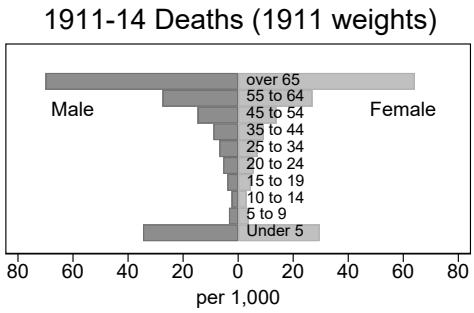
Panel D: Urbanisation level (1911 census versus 1918 estimated)



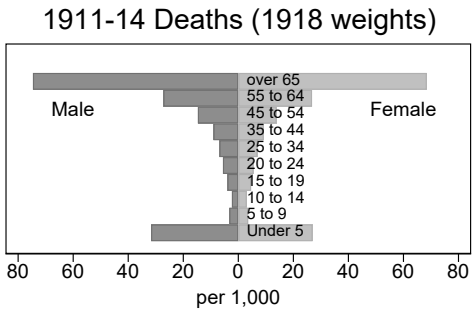
Note: Urban is defined here as Dublin City and Belfast, the island's two main urban centres.

Figure 3: Mortality rate by age group (1911 census versus 1918 estimated weights)

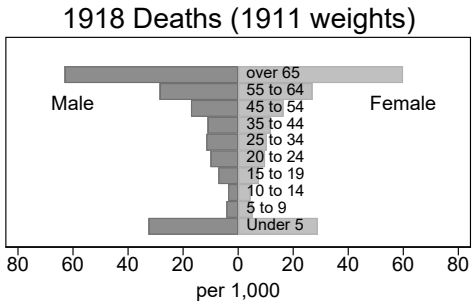
Panel A: All causes of death



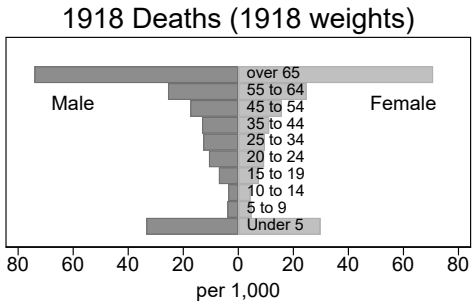
Source: Marriages, Births, and Deaths registered in Ireland in 1918



Source: Marriages, Births, and Deaths registered in Ireland in 1918

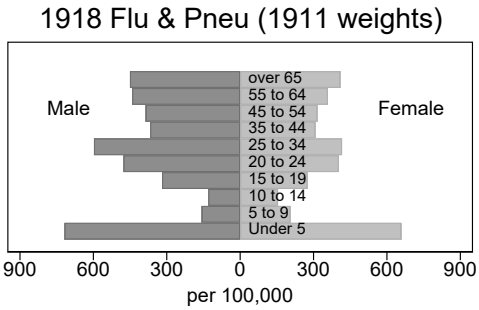


Source: Marriages, Births, and Deaths registered in Ireland in 1918

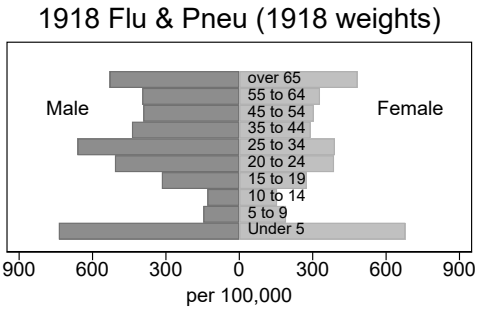


Source: Marriages, Births, and Deaths registered in Ireland in 1918

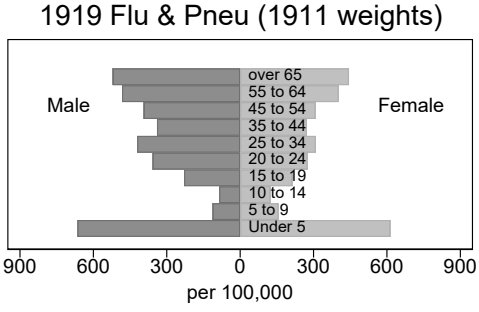
Panel B: Influenza-related deaths



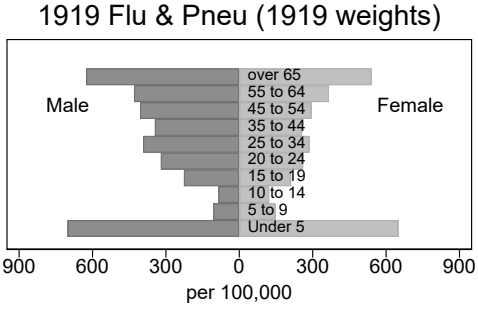
Source: Marriages, Births, and Deaths registered in Ireland in 1918



Source: Marriages, Births, and Deaths registered in Ireland in 1918



Source: Marriages, Births, and Deaths registered in Ireland in 1919



Source: Marriages, Births, and Deaths registered in Ireland in 1919

Figure 4: County map of age-adjusted influenza-related mortality rate (using 1918/1919 estimated weights)

Panel A: 1918

Panel B: 1919

Note: Mortality rate for influenza and pneumonia. Shading divided into five categories by equal quantiles for 1918 in scale.

Figure 5: Excess deaths by age group (compared to 1911-1914 average)

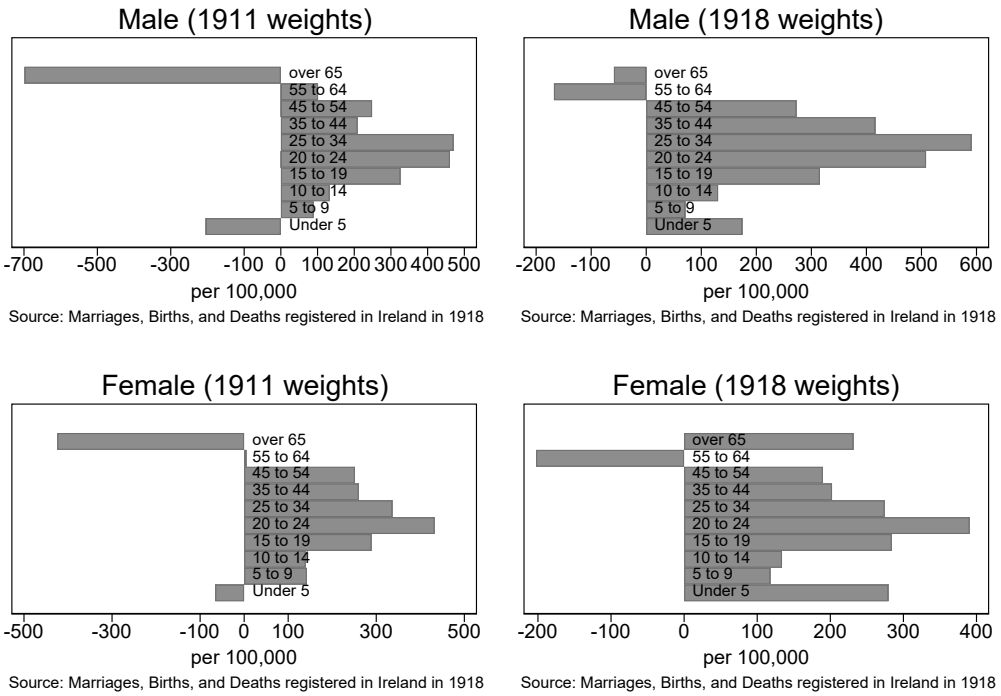
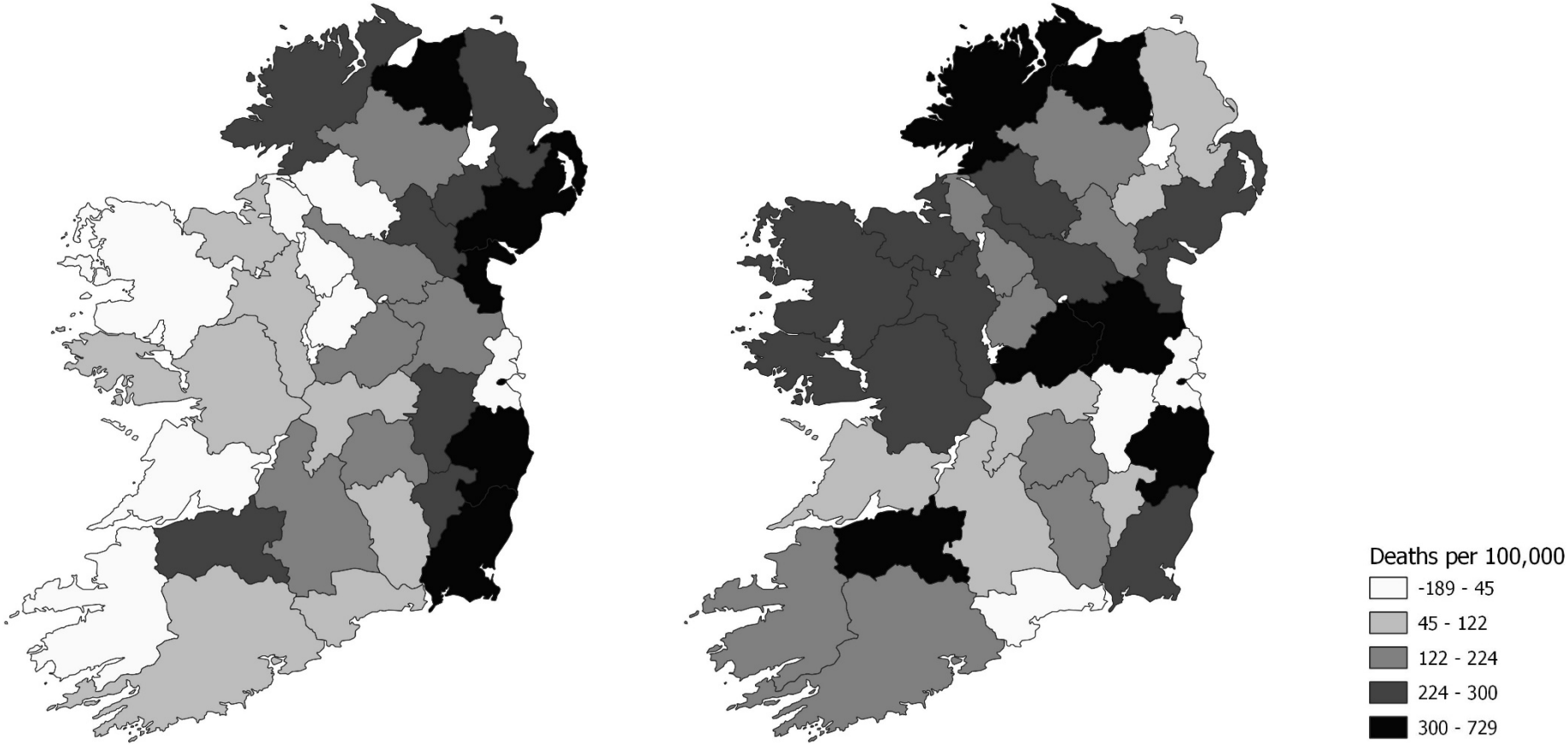


Figure 6: County map of age-adjusted excess mortality rate (compared to 1911-1914 average)

Panel A: 1918

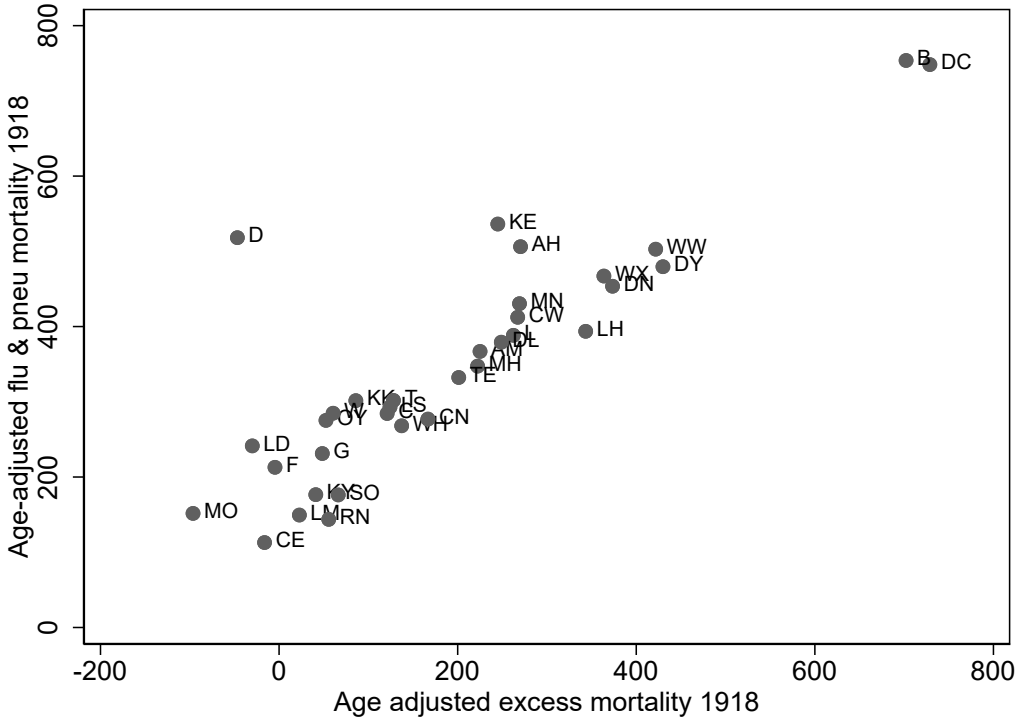
Panel B: 1919



Note: Shading divided into five categories by equal quantiles for 1918 in scale.

Figure 7: Scatter plots of age-adjusted influenza-related mortality and excess mortality

Panel A: 1918 (using 1918 estimated weights)

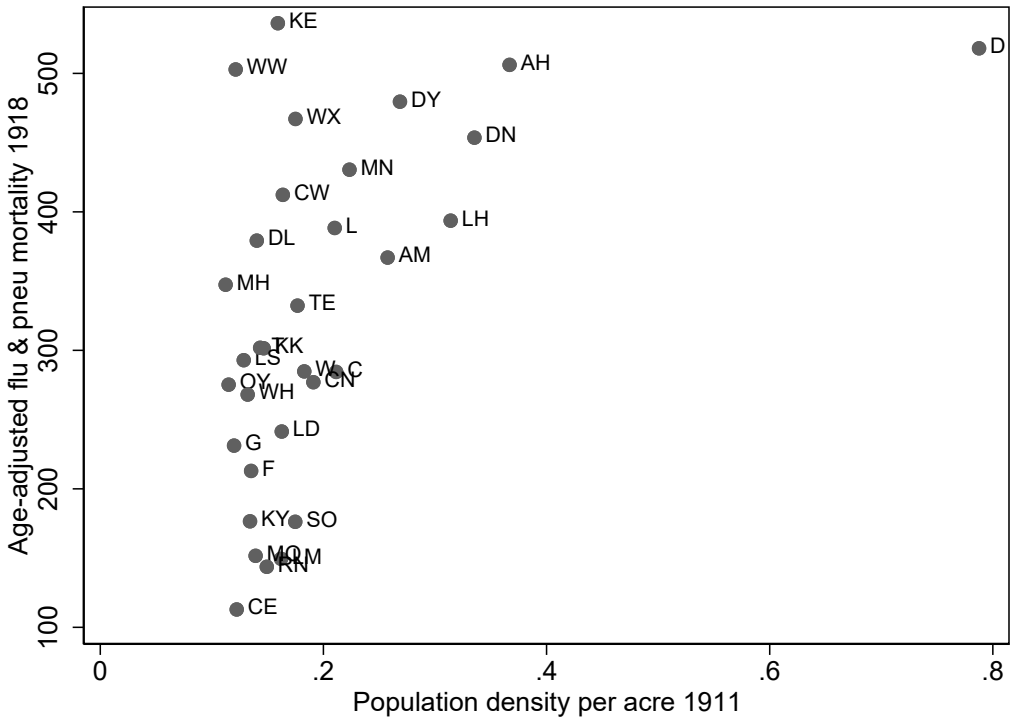


Panel B: 1919 (using 1919 estimated weights)

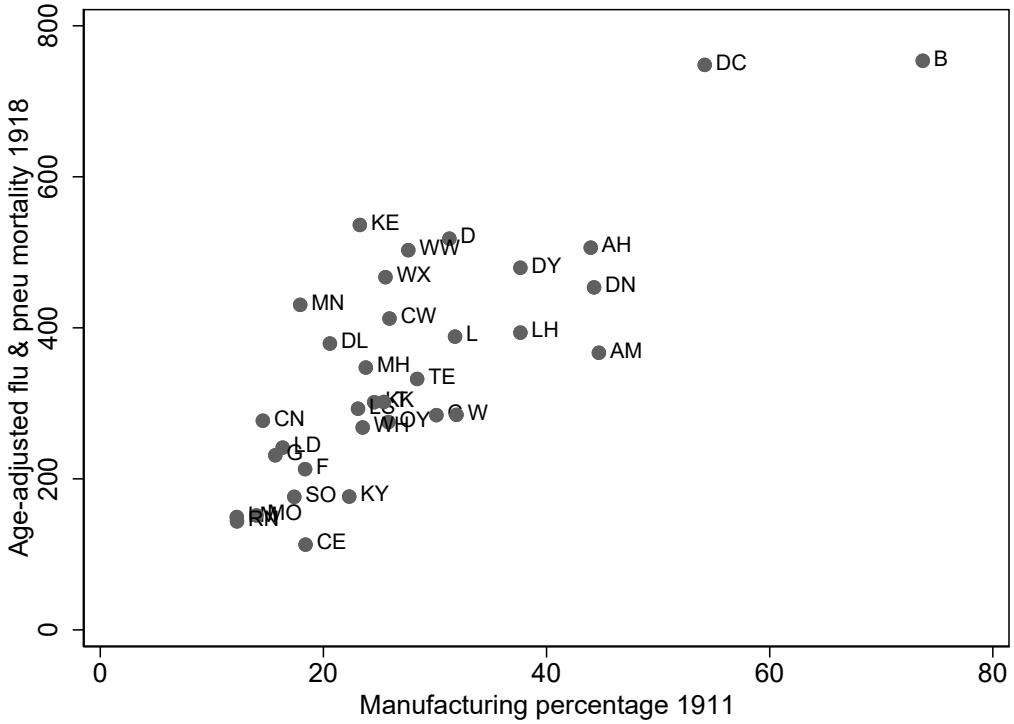
Note: Each point refers to a county or urban district using standard abbreviations.

Figure 8: Scatter plots of age-adjusted influenza-related mortality in 1918 (using 1918 estimated weights) and economic variables from the 1911 census

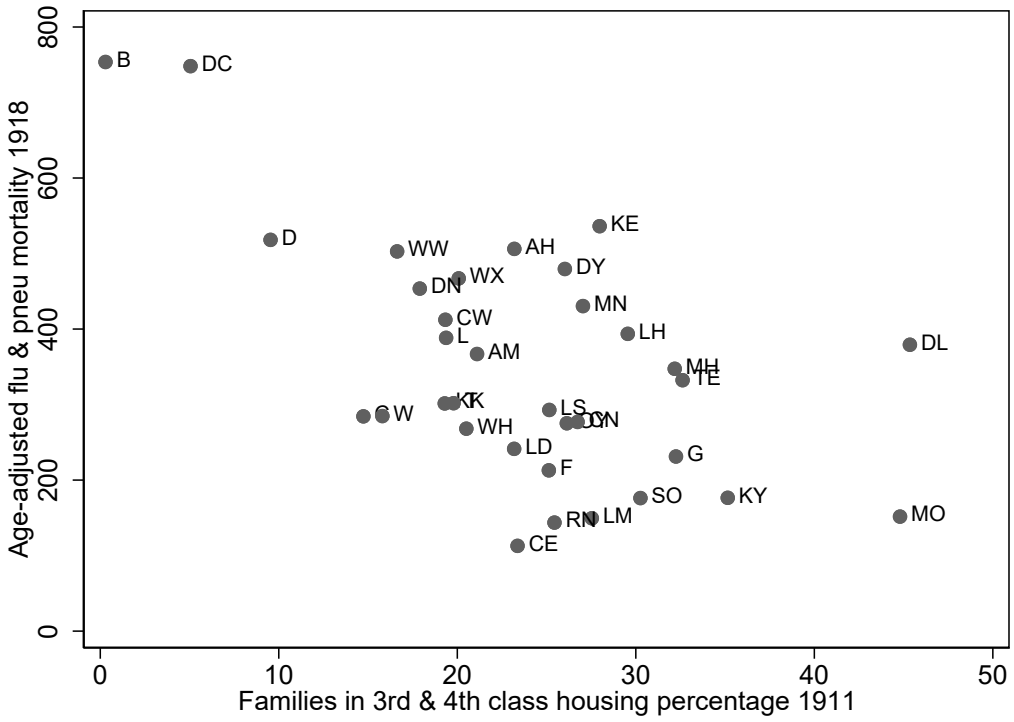
Panel A: Population density



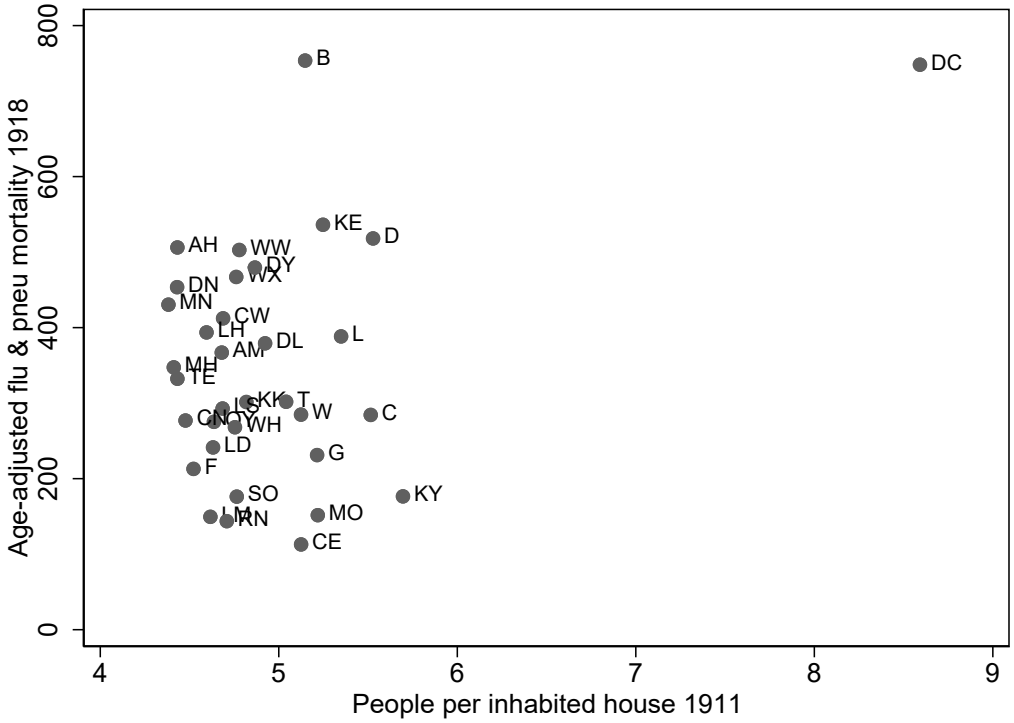
Panel B: Manufacturing share



Panel C: Share of families in 3rd and 4th class housing



Panel D: People per inhabited house



Note: Each point refers to a county or urban district using standard abbreviations.

Source: 1911 census (BPP 1913a); *Marriages, Births and Deaths Registered in Ireland* (BPP 1911-1919).