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Poverty, Religious Differences and Child Mortality in the Early 20th Century: The Case of Dublin

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Abstract

Across many cities in the early twentieth century, one in five children died before their fifth birthday. There is much we do not know about how infant and child mortality was reduced, nor why it declined at different rates across populations. This article investigates mortality using data from 13,247 families in Dublin City in the 1900s with a novel approach that incorporates geographic information systems, spatially-derived predictors and multilevel modelling. At this time, Dublin had one of the highest early-age mortality rates in the British Empire. While experts attributed the death of young children to the unhygienic behaviors of indigenous Roman Catholics, others made claims of a "Dublin Holocaust" rooted in economic inequality and the indifference of public authorities toward the health of the lower classes. The findings of this article support the latter argument. Although the rate of infant and child mortality was 50 percent higher for Catholics, these outcomes were strongly linked to poverty and the conditions engendered by residential segregation. This article finds that residential diversity was particularly beneficial for children at higher risk of death. The very low mortality rates among Dublin's Jewish population are not easily explained by location or economic characteristics.

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1. Introduction

Life expectancy at birth has increased by up to thirty years over the last century. These improvements began in the 19th century and were mainly achieved through reductions in under-5 mortality. However, these gains were not ubiquitous. Life expectancy improved first among higher socioeconomic status (SES) people and this resulted in durable class, ethnic, racial and religious disparities in health (van Poppel, Jonker, and Mandemakers 2005). Due to the lack of detailed historical spatial health data, the emergence of these inequalities is not well understood. This is of concern, as infant mortality rates in many countries today are still higher among low-income families and minorities (Flores, Escala, and Hall 2015).[1]

In this article, I use Dublin City as a case to study historically high rates of infant and child mortality (herein "early-age mortality") among Roman Catholics. I take advantage of data that detail the mortality outcomes, SES and locations of all households in Dublin in the early 20th century. Dublin's infant and child mortality rates of 150 and 115 per thousand were twice those of London and Edinburgh (Christopher 1997; Grimshaw 1890).[2] These death rates, just below those of Calcutta, were among the highest in the British Empire (O'Brien 1982, p. 102) and foreshadow the violent uprising for Irish independence immediately following this study period.

Experts disagree on whether high mortality in Dublin stemmed from poverty and strained urban infrastructure or if it was, as the medical journal *The Lancet* claimed, "the filthy habits of the people" (The Lancet 1900, p. 199). *The Lancet* blamed the "technical incapacity" of Irish Catholic teachers and praised Dublin's Protestant missions and its small Jewish community (The Lancet, 1899, 1900). These claims were refuted by others who argued that these conditions constituted a "Dublin Holocaust", which had its roots in poverty, underdeveloped urban infrastructure, and the indifference of the city government to the death of the lower classes (The Medical Press 1900, p. 40; Cameron 1901; Cameron 1898). Disagreements on this topic were not confined to Dublin, and occurred in many cities during this period, most notably in London and New York (see Brosco 1999).

I pursue this debate by asking: was inequality in mortality driven by religious and ethnic differences in behavior, or was it poverty and residence in (dis)advantaged places? I answer this question through a series of analyses which assess the effect of religion on mortality. I first examine if differences in mortality by religion can be explained by poverty and location. I then test whether ethnic and religious segregation influenced mortality, and if these effects varied by group. Finally, to identify effects directly associated with religion, I examine whether mortality was higher for Catholics than non-Catholics when both lived in conditions of poverty or were exposed to similar hazards and interventions.

This study contributes to a rapidly growing literature concerned with historical health inequality. There is a long established link between space, mortality and SES (Antonovsky and Bernstein 1977). Studies have found that income and nutrition can only explain a portion of historical health inequalities, and scholars increasingly emphasize the role of infrastructure, preventative health strategies and the diffusion of information (see Woods 1985; Reid 1997; Szreter and Woolcock 2004; Garrett et al. 2001). As such, historical spatial data are now being used to assess how environment and infrastructure affected mortality outcomes. Recent studies have attempted to quantify the effect of clean water provisions (Jaadla and Puur 2016; Wray 2015), sanitation and sewerage (Alsan and Goldin 2015; Kesztenbaum and Rosenthal 2016), and industrial air-borne pollution on mortality (Hanlon and Beach 2016).

However, the large ethnic and religious cleavages in urban mortality have not been the focus of this new literature. As such, we still do not understand why early-age mortality was so high among some groups. Findings show that income and genetic factors are unlikely to explain these outcomes (Preston and Haines 1991; Reid 1997). Indirect evidence has been used to argue that inequality in health resulted from cultural and religious differences in childcare, attitudes toward scientific knowledge and community support (Sawchuk, Tripp, and Melnychenko 2013; Ó Gráda 2006; A. Goldstein, Watkins, and Spector 1994; Derosas 2003). Other studies underscore the importance of segregation and social isolation (Thornton and Olson 2011; van Poppel, Schellekens, and Liefbroer 2002).

It has been challenging to bring direct evidence to bear on these mechanisms. This is because data constraints severely limit opportunities to evaluate the influence of poverty, ethnicity and religion on health (van Poppel, Jonker, and Mandemakers 2005).[3] While populations vary in their resources, behaviors and attitudes, they also tend to live in segregated neighborhoods and are differentially exposed to hazards. Detailed data are thus needed to analyze these people-place interactions, yet these effects are confounded in most traditional demographic sources (Praz 2012).

This newly constructed data from Ireland provides a valuable laboratory in which to study inequality in early-age mortality. This data set, expanded from the 1911 census of Ireland, contains sufficient information to measure mortality outcomes and to disentangle effects of poverty, religion and residential location. With these data, I study early-age mortality among 13,247 young couples living in the city at this time. I georeferenced the street location of 94 percent of this population and use these spatial data to describe intra-urban patterns of mortality.

These spatial data are used to examine how exposure to hazards and health interventions affected mortality. Specifically, I evaluate whether sanitation and proximity to water sources increased mortality, and if quality housing and pasteurized milk provision improved outcomes. Pasteurized milk is particularly relevant to this case, as low rates of breastfeeding and weaning on unhygienic substances, are frequently linked to infant mortality among Catholics in historical Dublin and elsewhere. The heightened risk associated with these behaviors would conceivably be greatest in places with contaminated water sources or where access to sterilized liquids was limited. Thus, sanitation, building quality and differences in weaning are plausible sources of mortality differences at this time (see Rioux 2015; van den Boomen and Ekamper 2015)

The findings of this article do not support the overriding claim that Catholic behaviors and habits were responsible for high mortality in Dublin. The children of Dublin-born Catholics *were* dying at a higher rate than their Protestant counterparts to be sure. However, more than half of this disparity can be attributed to the greater exposure of Catholics to poverty and disadvantageous places. These findings are more consistent with inequalities rooted structural disadvantage and poverty than with cultural interpretations of health.

After controlling for the influence of poverty on health, I find that ethnicity and religion remain significant. Consistent with the hypothesis that religious differences had greater influence in higher risk circumstance, I find that the gap in Catholic and non-Catholic mortality levels increases by 34 percent between households that were located on streets that rank in the top and bottom thirds as categorized by SES. I also show that Catholic couples benefited more from public health interventions, particularly pasteurized milk provision. These findings suggest that religious differences *did* exist but only materialized in high poverty circumstances.

Much of the remaining difference between Catholic and non-Catholic early-age mortality can be attributed to the deleterious effect of segregation. Dublin-born Catholics were more likely to live in mostly Catholic, poorer central city areas. However, I show that on more diverse streets, the mortality rate of Catholics was similar, or even below, those of their non-Catholic neighbors. Catholic mortality was particularly low for children living close to Dublin's small Jewish community; a population historically noted for their beneficial childcare practices and shown to have very low rates of early-age mortality (Ó Gráda 2006; A. Goldstein, Watkins, and Spector 1994).

Arriving at these findings required taking a novel approach to the study of historical European mortality. I exploited the hierarchical structure of the census data – couples living on streets – to employ a multilevel modeling strategy. This was key as studies show that inequalities in health are not easily understood through individual traits such as income, nor through aggregated definitions of place (Jones and Duncan 1995). As such, this multilevel approach provided a valuable means from which to study individual and aggregate effects, alongside spatial and place-based influences on health (Xu, Logan, and Short 2014).

The remainder of this article is structured as follows. Section 2 provides a detailed discussion of the preparation, strengths and weaknesses of the data, as well as the construction of the response variable. Section 3 details and justifies the use of multilevel modeling. Section 4 provides an overview of residential and mortality conditions in Dublin during at the beginning of the twentieth century. Section 5 discusses the main results and Section 6 offers some concluding remarks.

2. Constructing the Data

In this section, I provide a detailed discussion of the data used in this study. Considerable attention is devoted to the construction of the sample and the challenges these data pose to the research findings. This discussion is particularly necessary as the 1911 census of Ireland has been underutilized and this study is the first to use complete-count census data in an analysis of this form.

The primary research question is to account for inequality in under-5 mortality. To explore this question, I relied on the recently digitized A form of the 1911 census. The A form is the basic household return and contains information on all persons resident in the household on census night.[4] Variables include age, religion, birthplace, literacy, occupation, relationship to the head of household, marital status and street address. The 1911 census also asked about the number of children born and still living to each married woman resident in the household on census night. Even without explicit information on age at death, this is enough information to analyze early-age mortality.

I extracted the full population (henceforth "sample") of couples from the census who satisfied a strict demographic criteria. The retrospective reports of fertility and mortality from these couples are the primary units of analysis in this study. It was necessary to restrict the sample to produce stable estimates of mortality and to make valid comparisons across groups. The census contains 30,210 women in the 15-49 fertile age range with at least one child born by 1911. I confined the sample to the 13,247 wives with a co-resident spouse who were married for less than fifteen years and residing outside of group-quarters. Among other considerations, the restriction to early marital duration helps minimize the possibility that children died as teenagers or adults.

It was also necessary to exclude women with unknown fertility and mortality exposures (e.g. abandoned wives, widows and the unmarried). It is challenging to interpret the demographic information provided by these women, as less can be assumed about the environments faced by their children. For example, it was not uncommon for the children of unmarried women or widows to be taken into state and church institutions. As such, these children would have experienced a very different set of circumstances. The locations of these mothers in 1911 *would* provide misleading information on these experiences.

2.1 The Population of Interest

Table 1 provides an overview of the economic and demographic characteristics of the sample by wife's religion and birthplace. I focus on wife's religion, as mothers were more likely to be responsible for childcare. However, in the appendix I shows that ignoring mixed-marriages – which were rare – does not distort the results.[5] More than 85 percent of the Dublin and Irish born sample are Catholic and 72 percent of Catholic couples are Dublin-born. Many of the wives born outside Ireland were Russian Jewish or British-born Protestant. The high rates of endogamy by religion also imply large social distances between religious groups. While religious categories can mask within-group variation and reify boundaries (Watkins 1994), these endogamy rates underscore the salience of religious stratification in historical Dublin.

Dublin-born and Catholic couples tended to be of lower SES and experienced higher levels of early-age mortality. The occupational ranking of Catholics is seven to nine points below Protestant and Jewish levels.[6] Further, the share of Catholics living on the poorest third of streets by SES is three times higher than for Protestants and twelve times higher than for Jewish couples. Commensurate with this, the rate of early-age mortality among Catholics was substantially higher than for Protestant or Jewish couples. Catholic couples lost 17 percent of their children while Protestant and Jewish couples lost 12 and 6 percent respectively.

2.2 Response Variable

I used the data on parity (children born) and mortality from the census to construct the mortality index, which was used as the response variable in the regression analysis. This index is calculated as the share of children deceased to each married couple who satisfy the exclusion restrictions discussed above. It should be noted that while the focus of the analysis is the death of infants and children, these couple-level observations provide the conduit through which mortality is analyzed. In this section, I discuss a number of challenges in taking this approach.

Although the census asked married women to report their total number of children born and the survivorship of their children, these data are not ideal for they provide no information on the age of children at death (see Garrett, Reid, and Szreter 2012 for discussion). Further, older women were more likely to have children die at older ages or during periods when fertility and mortality was higher. Thus, it is problematic to analyze mortality using raw census returns.

A well-established set of "indirect estimation" techniques have been developed to better estimate early-age mortality from data sets such as the Irish Census of 1911 (Brass 1975; Garrett et al. 2001; Trussell 1975; United Nations 1983). This approach relies on earlier findings by Brass showing that the share of children deceased to couples married less than 15 years roughly corresponds to the under-5 mortality rate. I standardized the census data with life-table multipliers and aggregate demographic data for Dublin.[7] Following this exercise, I computed a measure of early-age mortality, standardized across the 0-4, 5-9 and 10-14 marital duration groups, for each couple.

This produced a single mortality index for each married couple to be used in regression analysis. This index can be interpreted as a ratio and represents the observed number of children deceased to a couple, divided by the number expected to have died within each marital duration group. This index is right skewed and bounded between zero and positive infinity. Although a Tobit model approach could be used without violating distributive assumptions, demographers have shown that more standard models yield similar results from the mortality index (see Preston and Trussell 1982, p. 31; Garrett et al. 2001, p. 441-469). The use of a Tobit model would also make the findings more difficult to estimate in a multilevel model, and to interpret and compare with earlier studies.

Figure 1 plots this index by religion against parity for all marital durations. On average, Catholic couples with large families have a mortality index of around 2. This implies that these couples experienced twice the expected mortality compared to couples within their marital duration groups. Jewish couples, who have borne two children or less, have an index value between 0.2 and 0.25. This indicates a level of mortality that is only 20 to 25 percent the expected level. The Jewish line in Figure 1 never crosses the threshold of 1. This implies that Jewish mortality is lower than the average at all levels of parity.

This said, Figure 1 also highlights the issue of inferring statistical differences by religion from p-values (see Wasserstein and Lazar 2016). While the Jewish-Protestant difference is statistically significant at the 0.05 level, the overlapping confidence intervals do not offer much credence. This issue may reflect the small number of Jewish couples in the sample. This small sample size itself raises a number of questions around the selectivity and unobserved characteristics of Jewish samples, and whether place effects can be reliably inferred from such a geographically localized population. As such, I combine Protestant and Jewish couples into a single category of "Other" when I begin to examine cross-level interactions and treatments in the results section.

2.3 Variables of Interest

Table 2 presents the census and distance-based variables of interest. Reporting in the 1911 census was inconsistent and these variables required a great deal of preparation. This not only entailed the cleaning of the census data, but also the geocoding of streets and the collection and linkage of these data to several external sources of information. This section provides an overview of this process.

The most challenging variable to standardize in the census is the measure of husband's occupation. There is a great deal of variation in the descriptions of occupations in the census returns. To create an interpretable measure of SES from the census data, I relied on the work of Fernihough, Ó Gráda, and Walsh (2015), who have recently classified each occupation in the Irish census. Their classification scheme ranks each occupation with the "HISCAM index". The HISCAM index is a continuous ranking of occupations constructed through the measurement of social distances between occupations in historical Europe (Lambert et al. 2013).

This occupational information was used to rank couples and streets by SES. The HISCAM index at the level of the couple is referred to as "husband's occupation" throughout this analysis. Further, the median HISCAM index of the adult male population of each street is binned into three categories of "low", "medium" and "high". This variable is referred to as "status of street" and is used as the primary measure of street-level SES or poverty. While it is not possible to directly calculate a poverty rate, low status streets provide a reasonable approximation of where poverty could be expected to be higher.

To analyze spatial determinants of mortality, 94 percent of the couples data were linked to one of 1,178 street segments. This linking relied on an improved version of the data discussed in Connor, Mills, & Moore-Cherry (2011). Each couple were assigned the coordinates of their street segment as their location of residence within the city. This database covers around 80 percent of Dublin streets or 94 percent of the sample. Although many of these streets have small populations, 80 to 90 percent have more than one couple in the sample. In the appendix I show that smaller streets were more difficult to geolocate but this selectivity does not adversely affect the findings of this study.[8]

The reliance on street segments is motivated by their being a fine and theoretically meaningful geographical aggregation. The next level below streets in the census are the buildings themselves, while the level above streets would be city wards, of which there were only 15. Nonetheless, one plausible concern is that these segments could pose a potential modifiable areal unit problem (Openshaw 1984). "On the ground", one might question whether streets are geographically meaningful or if their definition could distort these results (Owen, Harris, and Jones 2016).

I argue that streets are a reasonable unit of analysis for two reasons. First, the historical evidence suggests that streets were internally homogenous with respect to building quality, hazards and price (Lyons 2015; Prunty 2004). Further, there are on average only eleven couples on each street segment. This suggests that these segments were quite small and thus meaningful as approximations of couples' immediate environs. Second, it could be possible to scale up this analysis by creating neighborhood clusters from streets (e.g. Spielman and Logan 2013). It is plausible that neighborhood effects might not be fully captured by a street-level specification (Sampson 2012). However, not enough is known about the urban geography of Dublin at this time. As such, it is preferable to not impose an aggregation on the data at this point and instead analyze the data in their original form.

The geolocated data were used to measure the proximate effect of two hazards and two health interventions on mortality outcomes. The digitized 1911 census does not contain information on building quality or the square footage of building or streets. This is unfortunate as these could be used to better assess building quality and crowding. As a substitute, I proxy sanitation and housing quality by counting the number of deaths attributed to typhoid from 1882-1887 within 200 meters of each couples' residence.[9] I also measure the distance of each couple to the highly polluted River Liffey (see Jenner 1881). The enumeration of typhoid fatalities is lagged and will not fully reflect exposure to hazards for couples enumerated in the census. As such, this measure should be interpreted as a historical reflection of sanitation and housing conditions across the city.

I also analyze mortality with interventions directed toward housing and child nourishment. I assess the effect of housing by identifying 324 couples living in new, higher quality buildings constructed by Dublin Corporation and other philanthropic organizations.[10] These housing projects aimed to help families in poverty. I assess the effect of nourishment by exploiting the location of Dublin's only pasteurized milk depot at this time. Through this depot in Arbor Hill, the Women's National Health Association distributed 20 gallons of milk per day to the local poor. Although I cannot exactly identify which couples availed of this milk, it is reasonable to assume that low SES families in the immediate locale were more likely to benefit. This variable then provides exogenous variation in clean milk consumption.

Not only can residential location or segregation influence mortality through exposures to hazards and poverty, but also through the social mix of neighborhoods and streets. Aside from economic sorting, neighborhoods in Dublin were divided by religion and birthplace. Capturing this diversity requires a multi-group measure of segregation. I use an entropy-based diversity index (Theil 1972). This measure, used recently by (Xu, Logan, and Short 2014), is defined as:

$$Diversity_{ij} = -\sum_{m=1}^{m} (P_{j,m}) log_m (P_{j,m}) \quad (1)$$

where$(P_{j,m})$ is the proportion of religious or ethnic group m on street j. Religion is operationalized here as Catholic or non-Catholic while ethnicity can take three categories: born in Dublin; born in Ireland but outside of Dublin; and born outside of Ireland. The diversity index is bounded between 0 and 1, where values approaching zero indicate that a street is dominated by a single group and values closer to one imply greatest diversity.

2.4 Further Limitations

Before proceeding with the analysis, a final set of limitations should be noted. While these data provide many new opportunities to study historical health, they include no medical cause of death. Further, no data is observed on maternal mortality and this likely leads to some underestimation of mortality (discussed in appendix). The channels through which social and cultural life affect mortality could be better identified if this information was known. However, no historical data (known to the author) contains both the detail of the 1911 census data and information on medical causes of death.

One further issue pertains to the high rates of residential mobility in British cities before World War I (see Pooley 1979). The census information was enumerated in 1911 and as a result, the deaths of children may not have occurred at their parent's place of residence in the year of the census. Thus, it is unlikely that the address reported in the census fully captures the hazards faced by all children. The direction of this bias is currently unknown in the literature and cannot be easily remedied.

I investigate this issue by estimating mobility across city wards using a new linked sample of 2,000 men provided by Connor (2015). I find that 52 percent of men were located in the same Dublin ward after ten years. Further, ward boundaries were not stable, and this estimate comes from a sample with some matching error. As such, this is a conservative estimate of the true rate of persistence. Further, a recent study of Belfast by Reid et al. (2015) suggests that intra-urban moves in Irish cities tended to be over short distances and between similar neighborhoods. Given that this sample is focused on under-5 mortality, these findings suggest that the majority of past mortality events likely occurred in similar areas to the 1911 place of residence.

3. Multilevel Estimation Strategy

My approach builds on recent multilevel analyses of segregation and demographic outcomes (Spielman and Logan 2013; Xu, Logan, and Short 2014; Clark et al. 2015; Manley et al. 2015). I study early-age mortality using a contextual conceptualization of geographical effects with the addition of spatial variables (see Owen, Harris, and Jones 2016 for detailed discussion). This permits the study of spatial and place effects that go beyond the analysis of aggregate characteristics (Subramanian et al. 2005). Moreover, this approach allows for the exploration of within-place heterogeneity (Duncan, Jones, and Moon 1998; Jones 1991). Put differently, this approach allows me to study the effect of place on early-mortality and also whether these effects vary by religion.

I rely on hierarchical multilevel models throughout this study with couples at level one and streets at level two. This approach provides a number of statistical and interpretative advantages over classic Ordinary Least Squares estimation (OLS). Multilevel models perform at least as well as OLS approaches (Gelman and Hill 2006). These models reduce estimation errors due to spatial dependencies, provide an efficient means to model both couple- and street-level variation, and permit analyses of multiscalar processes. A common alternative, one typically utilized in econometric research, is to rely on geographical fixed-effects. However, "controlling" for differences between places in this way forgoes the ability to estimate contextual and heterogeneous within-place effects.

My modeling strategy is as follows. First, I used maximum likelihood estimation to examine mortality by regressing the mortality index on the variables of interest for all 13,247 couples. These models were estimated across two levels: couples (i) living on streets (j). I then estimated a set of cross-level interaction models, from which I examine whether Catholics and non-Catholics differ when living in similar places. Finally, I use a set of interaction models to determine the average and heterogeneous effects of hazards and interventions among the 12,429 geolocated couples.[11]

The lme4 package in R was used for all modelling (Bates et al. 2016) and the general two-level equation is estimated as:

$$Y_{ij} = \beta_0 + \beta_1 x_{1j} + \beta_2 x_{2ij} + u_j + e_{ij} \quad (2)$$

where Y_i refers to the mortality index of couple i on street j. βx_{ij} and βx_j refer to independent variables estimated at the couple- and street-level, respectively. The parameter e_{ij} is the error term for couple i on street j while u_j is the error term for each street. β_0 refers to the intercept for the overall model. The intercept for each street can be defined as $\beta_0 + u_j$.

There is considerable debate over the appropriateness of relying on p-values for significance testing when using multilevel models (see Bates et al. 2014). While many modelling packages include p-values, the lme4 package intentionally does not. I used the "lmerTest" package to estimate the p-values shown in this analysis (Kuznetsova, Brockhoff, and Christensen 2016). These are calculated using log-likelihood ratio tests and F-tests, and are similar to those found in most statistical software packages. However, I also cross-checked the significance of estimates with Wald tests (Goldstein 2011). These tests produce largely similar conclusions and are included in the appendix.

The fit of models and the significance of the fixed effect estimates were evaluated using a number of methods. To evaluate model fit, I include Akaike Information Criterion (AIC) and Deviance Information Criterion (DIC) with each model. With the addition of new variables, reductions in the AIC and DIC suggest an improvement in model fit. The significance of the random intercept models were tested using likelihood ratio tests and these were significant at the 0.01 level.[12]

4. The Disease Environment

This section provides an overview of mortality and residential conditions in Dublin. I first define the study area and then use street-level data to describe the relationship between mortality and general residential patterns. I show a tight link between segregation and health inequality. Mortality was higher in areas with greater shares of Catholics and lower in more ethnically and religiously diverse parts of the city. To examine within place differences, I compare Catholic and non-Catholic mortality on the same streets. While there is evidence of marginal within-street differences in mortality by religion, spatial inequality in health appears to be driven by differences other than religion.

Even at highly aggregate scales, there is evidence of spatial inequality in mortality. Figure 2 shows the level of mortality across the fifteen city wards of Dublin. This area was resident to 268 thousand people. In this map, zero references the average, positive numbers correspond to higher than average mortality while negative values refer to below average mortality. Mortality appears to have been lower in the more peripheral wards of Fitzwilliam and Arran Quay. These lower mortality areas stand in contrast to central city wards such as Inns Quay, North City, South City and Trinity where conditions were considerably worse.

Many reports highlight the poor quality of sanitation, water and housing in central city areas. While Dublin had clean water for decades, families on poorer streets obtained water from unhygienic public fountains. In these places, observers claimed to see spigots “surrounded with faecal matter” (The Lancet 1900 p. 159). These conditions did not improve until a city-wide upgrade of the sewage removal system in 1906 (O’Brien 1982). Housing was also of low quality in these places and slum closures were common. However, the congestion of Dublin’s housing market meant that these closures were limited in their effectiveness, as evictees struggled to find quality and affordable upgrades (Cameron 1898). The culmination of these factors exacerbated early-age mortality.

The pattern of high central-city mortality is corroborated after scaling down the analysis from ward- to street-level observations. In Figure 3, mortality is represented as a continuous surface derived from the street-level estimates of mortality. This surface was created using a standard interpolation method.[13] It is easier to interpret mortality patterns from this representation than from more cluttered street location data. On this map, areas colored with red show high mortality while areas shaded in green tones represent lower mortality. This map shows evidence that early-age mortality was highly localized. High mortality is visible in proximity to the River Liffey, and stretches into northern central and western areas of the city.

These patterns overlap with patterns of segregation by religion. During the nineteenth century, Dublin’s central-city had become largely Catholic, working-class and populated by tenement housing (Daly 1984; Brady and Simms 2001; McManus 2002). Figure 3 includes symbols for streets where the population was greater than 50 percent Jewish, Protestant or Catholic. Streets with high poverty and mortality also tended to be heavily Catholic. In contrast, areas shown to have lower mortality were more likely to be located on the edge of the city and comprise large shares of Protestant and Jewish families.

Migrants also disproportionately lived on low mortality, peripheral streets. The interpretation of Figure 4 is identical to Figure 3 but now includes points to represent streets heavily populated by Irish and overseas migrants to the city. Despite living in different areas to non-Catholics, the geography of migrants also intersects with low mortality areas. Streets with greater shares of migrants were largely located in the low-mortality southeastern and northwestern areas of the city, while the center of the city had few streets heavily populated by migrants.

Taken together, these maps show that mortality was highest in the central and northeastern areas of the city and lower elsewhere. In these high mortality places, poverty was higher, housing quality and sanitation poorer, and the population more likely to be Dublin-born and Catholic (Connor, Mills, and Moore-Cherry 2011; Ó Gráda 2004). However, returning to the original debate among experts over the "problem" of mortality, it is difficult to deduce from this description how much these spatial patterns in health reflect heterogeneity in people-place interactions and how much they reveal wider poverty and housing market sorting across streets.

This can be examined further by presenting Catholic and non-Catholic outcomes across streets of different composition. If religion was a key determinant of mortality, one would expect higher mortality for Catholics compared to non-Catholics living on the same streets. This is investigated in Table 3, which shows the literacy, occupational score, parity and mortality for Catholic and non-Catholic couples lived on streets with different religious and birthplace compositions. This table shows strong intra-street correlations in outcomes for Catholics and non-Catholics.

Catholic couples living on heavily Catholic streets experienced the highest level of mortality. These couples lost almost one in five of their children (19 percent) and held the lowest average occupational scores (42). However, non-Catholics living on these streets experienced only slightly less mortality (17 percent) but also held higher status occupations (44). This within-street similarity suggests the importance of place effects over religious influences.

These patterns reverse on streets with high shares of non-Catholics. Catholic and non-Catholic couples living on majority non-Catholic streets held high ranking occupations (55-56) and the mortality of their children almost halves (11-12 percent). However, in this case, Catholic mortality is actually lower than non-Catholic mortality. Although within-area differences *did* exist, this table suggests that differences between places, other than religion, drove spatial inequalities in health.

This said, Table 3 also reveals that residential sorting by economic status may not explain all of the variation in mortality between streets with different population shares. Catholic and non-Catholic couples on heavily Jewish streets held occupations slightly higher than average (48-50) but experienced very low levels of mortality (0-5 percent). In contrast, Non-Catholics living on heavily Protestant streets held even higher ranking occupations (56) but experienced two-fold higher mortality (12 percent) than their counterparts living on Jewish streets. This weakening of the relationship between SES and mortality suggests that standard economic characteristics are necessary but not sufficient to explaining spatial variations in mortality.

5. Main Results

The main results are presented in three sections. Section 5.1 assesses whether differences in mortality by religion can be explained by demographic characteristics and couple- and street-level measures of poverty. Section 5.2 examines the influence of street-level segregation on mortality by religion and birthplace. Section 5.3 tests for heterogeneous effects of poverty on Catholic and non-Catholic outcomes. Section 5.4 focuses explicitly on the geolocated sample to examine treatment and hazard effects on mortality, and interactions by religion.

Table 4 provides a baseline for comparison to subsequent analyses throughout the results section. Column 1 shows individual coefficients for 15 univariate regression models with one effect modelled at a time, while Columns 2 and 3 present the street- and couple-level ("Residual") variance estimates. These estimates are also reported for the two variance components models. These "null" models show the baseline variance partitioning between the couple- and street-levels for the full sample of 13,247 couples and the geolocated sample with 12,429 couples.

The univariate estimates in Column 2 provide estimates for the effect of religion, ethnicity and poverty on mortality with no control variables. These estimates show intuitive effect across all economic and residential characteristics. Most notably, the coefficients of -0.29 and -0.75, representing lower Protestant and Jewish mortality, provide an important benchmark. A primary objective of this study is to determine how much of the gap between Catholic and non-Catholic outcomes can be attributed to factors related to SES, location and segregation. To do this, these estimates can be compared against those from the multivariate models with control variables.

Baseline difference in the mortality index by religion can be interpreted in terms of the number of children deceased. An estimate of -0.29 for Protestants relative to Catholics is equivalent to a couple married five to nine years, losing only one of their five children compared to losing two. Interpreting the large Jewish coefficient is more challenging. This is because most of the variation in mortality is not driven by differences in the number of children deceased but the share of couples who had any children die at all. Roughly, 41 percent of Catholic couples lost at least one child, while that figure was 28 percent for Protestants and only 11 percent for Jewish couples.

At the level of the street, the determinants of early-age mortality can be inferred from the share of variance attributable to street-level differences. This share can be calculated by dividing the estimated street-level variance in Column 4 by the sum of the residual and street-level variance. In the variance components model for the full sample, slightly less than two percent of mortality can be attributed to differences between streets. While this share appears small, it is driven by the nature of the outcome: the majority of children on streets, irrespective of hazards, survive, and most couples experience no mortality.[14]

The estimates of street-level variance suggest that broader residential patterns by religion and ethnicity account for a large share of spatial inequality in mortality. Couple-level measures of SES, religion and birthplace explain roughly 25 to 30 of the difference between streets. In contrast, the economic status of the street explains almost 35 percent, while the diversity index explains 48 percent. The high explanatory power of SES, and ethnic and religious segregation on street-level differences underscores the link between these processes and health inequality in Dublin.

5.1 Baseline Effects on Mortality

In this section I formally test how much of the difference in Catholic, Protestant and Jewish mortality can be attributed to SES and residential characteristics. I do so by trying to explain differences in early-age mortality by religion using various control variables. These analyses take the following form:

$$Mortality\ Index_{ij} = \beta_0 + \beta_1 Religion_{1ij} + \beta_k x_{kj} + \beta_k x_{kj} + u_j + e_{ij} \quad (3)$$

Where the outcome variable is the mortality index for couple *I* on street j and the variable of interest *Religion* refers to whether the couple is Catholic, Protestant or Jewish. The coefficient $\beta_k x_{kij}$ refers to a set of couple-level controls while $\beta_k x_{kj}$ refers to street-level measures. The parameters e_{ij} and u_j are the couple- and street-level error terms.

SES and parity explain more than 55 percent of the gap in Catholic and Protestant early-age mortality but almost none of the difference in Jewish outcomes. The addition of control variables in Columns 2 and 3 reduce the Catholic-Protestant mortality gap from -0.29 to -0.13. Around 69 percent of this reduction is attributable to differences in SES with the remainder explained by wife's employment and fertility. At most, these measures can explain only 12 percent of the gap in Christian and Jewish outcomes.

These models show that mortality varied by characteristics other than religion. The effect of illiteracy, husband's occupation and living on a higher poverty street is commensurate or larger than the gap in Protestant and Catholic mortality. The persistence of these effects within the same model suggests that literacy, occupation and location capture different aspects of early-age mortality. This is most notable for the particularly large effect of wife's literacy which reduces mortality by -0.21. For comparison, a standard deviation in husband's occupation reduces mortality by -0.04. A standard deviation increase in husband's occupation is equivalent to the difference between building laborers and carpenters or carpenters and bookkeepers. Thus, it would take a very large occupational upgrade to be commensurate with the disadvantage of illiteracy.

Marital fertility and the employment of the wife also have strong and intuitive effects. These variables are hypothesized to be proxies for the potential time mothers can devote to childcare. Higher levels of marital fertility, in particular, is also suggestive of earlier weaning among infants. Consistent with these hypotheses, labor force participation and increases in the number of children per year married, are both associated with higher mortality.

The interpretation of these effects may be more suggestive of differences in poverty than in religious differences in childcare, breastfeeding and weaning. First, the women's employment was typically a means of supplementing income in low SES families. Further, while lower marital fertility is suggestive of differences in the methods of feeding infants, it is unlikely that this can be solely attributed to attitudes and norms toward breastfeeding. For example, historical reports from Ireland suggest that many women had difficulty in breastfeeding due to extreme malnourishment (Earner-Byrne 2006).

The interpretation of these measures of marital fertility and wife's employment should be regarded with caution. There is a possible endogenous relationship between the employment of women and marital fertility, with early-age mortality. The decision to work or to have more (or less) children not only affected child survival, but could also have been a response to the deaths of previous infants or children. In some cases, it is likely early-age mortality which drives wife's employment and fertility. However, it is unlikely that this could explain the entire effect of these variables.

These findings show that differences in SES account for a large share of the inequality in early-age mortality across space and between Catholics and Protestants. The Catholic-Protestant gap more than halved with the addition of economic and demographic controls. However, low Jewish mortality remained largely robust. This analysis also provided suggestive evidence that breastfeeding and childcare had important effects on mortality outcomes. The control variables explain much of the difference between places. The level of street-level variance declined fourfold from slightly under two percent of the total variance to less than half of one percent between the variance components models (Table 4) and Column 3 of Table 5.

5.2 Heterogeneous Effects of Segregation

This section tests if segregation had effects on mortality beyond individual characteristics, and whether these effects varied by religion and birthplace. It is plausible that the effect of segregation could amplify between group differences in resources, hazard exposure and behavior, on existing inequalities in health (Cutler, Glaeser, and Vigdor 2008; Sampson 2012). I model the effect of segregation (diversity index) by religion and birthplace. This specification takes the following form:

$$\begin{aligned} Mortality\ Index_{ij} &= \beta_0 + \beta_1 Religion/Birthplace_{1ij} + \beta_2 Diversity_{2j} \\ &+ (\beta_1 Religion/Birthplace_{1ij}\beta_2 Diversity_{2j}) + \beta_k x_{kij} + \beta_k x_{kj} + u_j + e_{ij} \end{aligned} \quad (4)$$

where the classification of couples by religion and birthplace is interacted with the characteristics of the street or with$\beta_k x_{kij}$, a set of k couple-level characteristics. The coverage of Jewish couples across streets is relatively thin and as a result, they are collapsed with Protestants, into a single non-Catholic category.

Table 6 shows that lower levels of Protestant mortality is not driven by differences in birthplace. One plausible explanation for the wider differences in early-age mortality by religion is that parents and children of different religion were differentially exposed to the urban environment. However, Column 1 shows higher mortality among Dublin-born Catholics but also that Protestant mortality is lower irrespective of birthplace. Mortality is lowest for Russian Jewish and British-born Protestant families ("Other-Outside Ireland"). Further, mortality among the "Other-Dublin" group was 0.22 points lower relative to Dublin-born Catholics.

Residential diversity was associated with lower mortality. Column 2 shows that a standard deviation increase in street-level diversity is associated with a 0.04 reduction in the mortality index. The result is robust to couple- and street-level SES characteristics. This suggests that the effect of diversity was independent of more traditional economic and housing market factors.

To explore this further, Column 3 interacts the diversity index with the Religion/Birthplace categories. The main effect for diversity now references the slope of the diversity effect for Catholics. Diversity appears to have been particularly beneficial for Dublin- and foreign-born Catholics. On a street with an average level of diversity (a diversity value of 0.42) the mortality of non-Catholics born in Dublin was 0.24 points lower than that of Dublin-born Catholics. From this point, a one standard deviation increase in diversity was associated with a 0.06 reduction in mortality for Catholics and a non-significant, 0.08 increase for non-Catholics. This comparison shows that the gap in Dublin-born Catholic and non-Catholic mortality strongly converges at high levels of residential diversity.

5.3. Exposure to Poverty

This section investigates whether exposure to poverty at the couple- and street-level varied in its influence by religion. If religious differences in behavior were important, it is plausible that these differences should be more easily observed in circumstances where disease and mortality risk was higher. This is tested with the following specification:

$$\begin{aligned} Mortality\ Index_{ij} &= \beta_0 + \beta_1 Catholic_{1ij} + \beta_2 Husband's\ Occupation_{2ij} \\ &+ \beta_3 Status\ of\ Street_{3ij} + (\beta_1 Catholic_{1ij} \beta_2 Husband's\ Occupation_{2ij}) \\ &+ (\beta_1 Catholic_{1ij} \beta_3 Status\ of\ Street_{3ij}) + \beta_k x_{kij} + \beta_k x_{kj} + u_j + e_{ij} \end{aligned} \quad (5)$$

where the level of poverty or the degree to which children are at higher risk is inferred from the effect of $Husband's\ Occupation$ and $Status\ of\ Street$. The interaction of $\beta_1 Catholic_{1ij} \beta_2 Husband's\ Occupation_{2ij}$ and $\beta_1 Catholic_{1ij} \beta_3 Status\ of\ Street_{3ij}$ are used to test whether Catholics experienced disproportionately higher mortality at lower levels of SES or on lower status streets.

These results are reported in Table 7 which shows that Catholic mortality was more responsive to changes in the poverty level. Column 2 shows the interaction of husband's occupation and religion on early-age mortality. A one standard deviation increase in husband's occupation is associated with twice the reduction in mortality for Catholics than non-Catholics. Column 4 corroborates this claim at the level of the street. The negative impact associated with residence on the bottom third of streets by SES is stronger for Catholics than non-Catholics.

Much of the impact of husband's occupation appears to be channeled through place of residence. Column 5 includes the main effects and interactions for the husband's occupation and the status of the street. In this model, the coefficient for occupation is halved and is now non-significant while the street-level effect is reduced by roughly 13 percent and is marginally significant.

Column 6 introduces the diversity index as a control variable. Although the interaction effects slightly attenuate in this model, the interpretation remains largely unchanged. Moreover, this indicates that at least a small portion of the beneficial diversity effect appears to be due to more diverse places having lower poverty.

5.4 Exposure to Hazards and Interventions

This section uses the 80 percent geolocated sample to assess whether exposure to hazards and interventions influenced mortality outcomes. This provides further analysis of the within-place inequalities in early-age mortality and also tests whether the consumption of contaminated substances contributed to higher early-age mortality among Catholics. These models are specified as:

$$\begin{aligned} Mortality\ Index_{ij} &= \beta_0 \ + \beta_1 Catholic_{1ij} + \beta_2 Proximity\ to\ Hazard/Intervention_{2ij} \\ &+ \ + \beta_1 Catholic_{1ij}\ \beta_3 Proximity\ to\ Hazard/Intervention_{3j} + \beta_k x_{kij} \\ &+ \beta_k x_{kj} + \ u_j + e_{ij} \end{aligned} \quad (6)$$

where the variable of interest, *Proximity to Hazard/Intervention* refers to either the distance of couple i on a given street j from a particular hazard or intervention, or where the couple can be identified as having directly received the intervention, such as in the housing quality variable. These variables are also interacted with whether or not the couple was Catholic. A set of economic and residential control variables are included to more robustly identify these effects.

Table 8 shows intuitive effects of hazards and interventions on early-age mortality. Column 1 provides baselines for religion, husband's occupation and neighborhood status before estimating these new effects in Column 2. Three of these four hazard and treatment measures have significant effects on mortality. Access to pasteurized milk and living in higher quality housing both reduce mortality. In contrast, living near earlier typhoid fatalities, a proxy for sanitation and building quality, is associated with significantly higher mortality. Notably, the effect of living in high quality housing is large enough to erase the difference between the average Catholic and non-Catholic couple. Moreover, these variables lead to substantial reductions in the effects associated with the status of streets

To examine whether hazards and interventions affected Catholics more than non-Catholics, Column 4 interacts these effects with religion. These treatments appear to have largely similar effects by religion. A notable exception is the (marginally significant) beneficial effect for access to pasteurized milk. Catholic mortality is substantially lower in areas close to the milk depot. Further, in these places Catholic mortality even drops below the average level of Protestant mortality. This provides support for the claim that weaning practices influenced mortality. However, this effect comes with the caveat of a large standard error. Thus, it is difficult to precisely infer the magnitude of this benefit.

For completeness, Column 3 controls for the level of diversity on each street. Aside from a slight increase in the p-values of the variable estimates, the interpretation of the model remains largely unchanged. Thus, these findings suggest that the effect of hazards and interventions and their interaction with religion are independent of residential diversity.

6. Concluding Remarks

A century ago, medical experts claimed that the behaviors and teachings of Dublin-born Catholics were responsible for the city's high rate of infant and child mortality. Others disagreed, arguing instead that these outcomes reflected inequality and political mismanagement akin to a "Dublin Holocaust". The findings of this article suggest that high mortality in Dublin had its roots in poverty and residential inequality rather than in Irish or

Catholic behaviors. Although I show evidence of religious difference in mortality, and benefits of residential diversity for Catholics, inequality in outcomes could have been curtailed by addressing poverty and the city's housing and infrastructural shortcomings.

This article contributes to the historical health literature by showing that mortality varied substantially across urban space during this period. For example, on the bottom tenth of streets, as ranked by either their ethnic diversity or SES, parents lost one in five of their children. These streets were largely concentrated in the center of the city. In contrast, on streets ranked in the top tenth, only one in ten children died. These areas were more likely to be located along the city periphery.

The article highlights four influential processes shaping spatial inequality in health. First, housing market sorting produced a distinct geography of health, and these patterns reflected various forms of socioeconomic and health inequality. Second, these places also influenced health by exposing low-income families to hazards. Improvements in these disadvantaged areas also appear to have been a low political priority for public authorities and private actors (see Prunty, 1998). Third, the impact of hazards and disease were mediated by group-specific differences in knowledge, behavior and resources. Finally, religious and ethnic differences in health attenuated on more residentially diverse streets. However, some unquantifiable mixture of market constraints and preferences created barriers to this beneficial social contact.

These findings suggest that more effective policy could have mitigated religious differences in mortality. For example, recent studies have shown that the effect of clean water on mortality was severely constrained in cities with poorly developed sanitation systems and low-quality housing (Alsan and Goldin 2015; Kesztenbaum and Rosenthal 2016). Sanitation in low SES areas of Dublin was poor and much of the housing stock was dilapidated. These conditions disproportionately affected low SES and Catholic families. As such, improvements in poverty and urban infrastructure would have had large benefits for these families.

Going forward, a key question is why parents that could have improved health outcomes for their children by leaving high risk areas did not do so. This puzzle is underlined by the reluctance of migrants to move into these less healthy places. Understanding this problem could provide insight into neighborhood lock-in and how at-risk populations respond to risk and infrastructural improvements.

Finally, this analysis provides an example for potential future research using complete-count historical data with a multilevel approach. The detail of this new historical data provides opportunities to study important questions in the contemporary context and also to interrogate questions and assumptions of historical significance. There is considerable scope to use historical data to recreate longitudinal samples and link these data to various forms of spatial information. Multilevel modelling provides a flexible apparatus from which to analyze these data in a statistically efficient and geographically sensitive way.

7. Notes

[1] The United States is the wealthiest country in the world but ranks 26th in infant mortality. African Americans and other minority populations have infant mortality rates up to double that of Caucasians.
[2] The WHO reports present-day under-five mortality rates of 76 per thousand for low-income countries and seven per thousand for high-income countries.
[3] Thornton and Olson (2011) are an important exception to this.
[4] The registrar general was responsible for the 1911 census and relied on the police for enumeration. Each census form was completed and signed by the head of household and the enumerator then provided a summary report. This was the last census taken of the entire island.
[5] Although mixed-marriages were rare in Dublin (see Table 1), I have included a separate analysis in Appendix Table 3 to show that classifying couples differently would not change the overall results.
[6] The HISCAM index refers to the relative position within the stratification structure. Values approaching 100 correspond to the most prestigious occupations, and approaching 0 for the lowest. For more details see: http://www.camsis.stir.ac.uk/hiscam/
[7] For consistency with earlier work, I used level 14 of the Coale and Demeny West model life table.
[8] See Appendix Tables 1 and 2 for selectivity in successfully geolocating streets.
[9] Cameron and Grimshaw (1888) commissioned the Royal Engineers' Department to map these typhoid fatalities in order to ascertain the source of excess mortality in Dublin's Royal Barracks. The spatial occurrence of these deaths was also a function of population density. Thus, I attempt to control for population density by summing the population of streets within 200 meters of each street midpoint.
[10] Although information on the quality of all housing was collected in the 1911 census it has not been indexed by the National Archives of Ireland. I identified this housing using addresses and other information contained in the name of street variable in the census.
[11] There are some slight differences in variable choice between the spatial and non-spatial models. Notably, in the spatial models I only modelled streets and not wards. Further, I modelled total population within 200 meters of the street instead of using the total population of the street.
[12] This comparison was done by comparing the variance components models to their OLS equivalent. There is considerable skepticism within the literature around doing this but I mention this for completeness.
[13] The point map is included in Appendix Figure 4 and would lead to the same conclusion. The mortality surface was estimated using an exact interpolation method (ordinary Kriging) using a spherical model variogram with a search distance of three hundred meters.
[14] It is difficult to find a point of comparison because few studies in this literature have undertaken a similar analysis. While two percent of the unexplained variance can be attributed to differences between streets, that value is 30 percent for a model predicting husbands' occupation.

8. References

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Tables

Table 1. Demography by Religion

Religion and Birthplace of Wife	**Obs.**	**Religion/ Birthplace**		**Endogamy**	**Occupation Ranking (HISCAM)**	**Lives on Poorest 1/3 of Streets**	**Child Born**	**Child Dead**
	Count	Catholic	Dublin	Share	Mean	Share	Mean	Share
Wife's Religion								
Catholic	11,581	-	72%	98%	45	37%	3.26	17%
Protestant	1,499	-	43%	95%	52	13%	2.81	12%
Jewish	167	-	7%	99%	54	3%	3.40	6%
Wife's Birthplace								
Dublin	8,962	93%	-	69%	45	40%	3.23	17%
Outside Dublin	3,392	87%	-	42%	47	24%	3.24	15%
Outside Ireland	893	36%	-	31%	50	16%	2.88	12%
All	13,247			98%	46	34%	3.21	16%

Table 2. Description of Variables

	Description & Categories	Count	Mean	SD
Couple-level				
Age of Wife	Age of wife		30.71	5.7
Age at Marriage	Age at marriage.		23.40	4.6
Marital Fertility	The number of children born per year of marriage.		3.11	2.1
Wife Works	Whether wife reports an occupation	1,022		
Husband’s Occupation (HISCAM)	Quantified occupational standing.		45.86	10.6
Literacy (c)	Husband can read and write	12,155		
	Wife can read and write	11,810		
Birthplace (c)	Dublin	8,962		
	Outside Dublin	3,392		
	Outside Ireland	893		
Religion (c)	Roman Catholic	11,581		
	Jewish	167		
	Protestant	1,499		
Religion/Birthplace (c)	Catholic-Dublin	8,309		
	Catholic-Outside Dublin	2,954		
	Catholic-Outside Ireland	318		
	Other-Dublin	653		
	Other-Outside Dublin	438		
	Other-Outside Ireland	575		
Street-level				
Status of Street	Low	4499		
	Medium	4393		
	High	4355		
Diversity	An index representing the diversity of street with respect to religion and birthplace. Index used by Theil (1982).		0.43	0.22
Proximity to River Liffey	Distance to the nearest point on the River Liffey (kilometers and inverted)		-0.75	0.44
Proximity to Milk Depot	Street is within 400 meters of the Arbour Hill milk depot in Arran Quay	614		
Proximity to previous typhoid fatalities	The number of typhoid fatalities from 1882-1887 within 200 meters of the street		8.73	6.5
Lives in Quality Housing (c)	Housing constructed by Dublin Corporation and other philanthropic organization; identified using the street address.	332		

(c) = categorical variable

Table 3. Catholics and Non-Catholics on Different Streets

	Population of Street	Obs.	Occupational Score (HISCAM)	Literate	Child Born	Child Dead
		Count	Mean	Share	Mean	Share
Catholics	> 95% Catholic	3544	42	81%	3.4	0.19
	> 75% Catholic	10205	44	87%	3.3	0.18
	> 50% Catholic	11409	45	88%	3.3	0.17
	< 50% Catholic	172	53	99%	2.9	0.10
	>50% Jewish	7	50	100%	2.3	0.00
	>50% Protestant	102	55	99%	2.8	0.11
	>50% Migrant	481	52	99%	2.8	0.13
Non-Catholics	> 95% Catholic	46	44	89%	3.2	0.17
	> 75% Catholic	704	49	96%	3.0	0.13
	> 50% Catholic	1357	51	97%	2.9	0.12
	< 50% Catholic	309	55	89%	2.8	0.11
	>50% Jewish	44	53	48%	4.0	0.05
	>50% Protestant	160	56	100%	2.4	0.12
	>50% Migrant	307	56	97%	2.5	0.07

Table 4. Variance Partitioning and Univariate Estimates by Variable

	1	2	3	4	5
	Unit	Estimate	Residual σ_e^2	Street σ_{u0}^2	Street Share
Variance Components Model (13,247 obs.)			2.69	0.050	1.8%
Age of Wife	Couple	0.02***	2.674	0.056	2.1%
Age at Marriage	Couple	-0.01*	2.688	0.047	1.8%
Religion [Reference = Catholic]					
Protestant	Couple	-0.29***	2.685	0.035	1.3%
Jewish		-0.73***			
Birthplace [Reference = Dublin]					
Outside Dublin	Couple	-0.11***	2.690	0.037	1.4%
Outside Ireland		-0.32***			
Husband's Occupation	Couple	-0.11***	2.686	0.037	1.4%
Husband Can Read and Write	Couple	-0.38***	2.686	0.034	1.3%
Wife Can Read and Write	Couple	-0.42***	2.683	0.039	1.4%
Status of Street [Reference = High]					
Low Status Street	Street	0.36***	2.684	0.032	1.2%
Mid Status Street		0.15***			
Wife Works	Couple	0.22***	2.686	0.046	1.7%
Marital Fertility	Couple	-0.08***	2.689	0.048	1.8%
Diversity	Street	0.10***	2.689	0.026	1.0%
Variance Components Model (12,429 obs.)			2.689	0.048	1.8%
Proximity to River Liffey (100m intervals)	Street	0.09***	2.676	0.044	1.6%
Proximity to Earlier Typhoid Fatalities (s)	Street	0.11***	2.679	0.038	1.4%
Proximity to Pasteurized Milk Depot	Street	-0.14	2.68	0.048	1.8%
Guinness, Corporation or DAD Housing	Couple	-0.18	2.679	0.049	1.8%
(s) = standard units		*p<0.1; **p<0.05; ***p<0.01			

Table 5. Baseline Effects on Mortality

	Dependent Variable: Mortality Index		
	(1)	(2)	(3)
Constant	1.09***	1.44***	1.42***
	(0.02)	(0.07)	(0.06)
Age of Wife	0.04***	0.04***	0.07***
	(0.004)	(0.004)	(0.004)
Age at Marriage	-0.05***	-0.04***	-0.07***
	(0.004)	(0.005)	(0.005)
Religion [ref = Catholic]			
Protestant	-0.29***	-0.18***	-0.13***
	(0.05)	(0.05)	(0.05)
Jewish	-0.75***	-0.66***	-0.67***
	(0.13)	(0.14)	(0.14)
Birthplace [ref = Dublin]			
Outside Dublin		-0.08**	-0.07*
		(0.03)	(0.03)
Outside Ireland		-0.10	-0.07
		(0.07)	(0.07)
Husband's Occupation		-0.05***	-0.05***
		(0.02)	(0.02)
Wife Can Read and Write		-0.21***	-0.21***
		(0.05)	(0.05)
Husband Can Read and Write		-0.23***	-0.23***
		(0.06)	(0.06)
Status of Street [ref = High]			
Low		0.15***	0.13***
		(0.04)	(0.04)
Medium		0.05	0.04
		(0.04)	(0.04)
Wife Works			0.17***
			(0.05)
Marital Fertility (s)			0.23***
			(0.02)
Street Variance	0.032	0.017	0.012
Residual Variance	2.66	2.62	2.62
DIC	50643	50485	50366
AIC	50724	50643	50550
Observations	13,247	13,247	13,247

(s) = standard units *p<0.10; **p<0.05; ***p<0.01

Table 6. The Effect of Diversity on Mortality

	Dependent Variable: Mortality Index		
	(1)	(2)	(3)
Constant	2.26***	2.24***	2.21***
	(0.28)	(0.28)	(0.28)
Religion/Birthplace [ref = Catholic-Dublin]			
Other-Dublin	-0.22***	-0.20***	-0.24***
	(0.07)	(0.07)	(0.08)
Other-Outside Dublin	-0.16*	-0.13	-0.04
	(0.08)	(0.08)	(0.11)
Other-Outside Ireland	-0.44***	-0.41***	-0.49***
	(0.07)	(0.07)	(0.09)
Catholic-Outside Dublin	-0.11***	-0.09**	-0.11***
	(0.04)	(0.04)	(0.04)
Catholic-Outside Ireland	-0.02	0.004	0.15
	(0.09)	(0.09)	(0.11)
Diversity (s)		-0.04**	-0.06***
		(0.02)	(0.02)
Diversity x Other-Dublin			0.08
			(0.07)
Diversity x Other-Outside Dublin			-0.07
			(0.09)
Diversity x Other-Outside Ireland			0.11
			(0.07)
Diversity x Catholic-Outside Dublin			0.08
			(0.04)
Diversity x Catholic-Outside Ireland			-0.25***
			(0.11)
Street Variance	0.012	0.012	0.012
Residual Variance	2.66	2.66	2.66
DIC	50488	50476	50444
AIC	50648	50650	50662
Observations	13,247	13,247	13,247

(s) = standard units *p<0.10; **p<0.05; ***p<0.01

Controls Include: age, husband's occupation street status

Table 7. The Effect of Poverty on Mortality by Religion

	Dependent Variable: Mortality Index					
	Occupation		Location		Both	
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.89***	0.85***	0.75***	0.81***	0.84***	0.88***
	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)	(0.07)
Wife's Religion: Catholic	0.24***	0.28***	0.23***	0.15***	0.16**	0.14**
	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)	(0.07)
Husband's Occupation (s)	-0.10***	-0.03			-0.03	-0.03
	(0.01)	(0.04)			(0.04)	(0.04)
Catholic x Husband's Occupation (s)		-0.08*			-0.04	-0.03
		(0.04)			(0.05)	(0.05)
Status of Street [ref = High]						
Low			0.31***	0.01	-0.02	-0.05
			(0.04)	(0.13)	(0.14)	(0.14)
Medium			0.11***	0.03	0.01	-0.01
			(0.04)	(0.10)	(0.10)	(0.10)
Catholic x Low Status Street				0.32**	0.28**	0.26*
				(0.14)	(0.14)	(0.14)
Catholic x Medium Status Street				0.11	0.09	0.09
				(0.10)	(0.11)	(0.11)
Diversity Control	N	N	N	N	N	Y
Street Variance	0.026	0.026	0.026	0.023	0.023	0.019
Residual Variance	2.66	2.66	2.66	2.66	2.66	2.66
DIC	50685	50678	50664	50653	50626	50608
AIC	50722	50777	50760	50763	50762	50759
Observations	13,247	13,247	13,247	13,247	13,247	13,247

(s) = standard units

*p<0.10; **p<0.05; ***p<0.01

Controls Include: age, birthplace

Table 8. The Effect of Hazard and Interventions on Mortality

	Dependent Variable: Mortality Index			
	(1)	(2)	(3)	(4)
Constant	0.12	0.17*	0.19**	0.16
	(0.28)	(0.28)	(0.28)	(0.10)
Wife's Religion: Catholic	0.24***	0.23***	0.21***	0.24***
	(0.05)	(0.05)	(0.05)	(0.06)
Proximity to River Liffey (s)		0.03	0.03	0.02
		(0.02)	(0.02)	(0.04)
Proximity to Typhoid Fatalities (s)		0.05***	0.04**	0.02
		(0.02)	(0.02)	(0.05)
Proximity to Pasteurized Milk Depot (s)		-0.15*	-0.14*	0.26
		(0.08)	(0.08)	(0.24)
Lives in Quality Housing		-0.24**	-0.21*	-0.13
		(0.11)	(0.11)	(0.31)
Diversity (s)			-0.04**	-0.04**
			(0.02)	(0.02)
Proximity to River Liffey (s) x Catholic				0.01
				(0.05)
Proximity to Typhoid Fatalities (s) x Catholic				0.03
				(0.06)
Proximity to Pasteurized Milk Depot (s) x Catholic				-0.44*
				(0.25)
Lives in Quality Housing x Catholic				-0.09
				(0.32)
Street Variance	0.029	0.026	0.023	0.023
Residual Variance	2.66	2.66	2.66	2.66
DIC	47551	47475	47463	47450
AIC	47604	47609	47612	47626
Observations	12,429	12,429	12,429	12,429

(s) = standard units *p<0.10; **p<0.05; ***p<0.01

Controls Include: age, husband's occupation street status

Figures

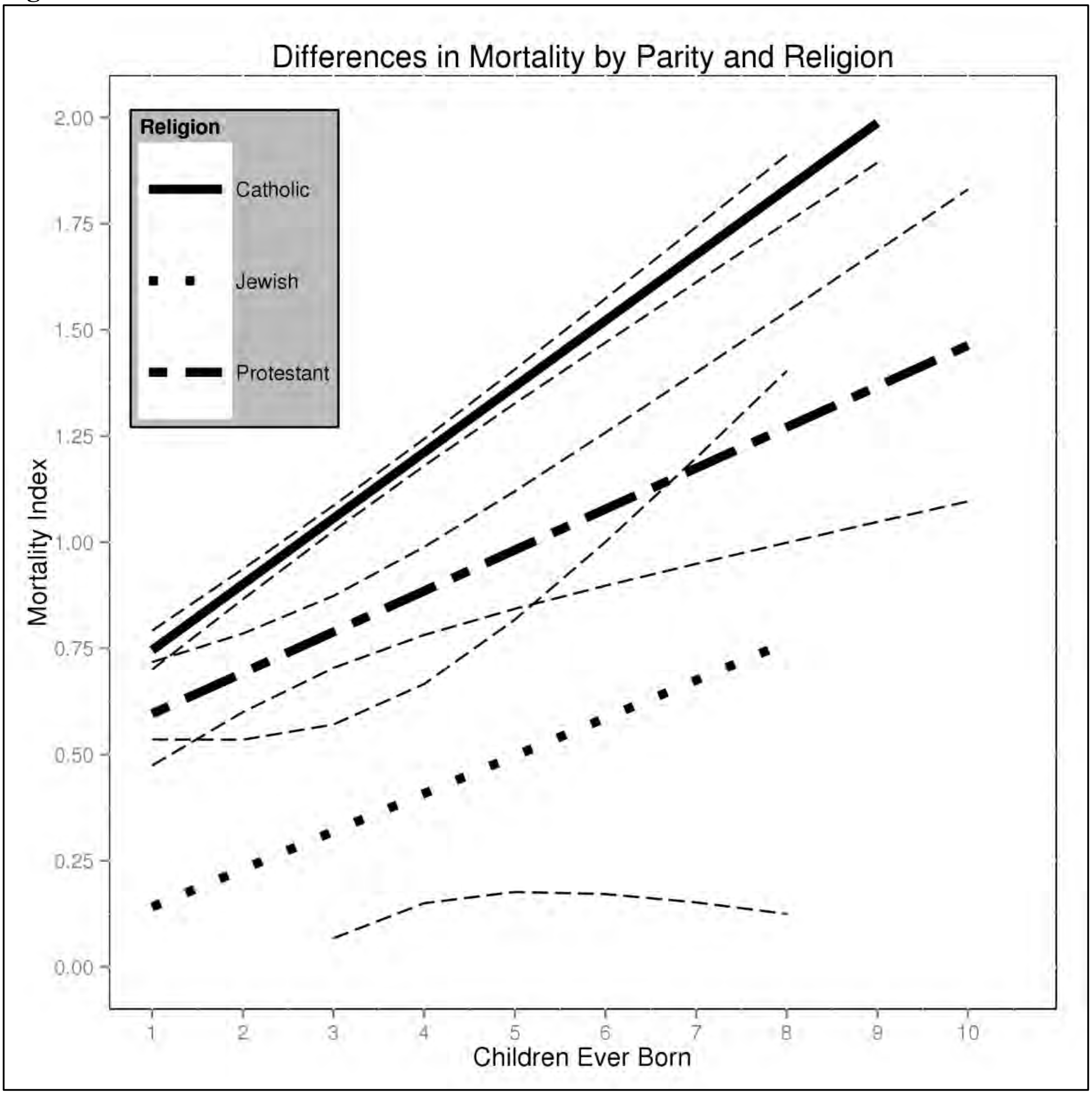


Figure 1. Differences in Mortality by Parity and Religion

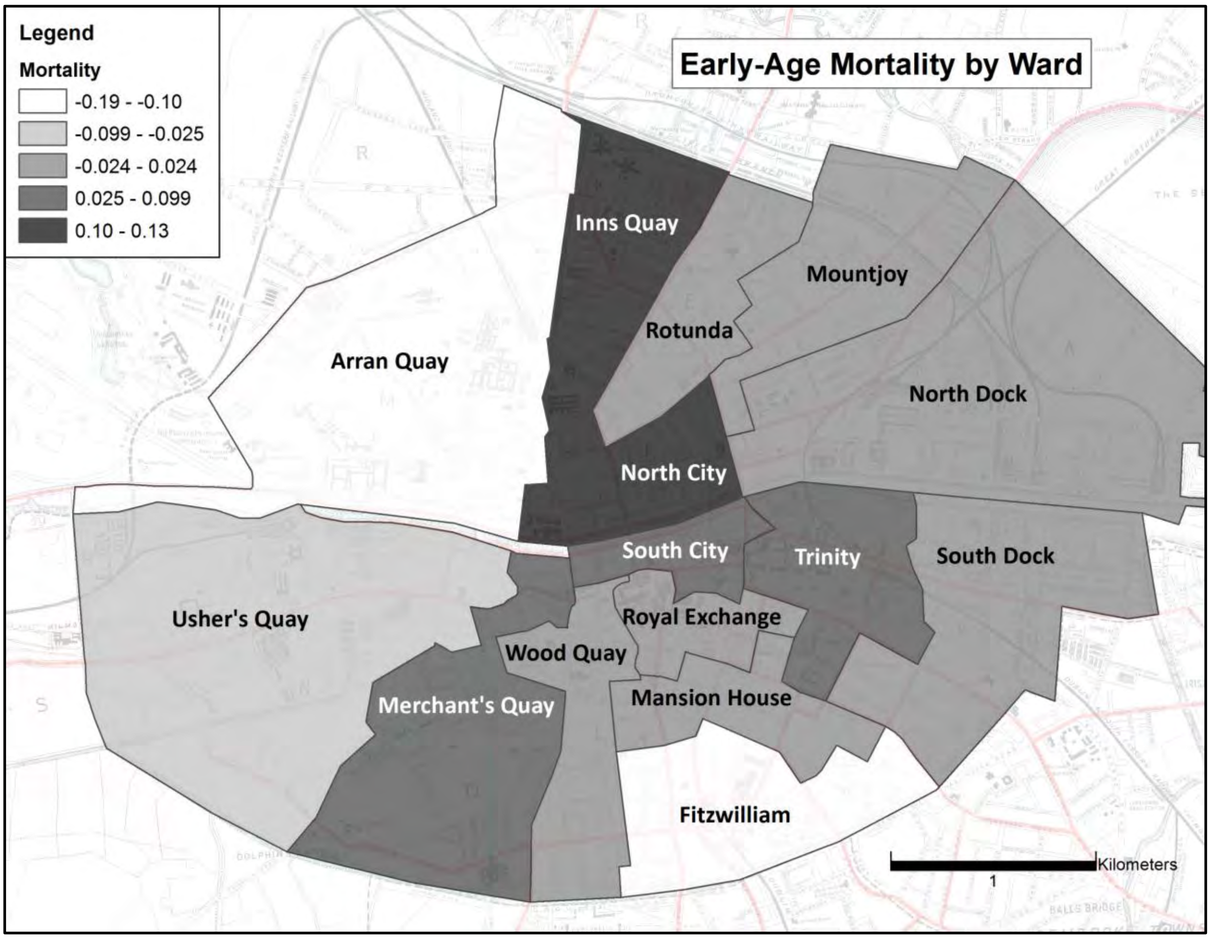


Figure 2. Early-Age Mortality by Ward

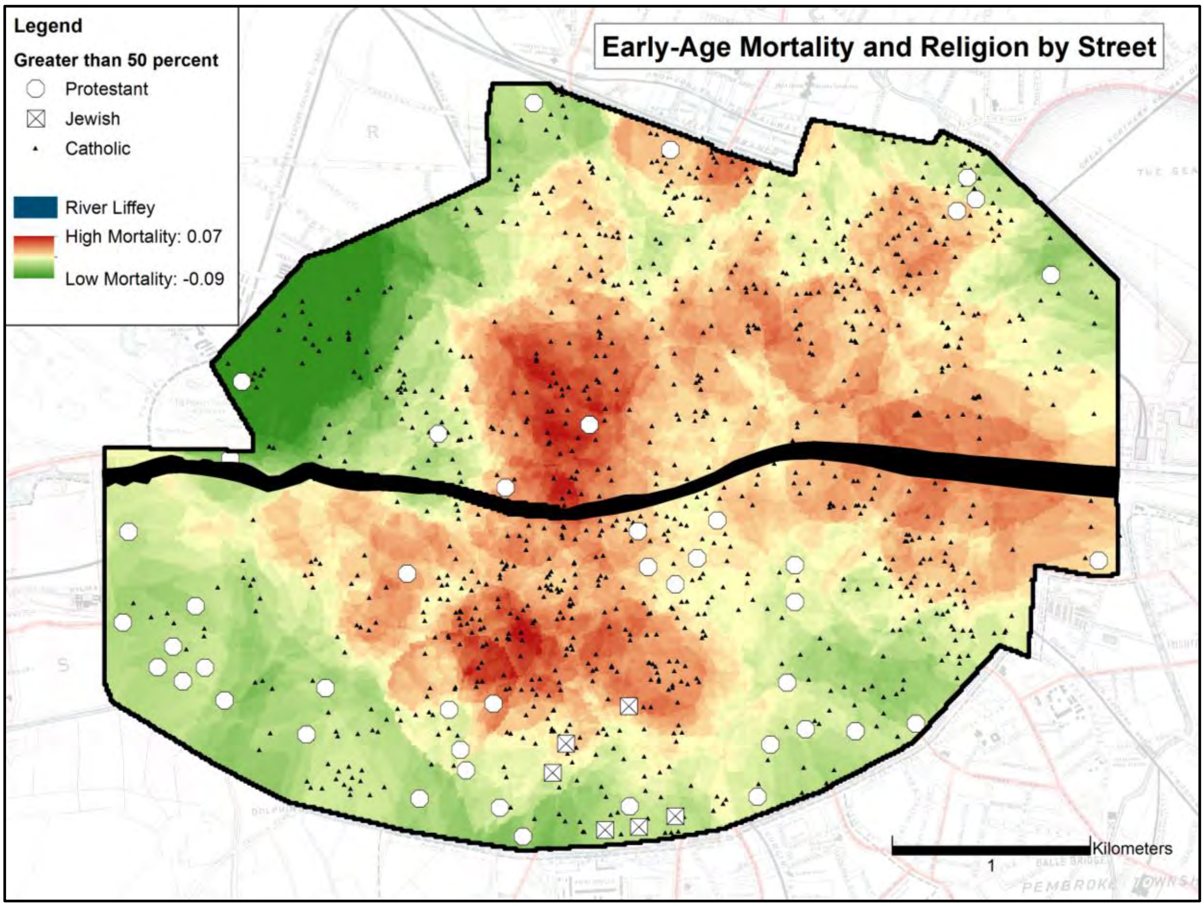


Figure 3. Early-Age Mortality and Religion by Street

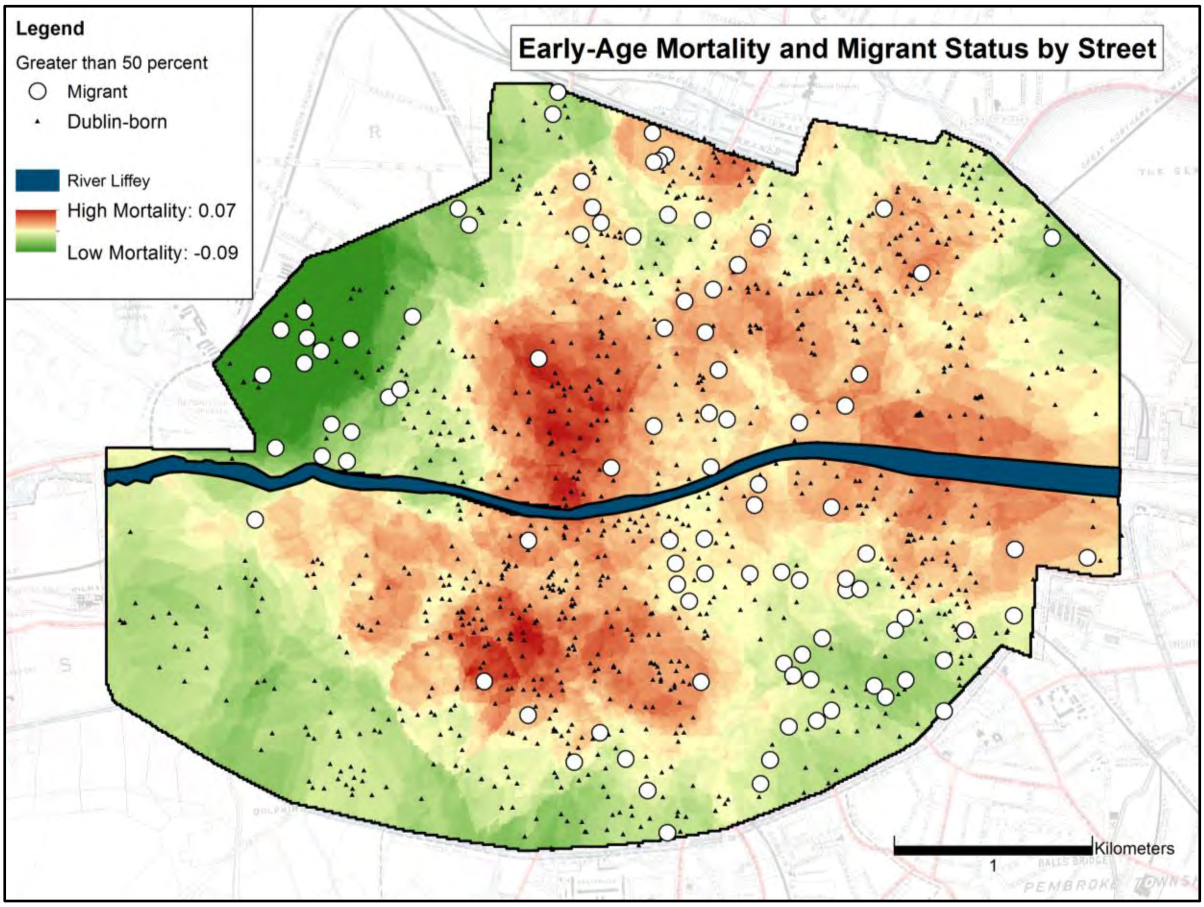


Figure 4. Early-Age Mortality and Migrant Status by Street

Appendix

1. Differences between sample and population be relationship to head

Street	Migrant				Non-Migrant			
	Total	Wife	Lodger	Other	Total	Wife	Lodger	Other
All	4717	0.12 (91%)	0.10 (1%)	0.10 (8%)	9469	0.15 (90%)	0.11 (1%)	0.13 (9%)
> 50% Migrants	683	0.07 (87%)	0.07 (2%)	0.06 (11%)	311	0.08 (87%)	0 (1%)	0.04 (12%)
<= 50% Migrants	4034	0.13 (92%)	0.10 (1%)	0.10 (7%)	9158	0.15 (90%)	0.12 (1%)	0.13 (9%)

Appendix Table 1. Mortality and the classification of mothers as lodgers

Appendix Table 1 shows the share of children deceased and variation in the classification of mothers as wives and lodgers between streets with high and low migrant shares (see Figure 4B street locations). I have shown in the analysis that the migrant share variable serves as a good proxy for streets outside of the city center and with lower exposure to hazards. This table reports the share of children deceased and the share of mothers classified as “Wife”, “Lodger” or “Other” in these areas. Only mothers classified as “Wife” are included in my sample and these women appear to have experienced slightly mortality. Thus, limiting the sample in this slightly underestimates mortality from the sample as a whole.

It is also possible that this classification might vary geographically with, for example, building quality and size or the presence of multifamily homes. If mothers were more likely to be listed as lodgers in areas with greater exposure to hazards, the regression would provide an overly positive effect of migrant status on mortality. My findings show the opposite. Mothers were more likely to be classified as lodgers outside on streets with a higher migrant share. Thus, beneficial migrant effects are probably being slightly underestimated in my sample.

I investigated several sources of bias in constructing the sample. Many husbands erroneously answered or were assigned the fertility information of the wife. Where possible wives with blank fertility information were reassigned the values of their husbands. I analyzed the distribution of missing values for the thirty five couples that did not state their number of years married, the sixty six that did not state their number of children born, and the 456 not stating their number still alive. For those missing responses on children born and years of marriage questions, there was overrepresentation among illiterates and husbands with lower class occupations, those likely to have higher rates of child mortality.

	Child Alive	
Children Born	Missing	Not Missing
One	0.57	0.25
Two	0.20	0.18
Greater than two	0.22	0.57

Appendix Table 2. Parity and Missing Mortality Information

The 'children alive' question is more problematic. Appendix Table 2 shows that younger couples with only two or less children ever born were more likely to not report to number of children still alive. It appears that many mothers whose children had all died left this response blank. This is consistent with a greater share of missing values among mothers with fewer children born. I assigned a zero value to mothers with complete information on parity but missing values for mortality. Following this imputation, the distribution of remaining non-response was similar to other martial fertility variables and appears to have been randomly distributed. I provide a sensitivity analysis for this decision in Appendix Table 3. Although there are some changes in effect size, the direction and significance of key coefficients remain unchanged. The decision not to impute would lower the gap in Catholic mortality but this is expected. Failure to undertake this imputation would lead to the underestimation of Catholic infant mortality.

	Omit Missing	Imputed Missing
(Intercept)	1.257***	1.536***
	(0.047)	(0.061)
Husband Can Read and Write	-0.172***	-0.195***
	(0.041)	(0.053)
Wife Can Read and Write	-0.133**	-0.198***
	(0.046)	(0.059)
Occupation of Husband (ref = Unskilled Worker)		
Farmers and Farm workers	-0.042	0.144
	(0.100)	(0.127)
Foremen and Skilled Workers	-0.111***	-0.154***
	(0.032)	(0.041)
Higher Managers and Professionals	-0.168*	-0.229**
	(0.069)	(0.088)
Lower managers and professionals, Clerical and Sales	-0.081*	-0.014
	(0.039)	(0.050)
Lower Skilled Workers	-0.085**	-0.144***
	(0.031)	(0.040)
Guinness, Corporation or DAD Housing	-0.150*	-0.171
	(0.076)	(0.102)
Religion (ref = Catholic)		
Jewish	-0.425*	-0.627**
	(0.177)	(0.230)
Other Religion	0.159	0.028
	(0.156)	(0.204)
Protestant	-0.117**	-0.121*
	(0.041)	(0.053)
Proportion Catholic on Street	0.030	0.031
	(0.017)	(0.022)
Birthplace (ref = Dublin)		
Ireland	-0.076**	-0.049
	(0.027)	(0.035)
Rest of World	-0.158	-0.137
	(0.123)	(0.158)
Russia	-0.183	-0.062
	(0.208)	(0.270)
Britain	0.033	0.028
	(0.056)	(0.072)
Age	0.091***	0.054***
	(0.003)	(0.004)
Age at Marriage	-0.084***	-0.042***
	(0.004)	(0.005)
Marital Fertility	-0.163***	-0.073***
	(0.006)	(0.007)
	(0.012)	(0.016)
Num. obs.	12859	13247

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Appendix Table 3. Sensitivity Analysis for Imputation of Missing Mortality Information

Three other notable issues pertain to those with missing spouses and maternal mortality. First, in the 1911 British and Irish census, some women may have intentionally misrepresented their marital status to avoid the stigma of illegitimate children; in other cases, women may have been erroneously classified as married. Others' husbands may have been working or travelling on census night. Although this group is heterogeneous, evidence from Belfast suggests that fertility was lower and mortality was higher for married women with absent spouses (see Reid et al. 2015) and this finding is corroborated here for Dublin.

Second, the apparent high rate of residential mobility in Irish cities at this time (see Reid et al. 2015) offers justification to restrict the analysis to those married for fewer years. The fertility and mortality experiences of older couples are more likely to have occurred in different places than to the places in which they were enumerated in 1911. Third, the maternal mortality rate was in in the region of 35 and 60 per 1000 child births during this time in Britain (Chamberlain 2006). Due to this risk, women with worse maternal care and with more children are likely to be underrepresented in the 1911 census and in my analysis.

	Model 1
(Intercept)	0.809***
	(0.010)
Catholic Share of Street (s)	-0.015
	(0.013)
Median Occupational Score of Street (s)	0.003
	(0.011)
Migrant Share on Street	0.032*
	(0.013)
Population Street (s)	0.105***
	(0.010)
Deviance	206.277
Num. obs.	1457

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Statistical models

Appendix Table 4. Logit of Finding Street on Historic Map

Appendix Table 1 shows that geolocated streets tended to be larger in population size. Appendix Table 2 shows logits from a logistic regression model predicting whether a street could be geolocated. While streets with larger populations and a greater migrant share (streets outside of the city-center) were more likely to be located, the Catholic share and economic status of the street had only negligible effects.

Number of Couples on Street	**All Streets**		**Geolocated Streets**	
	Count	Share	Count	Share
One	249	17.1%	131	11.1%
Five or less	789	54.2%	546	46.3%
Twenty or less	1300	89.2%	1024	86.9%
Fifty or less	1428	98.0%	1150	97.5%
One hundred or less	1454	99.8%	1176	99.7%
More than one hundred	3	0.2%	3	0.3%
All	1457	100.0%	1179	100.0%

Appendix Table 5. Comparison of the Population Distributions of Geolocated Streets to All Streets

	1	2	3	4	5	6
(Intercept)	1.440***	1.429***	1.630***			
	(0.047)	(0.048)	(0.028)			
Wife Catholic	0.192***	0.111				
	(0.049)	(0.092)				
Husband Catholic		0.092				
		(0.088)				
Marriage Composition (ref = both Catholic)						
Wife Catholic: Husband non-Catholic			0.015			
			(0.106)			
Wife non-Catholic: Husband Catholic			0.103			
			(0.150)			
Both non-Catholic			-0.220***			
			(0.051)			
Wife Dubliner				0.074*	0.044	
				(0.034)	(0.035)	
Husband Dubliner					0.074*	
					(0.034)	
Marriage Composition (ref = both Dubliners)						
Wife Dubliner: Husband in-migrant						-0.042
						(0.044)
Wife in-migrant: Husband Dubliner						-0.003
						(0.050)
Both in-migrants						-0.127*
						(0.039)
Num. obs.	13247	13247	13247			
Num. groups: street	1457	1457	1457			
Num. groups: ded	15	15	15			

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Statistical models

Appendix Table 6. Regression Showing Mixed-Marriage Effects on Infant and Child Mortality

Notes: these models included the full battery of independent variables. All coefficients were fully robust to the mixed-marriage specification.

	Outcome (Y) = log(mortality index)		Outcome (Y) = Standard mortality index	
(Intercept)	-2.384***	-1.967***	1.090***	1.419***
	(0.028)	(0.098)	(0.017)	(0.065)
relevel(religion, "Catholic")Protestant	-0.636***	-0.316***	-0.288***	-0.135**
	(0.074)	(0.074)	(0.046)	(0.049)
relevel(religion, "Catholic")Jewish	-1.343***	-1.353***	-0.726***	-0.672***
	(0.213)	(0.214)	(0.132)	(0.142)
agecent		0.289***		0.072***
		(0.006)		(0.004)
ageatmarriage_cent		-0.299***		-0.066***
		(0.007)		(0.005)
relevel(birthplace, "Dublin")Outside Dublin		-0.124*		-0.065
		(0.052)		(0.034)
relevel(birthplace, "Dublin")Outside Ireland		-0.110		-0.065
		(0.100)		(0.066)
scale(Mhiscam)		-0.079**		-0.048**
		(0.024)		(0.016)
relevel(e2, "Illiterate")Can Read and Write		-0.310***		-0.207***
		(0.079)		(0.052)
relevel(Me2, "Illiterate")Can Read and Write		-0.256**		-0.229***
		(0.088)		(0.058)
wife_worksyes		0.135		0.170**
		(0.080)		(0.053)
scale(martfert)		0.717***		0.229***
		(0.024)		(0.016)
Num. obs.	13247	13247	13247	13247
Num. groups: street	1457	1457	1457	1457
Var: street (Intercept)	0.088	0.020	0.035	0.016
Var: Residual	7.020	5.991	2.685	2.605

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Statistical models

Appendix Table 7. Comparison of effects in models with and without logged dependent variable

		Catholic	Protestant	Jewish
Can Read and Write	Wife	0.88	0.99	0.71
	Husband	0.91	0.99	0.74
Birthplace	Dublin	0.93	0.07	0.00
	Outside Dublin	0.87	0.13	0.00
	Outside Ireland			
		0.36	0.47	0.17

Appendix Table 9. Cross-tabulation Economic and Birthplace Shares by Religion

Wald Tests of Estimates by Model

Table 5. Model 3.	Chisq	DF	Pr(>Chisq)	
Age of Wife	220.6903	1	< 2.2e-16	***
Age at Marriage	109.0189	1	< 2.2e-16	***
Religion	29.0159	2	5.00E-07	***
Birthplace	4.8498	2	0.088487	.
Husband's Occupation	7.3587	1	0.006674	**
Wife Can Read and Write	16.3302	1	5.32E-05	***
Husband Can Read and Write	15.4975	1	8.26E-05	***
Status of Street	11.6425	2	0.002964	**
Wife Works	10.9719	1	0.000925	***
Marital Fertility	99.9883	1	< 2.2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Appendix Table 10a.

Table 6. Model 3	Chisq	DF	Pr(>Chisq)	
Age of Wife	146.1486	1	< 2.2e-16	***
Age at Marriage	69.1432	1	< 2.2e-16	***
Husband's Occupation	8.838	1	0.00295	**
Wife Can Read and Write	12.7773	1	0.000351	***
Husband Can Read and Write	12.0782	1	0.00051	***
Status of Street	6.3301	2	0.042212	*
Religion/Birthplace	38.7992	5	2.61E-07	***
Diversity	6.4076	1	0.011363	*
Religion/Birthplace X Diversity	14.4713	5	0.012877	*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Appendix Table 10b.

Table 7. Model 5.	Chisq	DF	Pr(>Chisq)	
Age of Wife	69.6838	1	< 2.2e-16	***
Birthplace	11.942	2	0.002552	**
Catholic	13.2456	1	0.000273	***
Status of Street	17.0092	2	0.000203	***
Husband's Occupation	14.3342	1	0.000153	***
Diversity	11.411	1	0.00073	***
Catholic x Status of Street	3.398	2	0.182868	
Catholic x Husband's Occupation	0.5197	1	0.47099	
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

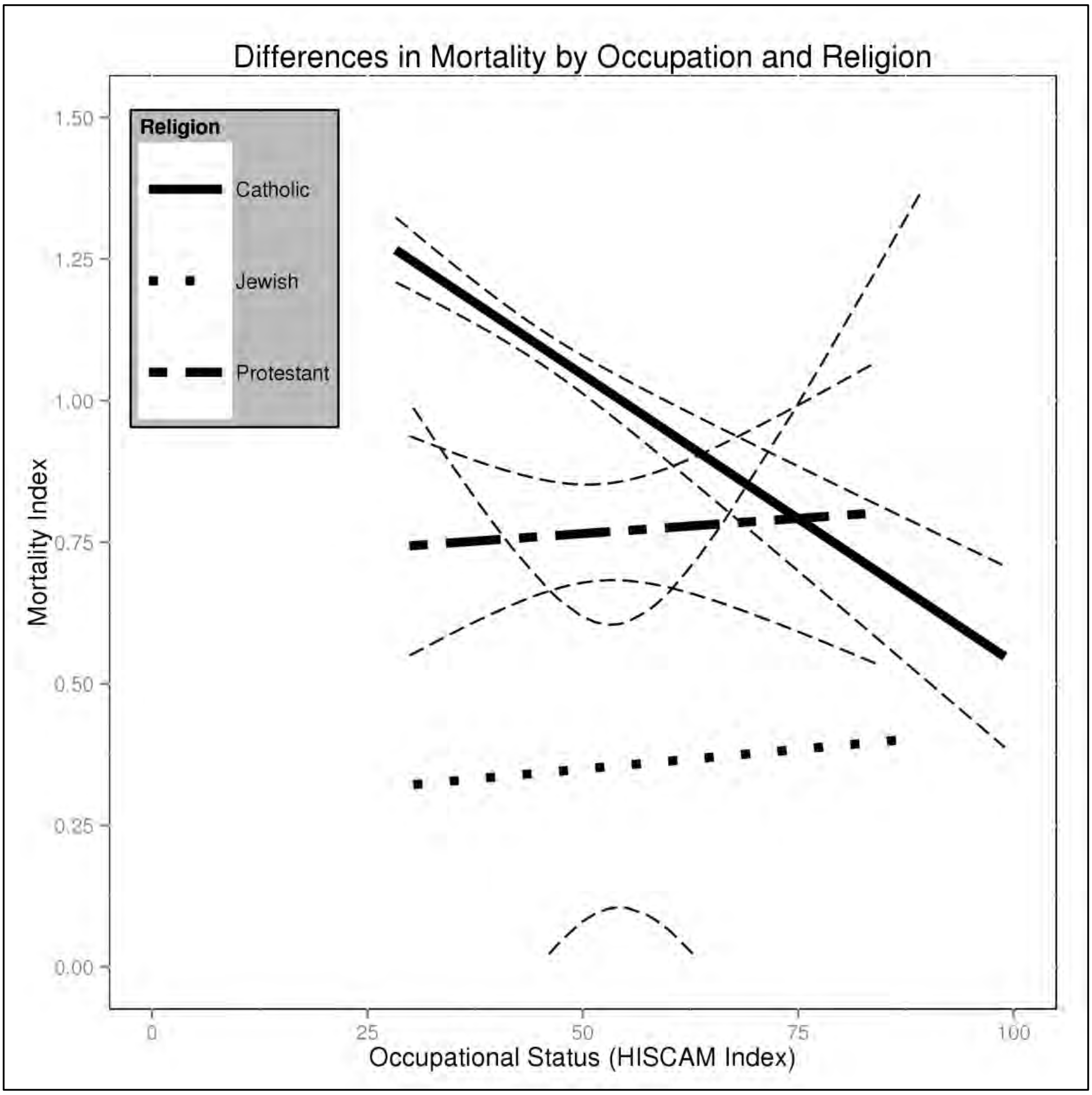
Appendix Table 10c.

Table 8. Model 4.	Chisq	DF	Pr(>Chisq)	
Age of Wife	58.0201	1	2.60E-14	***
Catholic	19.1652	1	1.20E-05	***
Husband's Occupation	13.1524	1	0.000287	***
Status of Street	6.4745	2	0.039271	*
Prox. to River Liffey	1.7416	1	0.186935	
Prox. to Typhoid	5.6438	1	0.017517	*
Prox. to Clean Milk	3.3734	1	0.066258	.
Quality Housing	3.6609	1	0.055703	.
Diversity	5.2282	1	0.022224	*
Catholic X Prox. to River Liffey	0.0575	1	0.81057	
Catholic X Prox. to Typhoid	0.2458	1	0.620032	
Catholic X Prox. to Clean Milk	3.1147	1	0.07759	.
Catholic X Quality Housing	0.0786	1	0.779147	
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

Appendix Table 10d.

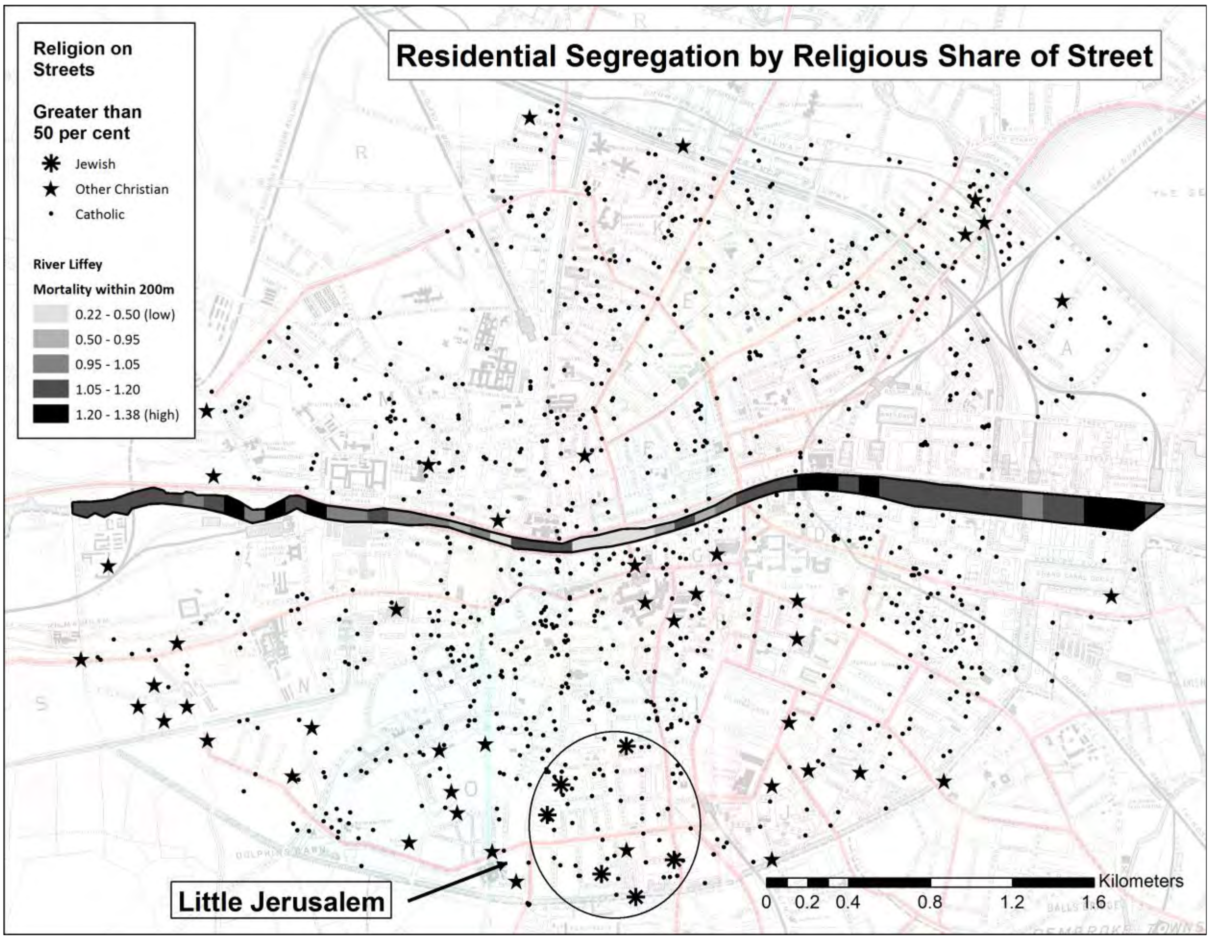
Appendix Figure 1. Age at Marriage

Protestants tend to marry slightly later than Roman Catholics. Jewish ages at marriage are skewed considerably more than both toward their early 20s.

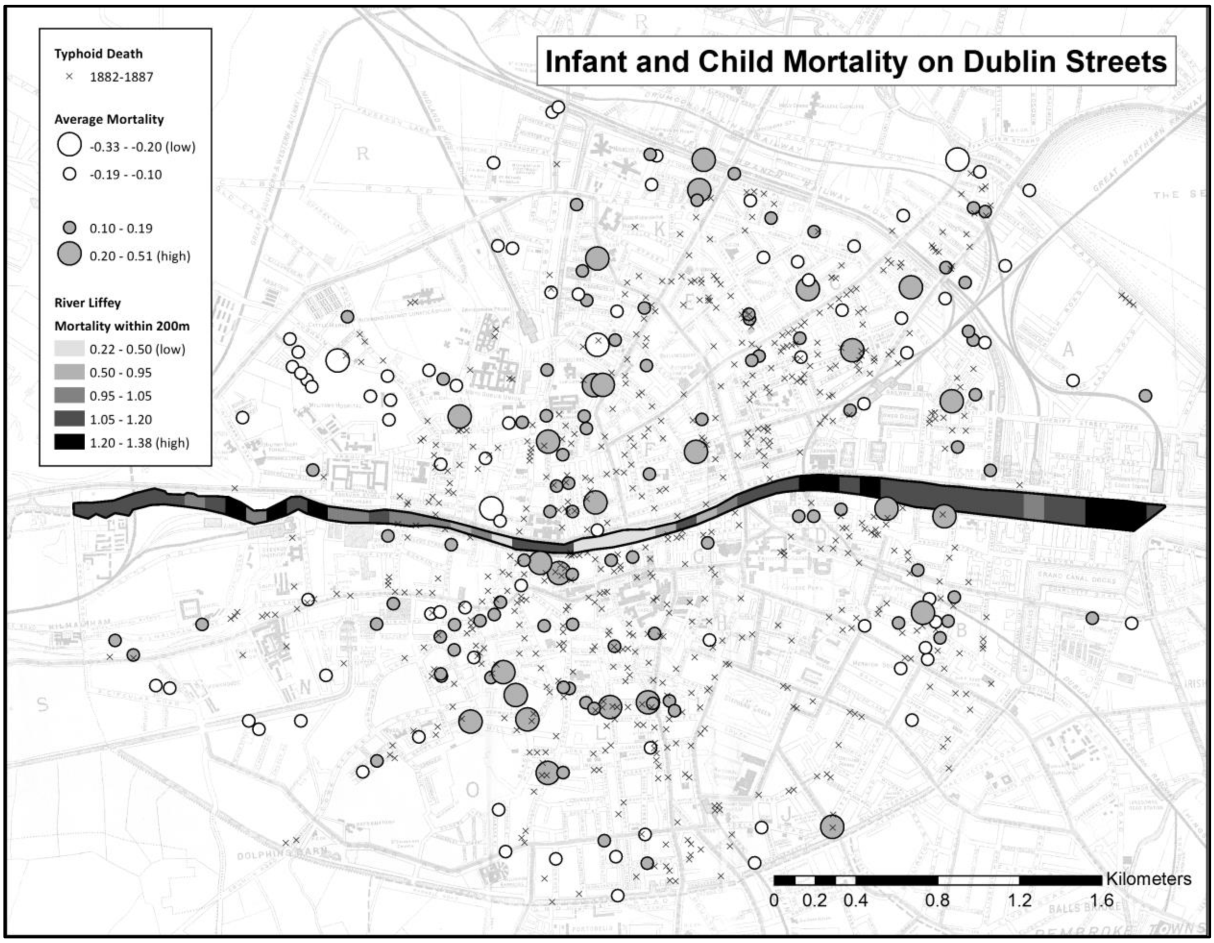


Appendix Figure 2. Differences in Mortality by Occupation and Religion

Differences in Mortality by Occupation and Religion. The downward slope for Catholics in figure 2a suggests a strong occupational gradient in mortality among Catholics. The lines for Jews and Protestants appear to have a slightly positive slope. This is likely the result of small samples sizes at the extremes. Confidence interval bands are calculated at the 95 percent level. These predictions are from a linear model with basic demographic characteristics.



Appendix Figure 3. Residential Segregation by street (including heavily Catholic streets)



Appendix Figure 4. Infant and Child Mortality on Dublin Streets with street location data

8. Figure and Table Captions

Table 4. This table shows estimates and univariate regression estimates from 17 different models. The intra-street correlation or variance partitioning coefficient (VPC) is calculated as $\rho = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_e^2}$ where σ_u^2 refers to the street level variance divided by the total variance.

Figure 1. Differences in Mortality by Parity and Religion. Confidence interval bands are calculated at the 95 percent level.

Figure 2. Early-Age Mortality by Ward. This map shows random effect extracted from a null-model for streets in Dublin. The base map is from Thom's Directory of Ireland, 1910 edition (source: Glucksman Map Library, Trinity College Dublin).

Figure 3. Early-Age Mortality and Religion by Street. This map shows mortality using a surface estimated from a spherical variogram in QGIS. The Base map is from Thom's Directory of Ireland, 1910 edition (source: Glucksman Map Library, Trinity College Dublin).

Figure 4. Early-Age Mortality and Migrant Status by Street. This map shows mortality using a surface estimated from a spherical variogram in QGIS. The Base map is from Thom's Directory of Ireland, 1910 edition (source: Glucksman Map Library, Trinity College Dublin).