

Living Standards and Plague in London, 1560–1665.

Neil Cummins, Morgan Kelly, and Cormac Ó Gráda*

Abstract

We use records of 870,000 burials and 610,000 baptisms to reconstruct the spatial and temporal patterns of birth and death in London from 1560 to 1665, a period dominated by outbreaks of plague. The plagues of 1563, 1603, 1625, and 1665 appear of roughly equal magnitude, with deaths running at five to six times their usual rate, but the impact on wealthier central parishes falls markedly through time. Tracking the weekly spread of plague before 1665 we find a consistent pattern of elevated mortality spreading from the same two poor northern suburbs. Looking at the seasonal pattern of mortality, we find that the characteristic autumn spike associated with plague continued in central parishes until the early 1700s, and in the poorer surrounding parishes until around 1730. Given that the symptoms of plague and typhus are frequently indistinguishable, claims that plague suddenly vanished from London after 1665 should be treated with caution. In contrast to the conventional view of London as an undifferentiated demographic sink we find that natural increase improved as smaller plagues disappeared after the 1580s, and that wealthier

*We would like to thank Ancestry.com and, in particular, Kim Harrison, for permission to download their parish records.

central parishes in the early seventeenth century showed positive natural increase outside plague years whereas the poorer suburbs showed substantial deficits and a strong positive check.

Introduction.

The central role of the urban colossus of London in driving Britain's distinctive economic development before the Industrial Revolution has long been recognised (Wrigley 1967, Fisher 1990, Allen 2009). However, while the population history of rural England from the sixteenth century has been well understood since the monumental work of Wrigley and Schofield (1981), the demography of London before 1665 has received little detailed attention. While many imagine that this is because its parish registers were destroyed in the Great Fire, in fact registers of most of the parishes of mid-seventeenth century London survive, usually back to the sixteenth century. Several studies, most notably Finlay (1981), Slack (1985, Chapter 6) and Boulton (1987), have analysed small samples of these records, but a comprehensive study of London population history before 1665 has been precluded by the sheer physical volume of its early parish records.

However, most of these records are now available online through Ancestry.com. This study uses downloaded records of roughly 870,000 burials and 610,000 baptisms in 115 of the 130 London parishes to reconstruct the spatial and temporal patterns of birth and death in London from 1560 to 1665, looking, in particular at their relation to living standards in different parts of the city. If our imputations of missing observations are correct, our sample comprises the burial records of three quarters of the people who died in London in this period. This large sample allows us to estimate total births and deaths in different parts of the city in each year; to track when and where major plagues started, their weekly spread, and their overall lethality;

to examine the seasonal pattern of mortality; and to look at the impact of living standards on births and deaths.

We find in particular that the plagues of 1563, 1603, 1625, and 1665 were all of roughly equal relative magnitude, with burials running at 5.5 to 6 times the average level in the previous five years. Assuming a normal mortality rate of around 3.0–3.5 per cent, this implies that one fifth of the city’s population died each time, within the space of a few months. While the relative size of major plagues remained fairly constant, their spatial distribution changed markedly. In 1563, mortality was fairly equal across parishes within the walls and surrounding extra-mural parishes, but by 1665 mortality in the central intra-mural parishes was considerably lower than elsewhere, reflecting the marked increase that we find in the concentration of wealthy households in these areas.

Next we consider the weekly spread of crisis mortality in plague years, taking a surveillance approach of the sort used in epidemiology to monitor disease outbreaks in real time. Weekly deaths in each parish are compared with a threshold level, based on average deaths during the same and surrounding weeks in previous years, and weeks above the threshold are flagged as potential epidemic outbreaks. For the period 1560–1665, we find that deaths above the crisis threshold accounted for about one fifth of total mortality: large plague epidemics were devastating but infrequent, and most Londoners died of other causes. While major plagues dominate our period, the frequency and lethality of smaller plague outbreaks falls markedly after 1590.

Considering at the spread of crisis mortality, in all major plague outbreaks from 1563 to 1625 we find a consistent pattern, with anomalous rises in mortality first occurring in the large, poor suburbs of St Giles Cripplegate and Shoreditch, in the north of the city, and then spreading over the next 14 weeks to the other parishes outside the walls, before moving inside the walls. In 1665 the first outbreak occurs a few hundred metres to the southwest in

the rapidly growing parish of St Giles in the Fields. That plague consistently appears away from the Thames is consistent with its being endemic in London rather than an occasional exotic import.

It is well known that the last recorded case of plague in the London Bills occurs in 1679, leading to a debate on the causes of its sudden disappearance ([Appleby, 1980](#); [Slack, 1981](#)). However, these discussions ignore a basic diagnostic fact: before the late nineteenth century it was usually hard, even for expert pathologists, to distinguish individual adult cases of plague from typhus. The symptoms of typhus and plague are often similar; plague epidemics tended to follow earlier outbreaks of epidemic typhus; and there is a growing epidemiological literature arguing that, while rat fleas are responsible for minor episodes of plague, the main vector of transmission in serious plague outbreaks is the same human body louse that spreads epidemic typhus: see [Section 3.2](#) below.

Given the difficulty of distinguishing plague from typhus we should be cautious of claims that plague suddenly disappeared from England after 1665. In fact, a sudden disappearance of plague is not apparent in our data on burial seasonality. While rural England experienced a v-shaped pattern of seasonal mortality, with deaths peaking near the start of each year and reaching a minimum in early summer, London deaths before 1665 show a strong peak in the autumn, even in years with few reported plague deaths. After the supposed disappearance of plague in 1679, we would expect the seasonal pattern of London mortality to start to display the same late winter maximum as the rest of England. Instead we find a strong, but gradually diminishing, autumn peak in the more affluent central parishes until the early 1700s, and in the surrounding extra-mural and out-parishes until the end of the 1720s. It does not appear possible to reject the view that isolated incidents of plague continued—mis-identified, accidentally or intentionally, as typhus—until the general ending of the second global plague pandemic in the 1730s.

Looking at natural increase, the popular impression is of London as an undifferentiated demographic sink where deaths considerably exceeded births. However, looking at the different parts of the city in the early seventeenth century, we find that spatial patterns varied widely, with the wealthier central parishes experiencing a positive natural increase outside plague years, the surrounding poorer parishes suffering an average deficit of ten per cent, but with average deficits of thirty per cent occurring in the out-parishes. In other words, the spatial cross-section of London mortality is strongly Malthusian, with wealthier households replacing themselves (outside plague years, to which affluent areas became less vulnerable as time passes) while poor districts suffered a marked excess of deaths over births even between major plagues.

While there are several notable studies of London population for the London Bills period after 1665 (in particular [Landers 1993](#), [Spence 2000](#), [Boulton and Schwarz 2010](#), and [Davenport, Boulton and Schwarz 2010](#)), detailed studies for our period at the level of parishes are few: [Hollingsworth and Hollingsworth \(1971\)](#), [Finlay \(1981\)](#), ([Slack, 1985](#), Chapter 6), and [Boulton \(1987\)](#) although notable recent contributions include [Razzell and Spence \(2007\)](#) and [Newton \(2010\)](#).¹

The rest of the paper is as follows. Section 1 outlines the parish records that we use and compares our estimates of deaths with those of early London Bills. Section 2 looks at the social geography of London, showing how geographical segregation of the affluent increased between the late sixteenth and early seventeenth centuries. Section 3 imputes missing parish records to estimate total mortality in London from 1560 to 1665, focusing in particular on the relative magnitude of major plagues in different parts of the city; while Section 4 uses weekly burials in the parishes in our sample to track the

¹While our focus is on annual deaths and births, there is a related literature on estimating London's total population beginning with [Jones and Judges \(1935\)](#) and continuing through [Wrigley \(1967\)](#), [Sutherland \(1972\)](#), [Finlay and Shearer \(1986\)](#) with a useful survey in [Harding \(1990\)](#).

spread of plague epidemics from 1563 to 1665 while Section 6 looks at the strength of the positive and preventive checks in different parts of the city. Section 5 looks at the seasonality of deaths in different parts of the city for inter-plague periods up to 1729. Finally Section 7 imputes the number of births and estimates the rate of natural increase in different parts of London.

1 London Parish Records.

This paper uses records of roughly 870,000 burials and 610,000 baptisms to reconstruct the spatial and temporal patterns of birth and death in London from 1560 to 1665. We define London as the area covered by the Bills of Mortality in 1660: the 97 parishes within the Walls; the 16 parishes outside the Walls (these two areas making up the City of London); the 12 out-parishes in Middlesex and Surrey; and the five parishes of Westminster.² The parishes covered, along with the starting dates of their burial records, are mapped in Figure 1: blank areas correspond to parishes outside the 1660 Bill or to extra-parochial areas like Inns of Court or the Tower of London.³

The record is remarkably complete.⁴ We have records for 86 intra-mural parishes, although in 10 cases there are fewer than 10 years of observations. However, the missing parishes are generally the smaller ones, recording fewer

²On the changing definition of London see [Harding \(1990\)](#).

³Parish shapefiles are taken from [Southall and Burton \(2004\)](#) with parishes created after 1665 being included in their original parish. Names of the parishes in the map can be found in [Landers \(1993, Appendix 3\)](#)

⁴In addition to the records downloaded from [ancestry.com](#) we have burial records for the three largest Westminster parishes of St Martin in the Fields (from 1551 to 1636 taken from [Mason 1898](#) and [Kitto 1936](#)), St Clement Danes (from 1538 to 1638 based on facsimilies of the burial register downloaded from [findmypast.com](#)), and St Margaret Westminster (from 1538 to 1638 from [freereg.org.uk](#). The [freereg](#) series for Martin in the Fields is considerably lower than the Harleian Society series used here so we are uncertain of the accuracy of this St Margaret series). Births for these three parishes are from the International Genealogical Index (<https://familysearch.org/search/collection/igi>). We have also included birth and death records for the intra-mural parish of St Vedast from [Littledale \(19021903\)](#).

than 100 deaths in 1660, and we will see below that they can be fairly reliably interpolated from records of surrounding parishes. For the 16 parishes without the walls we are missing all or nearly all records for the two small parishes of Bridewell Precinct and Bartholomew the Less (each accounting for 0.2 per cent of recorded deaths in the surviving annual Bill for 1636); while records for the large parish of St Sepulchre Holborn (5.7 per cent of deaths in 1636) start only in 1660, but we have extensive records for most other parishes. For the 12 out-parishes we have records for all except St Giles in the Fields (3.7 per cent of deaths in 1636) and the small parish of Lambeth (absent from the 1636 Bill, 1 per cent of deaths in 1663). For the five Westminster parishes, we are missing records for the two smallest parishes of St Mary le Strand (0.4 per cent of deaths in 1636) and St Paul Covent Garden (absent from 1636 Bill, 0.8 per cent of deaths in 1663)

Of surviving parish registers for our period listed by [Webb \(2009\)](#), only the following extant registers are absent from our sample: St Giles in the Fields (starts 1561); All Hallows Barking (starts 1558, 0.6 per cent of deaths in 1636); St Mary le Strand (starts 1558); All Hallows Bread Street (starts 1538, 0.06 per cent of deaths in 1636); while we are missing the first 40 years of burial registers (baptisms are complete) for St Dunstan, Stepney where surviving registers start in 1563.

The parishes in our sample therefore account for a substantial proportion of London's population in the early seventeenth century. For 1578, the 72 intra- and extra-mural parishes in our sample account for 79 per cent of deaths recorded in the London Bill. For 1636, the earliest Bill that gives reliable deaths by parish, the parishes for which we have data account for 71 per cent of the London total. By region, our parishes account for 63 per cent of deaths in the intra-mural parishes, 77 per cent in the extra-mural parishes, and 65 per cent in the out-parishes.

We are not using the original registers but downloads of individual records from Ancestry.com. This creates three sources of potential error: the regis-

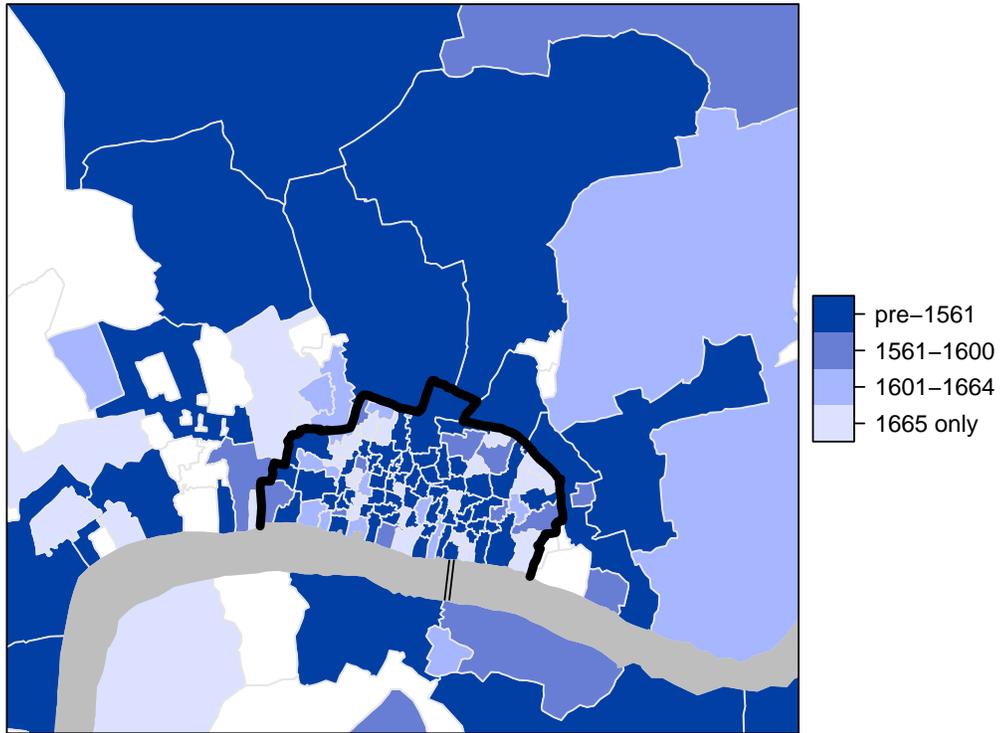


Figure 1: Starting dates of available burial records in parishes covered by the London Bills.

ters may have been transcribed imperfectly; we may have failed to download all relevant records; or we may have failed to remove all duplicated entries that frequently arise from including bishops' transcripts of the original registers⁵ We can judge the accuracy of our procedure in two ways: by comparing our

⁵We are agnostic as to the accuracy of the parish registers as records of mortality, taking the view that so long as the proportion of deaths recorded each year in each parish

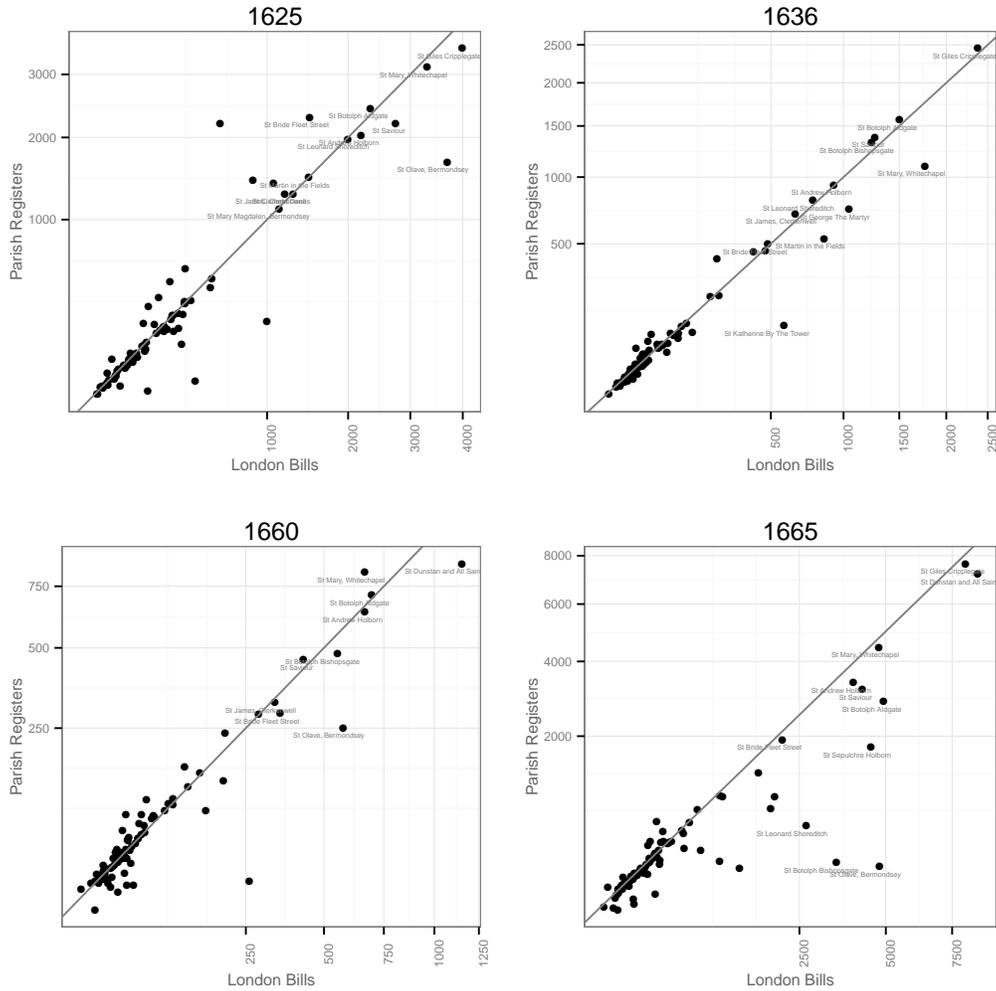


Figure 2: Recorded Deaths in Parish Registers versus London Bills.

parish totals with parish totals in surviving London Bills; and by comparing our estimate of total deaths, after imputing missing observations, with known annual totals that run continuously from 1603, and also exist for 1578–1582 and the plague years of 1563 and 1593.

remains fairly constant, we can trace the spatial and temporal variations in mortality that concern us here.

Figure 2 gives our estimate of annual deaths compared with the totals reported in the London Bills for three plagues—1625, 1636, and 1665—and one non-plague year, 1660.⁶To prevent small intra-mural parishes clustering indistinguishably around the origin, we use square-root axes. Most missing parishes are small, recording fewer than 100 burials in 1660.

It can be seen that, before 1665, most parish totals match the London Bills totals fairly closely, although there are a few cases where the parish record is considerably lower. In particular, recorded burials in the largest parishes during the severe plague of 1625 tend to be considerably lower than totals recorded in the Bills. Similarly, in 1665 we can see how several large parishes appear to have given up recording individual burials, although parish clerks must have maintained running totals that they reported in their weekly meetings to compile the London Bills.

2 The Social Geography of London.

The social geography of mid-seventeenth century London has been well known since Finlay (1981, 70–82) used the *Settlement of Tithes 1638* to map the distribution of “Substantial Householders” (those living in property valued at a rent of £20 or above). Finlay’s data are reproduced in the second panel of Figure 3 which shows how the affluent were strongly concentrated in a central belt of intra-mural parishes, with prosperity declining as one approached the city wall and river. Using a sample of 13 rich and 14 poor parishes, with data from the forced loan of 1522, the lay subsidy of 1572, the 1638 settlement of tithes, and the 1695 duty on births, marriages, and deaths, Slack (1985, 170–172) found that the same parishes tended to be among the richest or poorest over two centuries, and concluded that there was a fairly constant social geography of rich central parishes surrounded by a poorer periphery.

⁶All parish register dates have been shifted ten days into Gregorian form. Annual London Bills ran from the Thursday before Christmas (Julian Calendar), which is close to the start of January in Gregorian form.

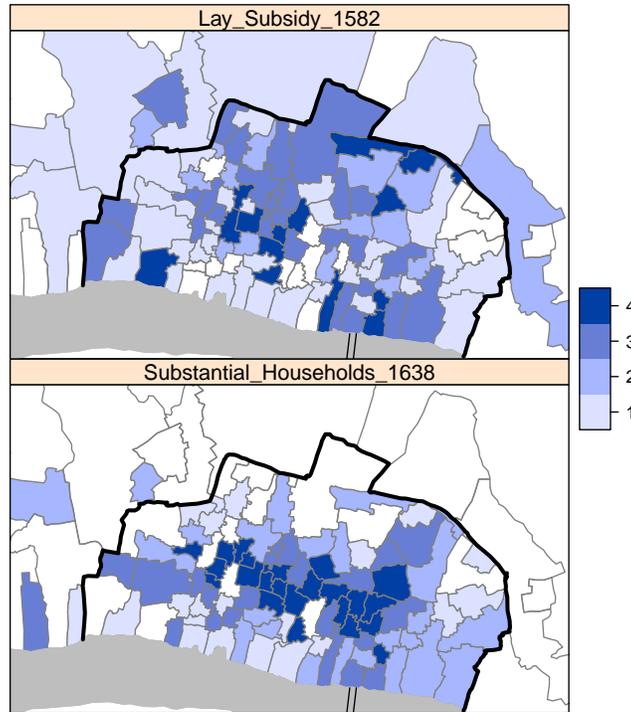


Figure 3: Spatial distribution of wealth, with parishes grouped by quartile, 1582 and 1638.

This view that the social geography of London was relatively fixed during the sixteenth and seventeenth centuries is shared by [Boulton \(2000, 327–328\)](#).

To test this consensus about a fixed social geography, we analyse the spatial distribution of wealth during the late sixteenth century using a new set of data: the returns of the 1582 Lay Subsidy.⁷ Excluding companies, this covers 6,632 individuals. When we leave out servants of taxpayers, who paid 4d each, this gives a sample of 5,747 taxpayers. The upper panel of [Figure 3](#) gives the median tax paid by parish, with parishes again being assigned to four quartiles.

⁷This was downloaded from the London Record Society <http://www.british-history.ac.uk/source.aspx?pubid=160>

It can be seen that although the central parishes tend to be rich and the peripheral ones poor, as Slack argued, the spatial distribution of wealth is more diffuse in 1582 than in 1638, with less concentration in the central parishes. We shall see below that trend of increasing self-segregation by the affluent coincides with the tendency for plague mortality to become concentrated in outer parishes.

We can test formally for spatial autocorrelation in these wealth data using a Moran I test (Bivand, Pebesma and Gomez-Rubio, 2008, 258–268). For 1638, none of the included parishes outside the walls has a neighbour that is included, so we restrict our sample to intra-mural parishes, excluding St James Duke Place which is also isolated. The Moran statistic for no spatial autocorrelation (assigning equal weight to each of a parish’s neighbours) has a p -value of 0.07 for 1582, consistent with the distribution of wealth within the walls having low spatial organisation. Adding the extra-mural parishes, which can be seen from Figure 3 to be poorer on average than those within the walls, causes the p -value to fall to 0.04. For 1638, the strong spatial autocorrelation is clear with a p -value for the test statistic of 0.00.

3 Reconstructing Deaths.

To estimate total annual deaths for London we need to reconstruct mortality for parishes in years where records are missing. Using recorded and imputed burials we can estimate annual mortality from 1560 to 1660, and compare our estimates with the totals recorded by Graunt (1662) from the London Bills from 1603 to 1642, and from Marshall (1832) from 1643 to 1664. Graunt recorded total burials in London, and non-plague deaths for the intra-mural, extra-mural and out-parishes: in other words, plague deaths by district are not given. Creighton (1891, 341–344) also reports weekly mortality from 1578 to 1582, and for the plagues of 1563 and 1593.

Mathematically, we are trying to impute the missing values in a matrix where, from 1560 to 1659, 41 per cent of the entries are missing. The canonical version of this problem is the Netflix Prize, where, based on ratings of some films by users, the goal is to predict how these users would rate other films. The most successful approach, that we will follow here, is to reduce the dimensionality of the problem through a singular value decomposition (SVD). In terms of films, each is scored according to a few different genres, and the score that each user assigns each genre is calculated, allowing the score for an unknown film to be calculated as the vector product of these two scores. We tried a variety of SVD algorithms but found that the most reliable performance, particularly for reproducing known death totals from 1578–1582, came from the procedure of [Mazumder, Hastie and Tibshirani \(2010\)](#) implemented in the R package `softImpute`.⁸ Because records may stop or start during a year, causing the annual total to be an underestimate, any year preceded or followed by missing entries was treated as a missing entry. Mortality in each parish in each year is expressed as a fraction of known deaths in 1660. This procedure led to unrealistically low estimates for deaths in the two largest missing parishes in our sample—St Sepulchre, Holborn and St Giles in the Fields—and for these we estimated annual deaths based on a spatial interpolation of parishes with known deaths north of the Thames.⁹ These estimates were then included in the SVD procedure.

Figure 4 plots our estimates of annual burials alongside the London Bills totals for three groupings of parishes: the intra-mural parishes, the intra-

⁸SVD procedures ignore spatial and temporal information on deaths. We attempted to incorporate these by giving each parish a location equal to the centroid of its map polygon, and using this location and year as explanatory variables for two procedures: penalized regression splines ([Wood, 2006](#)) and regression trees [Taddy, Gramacy and Polson \(2011\)](#). When predicting missing values, each produced results close to known totals after 1604, but generated serious over-estimates for 1578–1582. Spatially, London mortality rates were bowl shaped, rising as one moves outwards, and extrapolating these spatial trends to large missing suburbs led to excessive estimates.

⁹Interpolation was carried out using nonparametric kernel smoothing: [Hayfield and Racine \(2008\)](#).

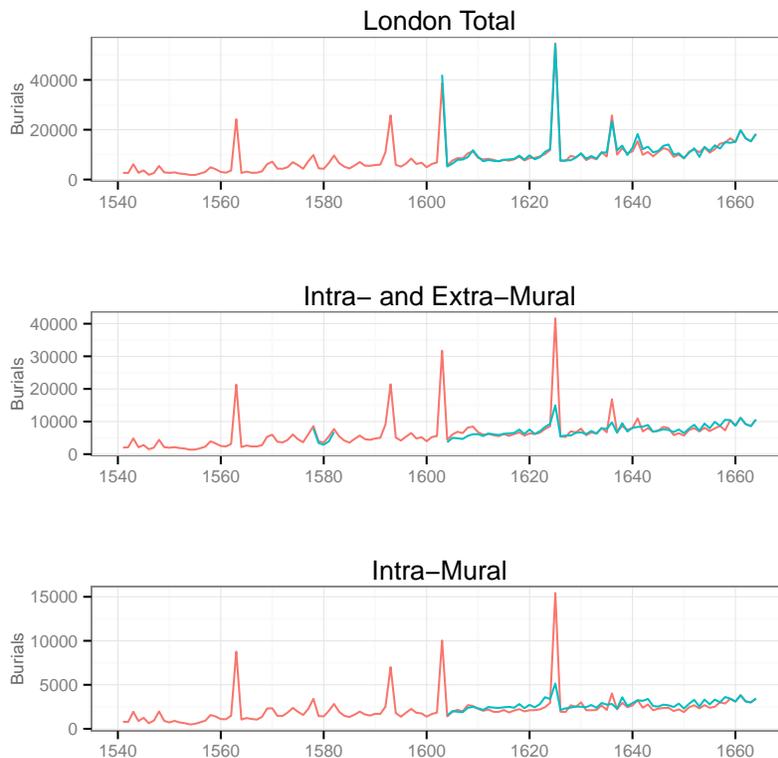


Figure 4: Estimated versus recorded burials in groups of London parishes.

and extra-mural parishes (i.e. the City of London), and the total for London. Before 1636, the London Bills only reported mortality for nine out-parishes, adding seven distant parishes after that year. Our London Totals therefore omit the distant parishes before 1636.

What is most notable about Figure 4 is how closely our estimates match the recorded London Bills totals. In particular our estimates for 1578–1582 are close to those recorded by [Creighton \(1891, 341–344\)](#).¹⁰

¹⁰Creighton does not give a location for these numbers but his total of 6,772 for most of 1582 is close to the 6930 reported by [Christie \(1893, 135\)](#) for the intra- and extra-mural parishes, suggesting that Creighton’s numbers are for the intra- and extra-mural parishes.

Some totals for major sixteenth century plague years survive. For 1563, [Creighton \(1891, 305–306\)](#) gives Stow’s estimates of 20,322 deaths for the intra- and extra-mural parishes, and 3,288 for 11 out-parishes; whereas our estimates are 21,000 for the intra- and extra-mural parishes; and for the out-parishes excluding distant parishes 3,000.

For 1593 our estimate of 21,000 deaths in the intra- and extra-mural parishes is somewhat higher than the figure of 18,000 given by Stow and Graunt ([Creighton, 1891, 353–354](#)), but it is immediately evident that this latter figure is implausibly low. The 72 parishes in our sample for that year recorded 17,273 burials, before including the 41 missing parishes. Creighton also cites an estimate of 26,000 deaths “in and about London”; and this is also the figure given for the intra- and extra-mural parishes from March to December 1593 in the *Collection of the Yearly Bills of Mortality* ([Birch, 1759](#)).¹¹ Excluding distant parishes, our estimate for total mortality is 26,000.

3.1 Relative Magnitudes of Plagues.

These successive plagues occurred in a rapidly growing city so it is necessary to ask how large each was relative to the size of London at the time. To do this, we compare estimated mortality in each plague year with the median number of deaths over the preceding five years, including only parishes with a complete five years of records. Given the unreliability of the 1625 burial registers in large parishes, and to an even greater extent those for 1665, we use London bill totals for each parish in those years; and also use the London Bill figures for 1660–1664 to calculate normal mortality for every parish.

Given the increasing concentration of the rich in central parishes, we divide the intra-mural parishes into two groups based on the proportion of substantial households in 1638. For brevity, we refer to these as rich and

¹¹This Collection also contains a bill purporting to give a breakdown by parish but gives an implausible total of 32,000 for the intra- and extra-mural parishes and a total of 39,000. These may possibly be combined totals for the two plague years of 1592 and 1593 but the correlation with individual parish records in our sample is low.

	Intra rich	Intra poor	Extra-m	City	Out-parishes	Total
1563	7.7	5.5	5.3	5.4	3.5	5.0
1593	4.1	4.4	4.8	4.6	3.4	4.4
1603	5.3	6.0	6.4	6.2	7.1	6.4
1625	4.6	5.8	5.6	5.5	4.2	5.2
1636	1.2	1.4	2.8	2.4	3.5	2.6
1665	3.2	5.5	6.8	6.2	6.1	6.1

Table 1: Mortality in plague years relative to median mortality in preceding five years.

poor. The proportion of substantial households for some parishes is not given: these are the blank areas in Figure 3. We assign two of these—All Hallows Bread Street and St Swithin—that are completely surrounded by affluent parishes, to the rich category; and the rest to the poor.

Looking at mortality across the intra- and extra-mural parishes, Table 1 shows that the plagues of 1563, 1603, 1625 and 1665 were of roughly equal lethality, with deaths running from 5 to 6 times their usual level; while the plague of 1593 saw deaths running at 4.6 times normal, and in 1636 deaths were 2.4 times normal.

The major trend apparent in Table 1 is the sharp fall in mortality in the central intra-mural parishes. In 1563 these fared somewhat worse than the rest of London but, after 1603, their experience becomes markedly better than their poorer neighbours, with a rise in mortality in 1665 less than half that of the extra-mural parishes. While Slack (1985, 160–163) argues that increased overcrowding made the extra-mural parishes more vulnerable to plague over time, our results do not indicate any large increase in the lethality of plague there. The largest increase occurs in the rapidly urbanizing out-parishes which go from a plague mortality of 4 times normal in earlier major plagues, to 6 times normal in 1665.

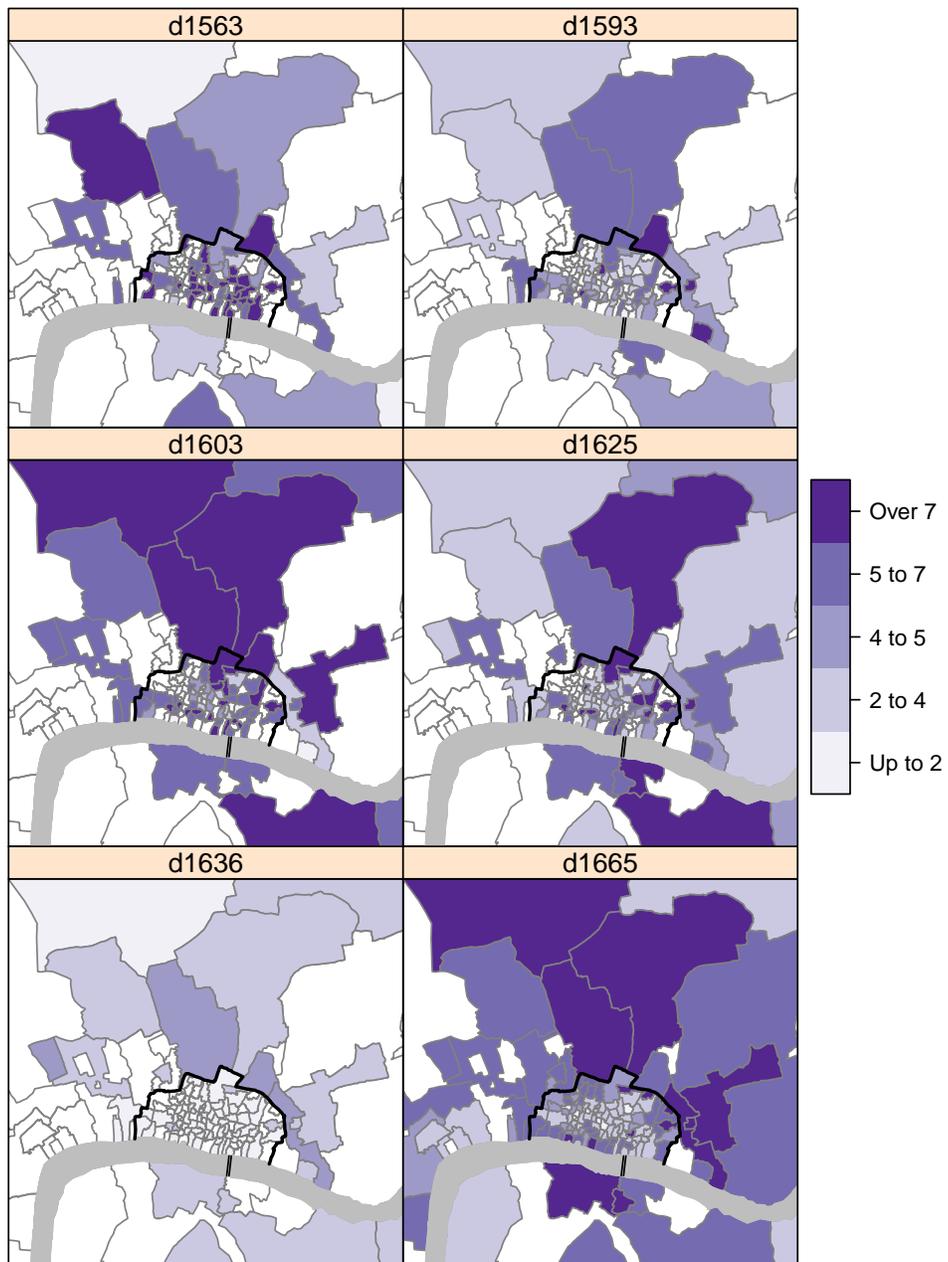


Figure 5: Mortality in London plague years relative to median mortality in preceding five years.

Figure 5 plots the mortality in each parish during the major plagues, again relative to median mortality in the parish over the preceding five years. The changing spatial pattern of mortality within the walls is immediately apparent. During 1563 several central parishes were among the hardest hit and this was still the case, although less markedly, in 1603. By 1665, however, the most prosperous parishes, based on the 1638 proportion of substantial households in Figure 3, stand out as an island of low mortality. Looking at the parishes outside the walls, a consistent pattern emerges from 1593 onwards: the poor northern suburbs of St Giles Cripplegate and Shoreditch are always among the worst hit. When we look below at the weekly spread of crisis mortality we shall see that these northern parishes are consistently among the first to show unusual rises in mortality.

3.2 Plague and Typhus.

While the London Bills, and most modern authors, confidently distinguish between plague and typhus as causes of death, in practice the symptoms of the two diseases were often similar. Under “Plague—Morbid Anatomy” the 1902 *Encyclopedia Britannica* notes that in autopsies “The appearances are those of death from an acute infective disease, and resemble those of typhus, except for the special affection of the lymphatic glands.” In the standard Victorian reference on typhus, Murchison (1884, 219–220) notes that the symptoms of typhus and plague are almost identical, with the characteristic petechial spots (caused by intradermal bleeding) of typhus (hence its name of spotted or purple fever) corresponding to plague tokens (the “ring of roses”); while swift, agonising death and the appearance of swollen lymph glands or buboes in typhus is not uncommon. Epidemic outbreaks of the two diseases can be distinguished by the fact that typhus rarely kills children whereas plague kills equally at all ages, but telling isolated adult cases apart was almost impossible before improvements in microbiology in the early twentieth century.

Writers on plague before the twentieth century note that severe epidemics of plague tend to occur a year after, or concurrently with, a major typhus epidemic: In his discussion of “the praecursor Diseases of Pestilence”, [Hancock \(1821, Chapter 8\)](#) notes that the London plagues of 1625, 1636, and 1664, as well as most of the major European epidemics since the sixteenth century, were preceded by an epidemic of pestilential fever; [Murchison \(1884, 223\)](#) observes that “many epidemics of plague in Europe have been preceded and accompanied by a great prevalence of typhus”; while [Crawford \(1914, 32\)](#) writes “There is scarcely a single writer of the sixteenth, seventeenth, or eighteenth centuries on the subject of fevers, who has not commented on the concurrence of malignant fevers with epidemics of Oriental plague.”

Given the current orthodoxy that plague is spread by rat fleas, the tendency of epidemic typhus (spread by human body lice) to precede plague outbreaks appears coincidental, and it disappears from discussions of plague after the early twentieth century. However, based on the experience of French doctors dealing with plague outbreaks in North Africa between the 1920s and the 1940s, [Drancourt, Houhamdi and Raoult \(2006\)](#) argue that, although rat fleas are indeed the vector behind minor plague outbreaks, in severe epidemics of bubonic plague most transmission occurs through human lice and possibly human fleas. [Houhamdi et al. \(2006\)](#) demonstrate that human lice can act as effective plague vectors (rat fleas are notably inefficient vectors, requiring many bites to transmit infection: [Lorange et al. 2005](#)), being able to infect and be infected by rabbits.¹²

Returning to the falling impact of plague epidemics on wealthier parishes, looking at the 1613 plague in the Saxon town of Freiberg, [Monecke, Mon-](#)

¹²The rapid spread and high fatality rate of plague during the second pandemic from the early fourteenth to eighteenth centuries compared with the third pandemic starting in the late nineteenth century led some to conclude that medieval plague was not *Yersinia pestis* but some haemorrhagic fever like Ebola: see for instance [Cohn \(2002\)](#). However, excavations of medieval plague pits have found the presence of *Yersinia pestis* in a closely related genetic form to modern plague ([Achtman, 2012](#)). The greater role of human lice in spreading earlier plagues may explain their higher lethality.

ecke and Monecke (2009) argue that the lower mortality in wealthy parishes was due to their stone buildings which gave the inhabitants greater protection against rats and their associated fleas. In the case of London, improved housing in affluent areas—“from sticks to bricks” in the words of James I (Brett-James, 1935, 15)—may have lessened the impact of plague. To the extent that serious plague was transmitted by human fleas and lice (Dran-court, Houhamdi and Raoult, 2006), greater physical segregation of rich from poor would have lessened the force of epidemics among the rich, as would improved personal hygiene.¹³

4 Mortality Crises.

We have seen that London mortality until 1665 was characterized by sudden spikes when deaths ran at 5 to 6 times their usual level as a result of plague. The burial register data rarely give cause of death, unlike the London Bills which list the number of plague deaths by parish. However as noted above, plague deaths suffer from severe under-registration.

To analyse crisis mortality we therefore look instead at unusual increases in mortality, applying surveillance techniques from epidemiology. The specific algorithm we use is due to Farrington et al. (1996), implemented by Hohle (2007). To detect epidemic outbreaks in real time, these compare number of cases in a given week with a threshold equal to the 99 per cent upper tail value of a Poisson distribution with parameter equal to the average number of cases in the same and surrounding 5 weeks over the 3 previous years, adjusted for a time trend if necessary. Using other surveillance algorithms from Hohle (2007) gave almost identical results and they are not reported here.

¹³Although, to judge from Pepys, lice remained a problem even among the affluent. For example: January 1, 1669: “I am louzy, having found in my head and body above 20 lice, little and great”

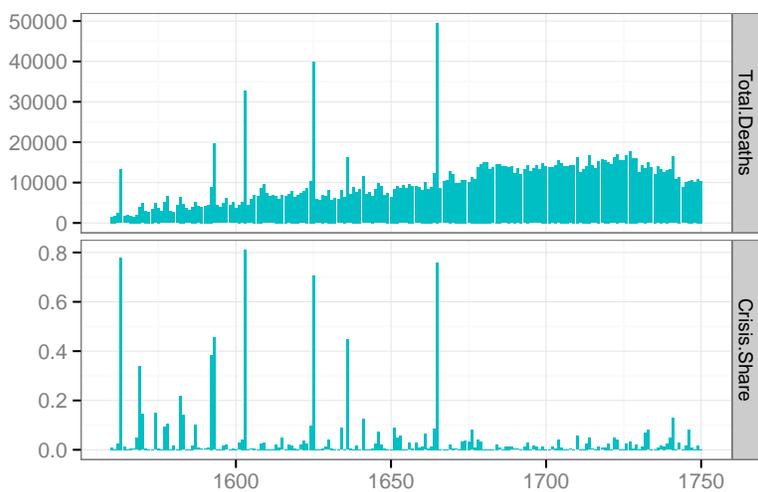


Figure 6: Annual deaths, and proportion of deaths in excess of the Farrington threshold, 1560–1750.

Figure 6 shows annual deaths in our sample of London parishes from 1560 to 1750, and the share of these deaths that are classified as crisis deaths, where crisis deaths are defined as the number of deaths each week in excess of the Farrington threshold. One shortcoming of the Farrington methodology is that, in years following a severe rise in deaths, crises are hard to detect so that continued plague deaths the year following a major epidemic are not recorded.¹⁴ However, the magnitude of these plague after-shocks are small relative to the preceding plagues.

The fundamental change in London mortality after 1665 is immediately evident in the fall in the number of crisis deaths which are due, nearly always, to plague epidemics. Between 1560 and 1665, crisis deaths account for 18 per cent of deaths; and this falls to 1.8 per cent after 1665. Annual London mortality goes from being highly volatile and unpredictable, to being smooth and predictable. However, even before 1665 there is clear evidence of a

¹⁴The algorithm contains an attempted correction for this, but the magnitude of plague mortality overwhelms it.

diminution of crisis mortality from the 1590s onwards: from 1563 to 1593, there are ten years when crisis mortality exceeded ten per cent of deaths, but from 1594 to 1665 there are only five years. In other words, there appears to be a disappearance of minor plague outbreaks from 1590 onwards.

There does seem to be an upward trend in crisis mortality during the first half of the eighteenth century but the levels are low compared with those of the plague era. There is however one notable spike in 1741, during a major mortality crisis in the Midlands ([Wrigley and Schofield, 1981](#), 683) when crisis deaths are 13 per cent of the total.

4.1 Diffusion of Plague.

By examining weekly crisis mortality in the individual parishes in our sample we can track the geographical diffusion of plague during major epidemics from 1563 to 1665. In particular we can look at where and when epidemics originated, and how rapidly they spread. For 1665, where weekly bills collected by [Graunt \(1665\)](#) survive, we can compare the timing and pattern of crises detected by the surveillance algorithm with official notifications of plague deaths.

Figure 7 shows snapshots of the weekly mortality by parish in the three major plagues before 1665: 1563, 1603 and 1625. The value for each parish is the number of deaths each week relative to its Farrington threshold. A slide show of each week in each plague year, including also 1593 and 1636, is available on our webpage. In each case, the map starts at the first week where a parish experiences elevated mortality that lasts more than two weeks: with roughly one hundred parishes we can expect about one parish each week to be above its 1 per cent Farrington threshold in the absence of mortality crises.

The spatial and temporal pattern of crisis mortality in the three major plagues before 1665 is notably consistent. Elevated mortality appeared first in mid to late June in the Northern parishes of St Giles Cripplegate and

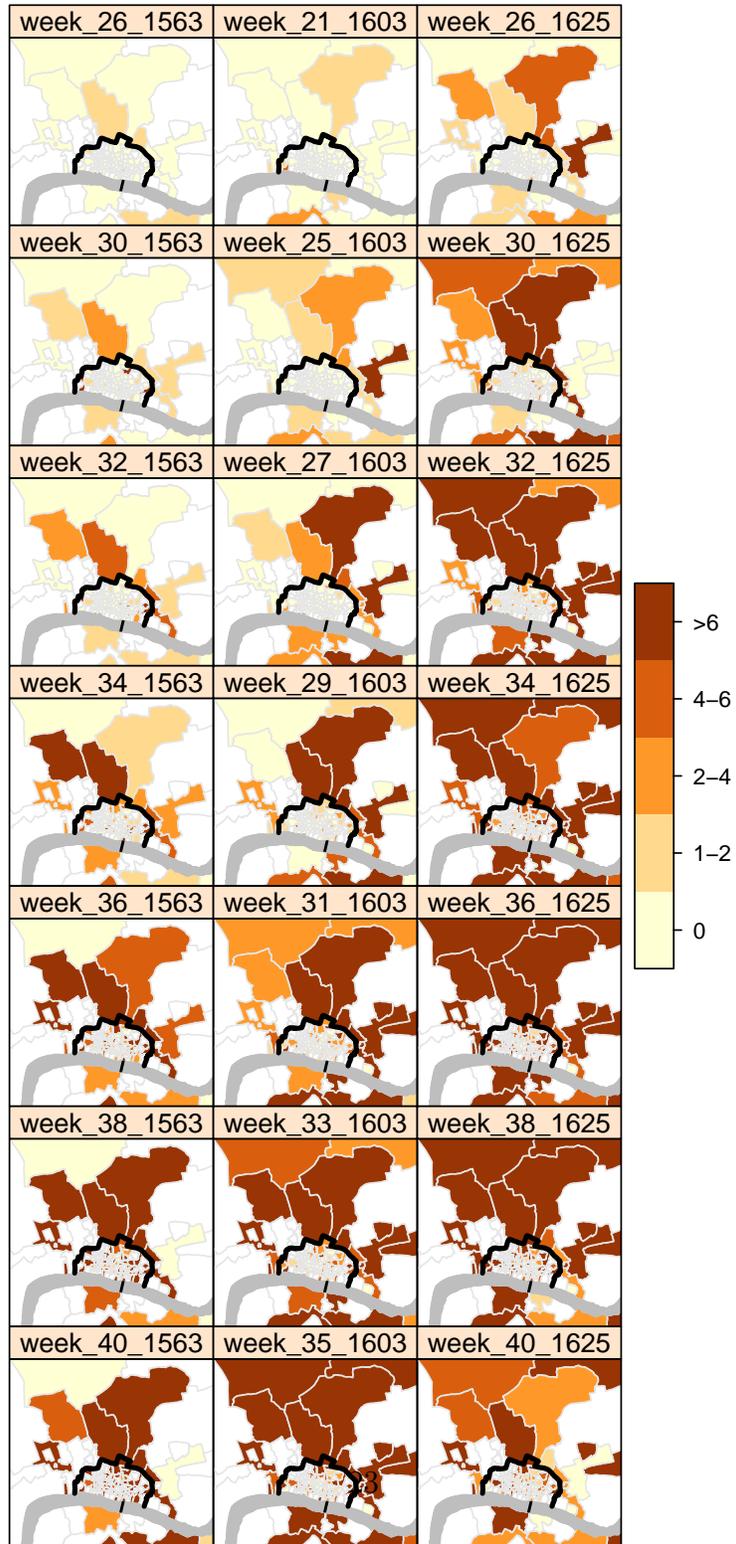


Figure 7: Weekly spread of crisis mortality: 1563, 1603, and 1625.

Shoreditch. In the following 6–8 weeks it spread to other suburban parishes. By 14 weeks it had spread inside the walls.

That plague consistently originates away from the port suggests that it was endemic, rather than an occasional exotic import as [Slack \(1981\)](#) suggests. [Keeling and Gilligan \(2000\)](#) simulate a model of transmission of plague from fleas to rats to humans show that, for biologically plausible parameters, a city with a population of 60,000 (the size of London by the mid-sixteenth century) can sustain plague in its rat population for a hundred years, supporting the view that plague was native to the city. However, their model relies on some fraction of rats being able to transmit immunity to their offspring, whereas [Drancourt, Houhamdi and Raoult \(2006\)](#) point out that plague appears to disappear completely from rodent populations between epizootics, and suggest instead that it is a telluric (soil based) organism that occasionally infects animal populations.

For 1665 we have weekly data for all London Bills parishes compiled by [Graunt \(1665\)](#).¹⁵ To assess weekly mortality in earlier years for parishes where burial registers are unavailable we assume that there is no seasonal trend in mortality so that if d_{it} burials took place in parish i in week t , weekly burials in that parish follow a Poisson distribution with parameter $d_{it}/52$.¹⁶ These simulated burials are then used as inputs into the Farrington procedure.

Given the low opinion of the accuracy of the London Bills, and particularly their plague statistics, held by [Graunt \(1662\)](#), and others, it is notable that the pattern of crisis that emerges is exactly that given in the plague figures in the Bills: the first outbreak of sustained crisis mortality occurs in St Giles in the Fields, with the London Bills picking up the first plague deaths one week before the Farrington procedure. After this crisis mortality spreads into the northern parishes over the next 8 weeks.

¹⁵Earlier studies of 1665 include [Twigg \(1993\)](#) and [Champion \(1995\)](#).

¹⁶Allowing the Poisson parameter to show a seasonal trend of the sort outlined in Section 5 did not change the results in any way.

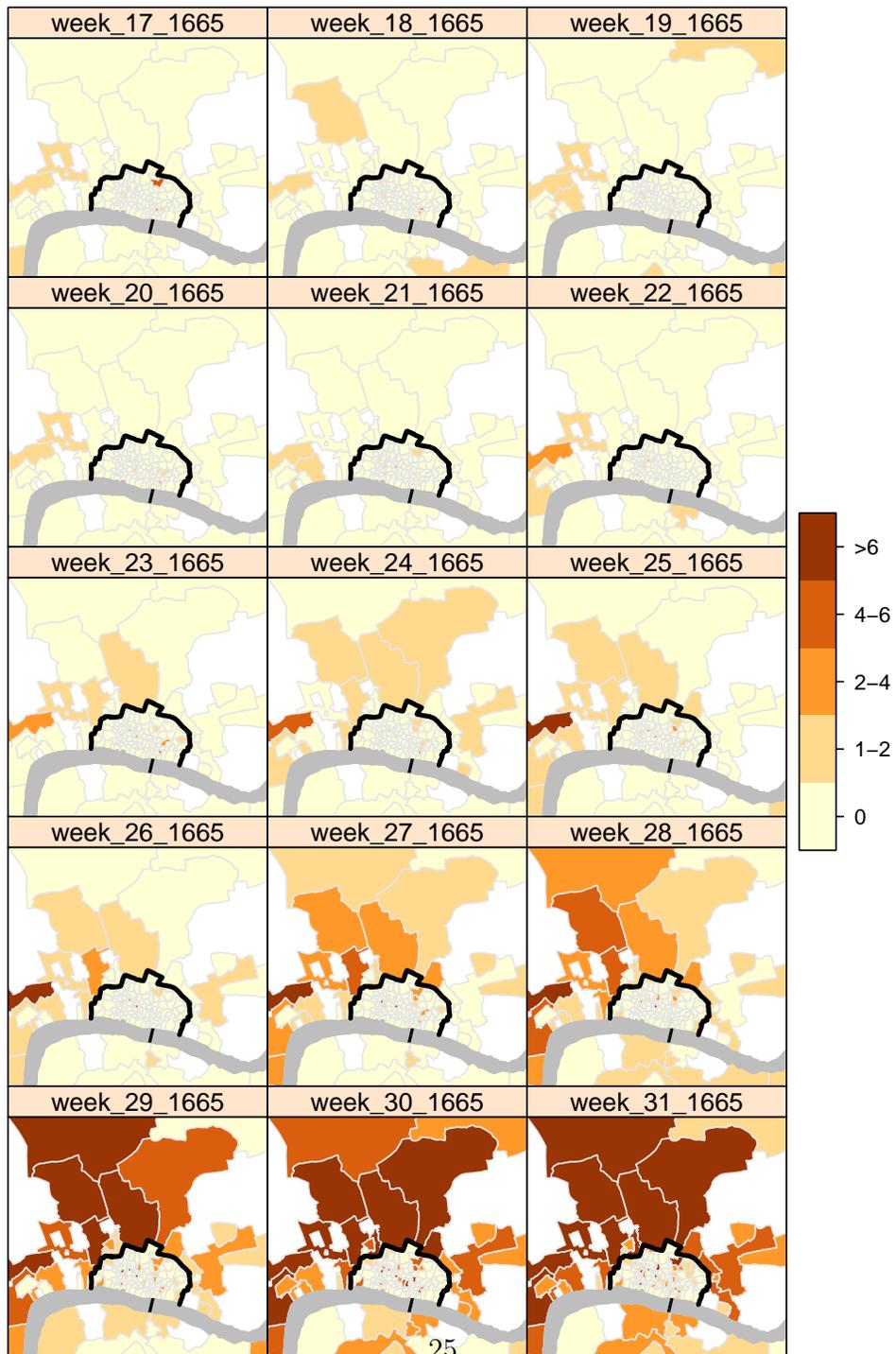


Figure 8: Spread of crisis mortality, 1665.

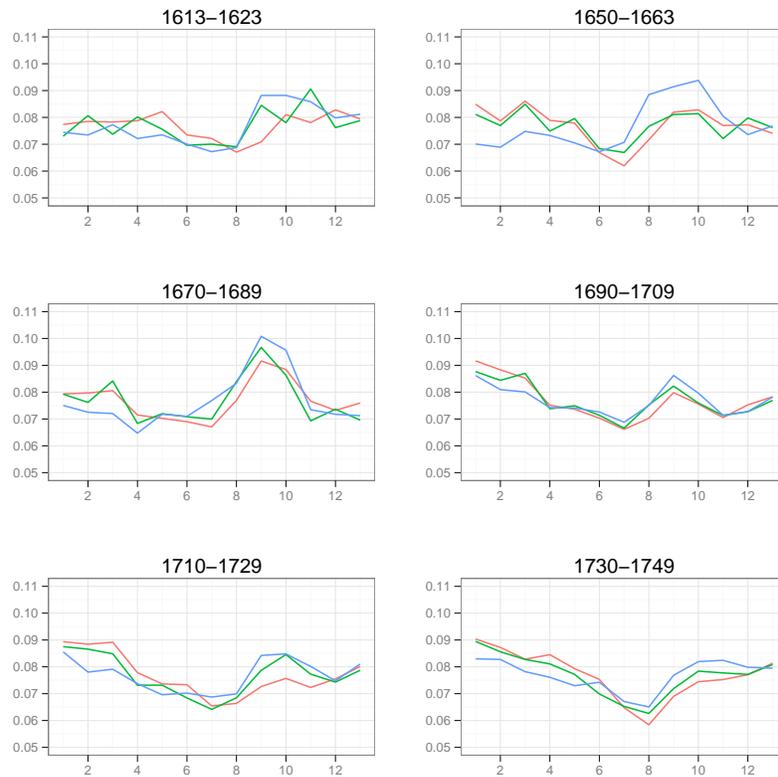


Figure 9: Share of deaths by months in intra-mural, extra-mural, and out-parishes.

While we do not have data for St Giles in the Fields for earlier plagues, it is evident that the plague is not emerging there as it does not first spread to Holborn and Clerkenwell before reaching St Giles Cripplegate. This changing source of the plague probably mirrors the changing map of London poverty in the mid-seventeenth century with the rapid growth of the west of the city.

5 Seasonality.

How did mortality vary during the year? For rural England at this time, [Wrigley and Schofield \(1981, 293\)](#) show that mortality peaked in March and reached a minimum in July. By contrast, plague mortality usually peaked in the autumn, and this is the pattern we see in London before 1665, even in years with few recorded plague deaths between major epidemics. Typhus in England, by contrast, showed little seasonality, with epidemics occurring at any time of the year, with a slight prevalence in colder months ([Murchison, 1884, 66–68](#)).

Figure 9 shows the seasonal pattern of mortality for the parishes in our sample, divided into groups for the intra-mural, extra-mural, and out-parishes which are coloured red, blue, and green respectively. Each year is composed of 13 four week months, and the diagram shows the share of total deaths over the period that occurred in each month. The first two panels focus on two periods between major plague episodes, 1613–23 (when the London Bills record between 9 and 37 plague deaths per year out of a total deaths ranging from 7,500 to 11,000) and 1650–1663 (with 4 to 36 plague deaths reported annually out of a total of 9,000 to 20,000 deaths). Looking at the first period, the intra-mural parishes shows a summer minimum and winter peak, but the extra-mural and out-parishes both show strong autumn peaks consistent with fairly substantial mortality from plague or some other disease associated with warm weather. For 1650–1663, all three areas, but especially the extra-mural parishes, show a strong autumn peak.

After 1665, the conventional story of the sudden disappearance of plague would lead us to expect a rapid transition to the winter peak pattern of mortality shown by the rest of England. However, looking at the third panel of Figure 9, for 1670–1689, all districts continue to show a very marked autumn peak in mortality that persists, although substantially weaker and lower than January mortality, during 1690–1709. By 1710–1729, the intra-mural area has reached the standard v-shaped mortality profile but the extra-

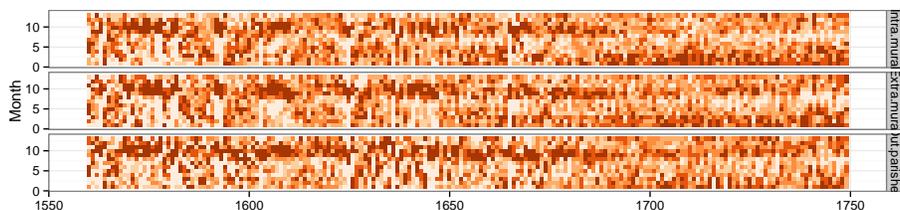


Figure 10: Heat-map of monthly mortality by district, 1560–1750.

mural and out-parishes continue to show marked autumn peaks. It is only after 1730, in the last panel, that all regions show a v-shaped profile.

Figure 10 gives a heat-map of monthly mortality share (again using 4 week months) where months are assigned into quartiles according to their share of annual mortality. The pre-1665 plague era pattern is apparent, with dark squares towards the top of each diagram corresponding to large autumn shares of mortality. Looking at the top panel, for the intra-mural parishes, this pattern of autumn peaks continues until the 1690s, when a marked late-winter peak appears along the bottom of the diagram.

It therefore appears that the same seasonal pattern of mortality as during earlier periods between plague epidemics persisted after 1665 until the 1720s, most strongly in the poorer extra-mural and out-parishes. This seasonality is consistent with the continued presence of plague but could, of course, be associated with some other autumn disease, perhaps dysentery. However, the question then arises of how this unknown disease suddenly disappeared after 1730. Given the similarity of plague to typhus it therefore appears possible that isolated cases of plague may have continued to occur annually in the autumn in London until the 1720s, as they had in earlier intervals between epidemics, but were recorded as typhus or other fevers.

6 Positive Preventive Checks.

To what extent did London deaths respond to living standards? In [Kelly and Ó Gráda \(2011\)](#) it is shown that England, outside London, saw the disappearance of the positive check during the early seventeenth century, while London after 1665 showed a continued strong positive check until the early eighteenth century.

As in [Kelly and Ó Gráda \(2011\)](#) we assume that the death rate is a simple log-linear function of past death rates and real wages

$$\ln(D_t/N_t) = \alpha + \beta' \ln(D_{t-1}/N_{t-1}) + \gamma' \ln(w_t) \quad (1)$$

where D are annual deaths, N is population, w is the real wage. The right hand side variables are vectors of current and lagged values. In what follows we do not know population levels N , only annual deaths. We therefore assume in each regression that annual population growth is roughly constant $N_t = (1 + g)N_{t-1}$

It follows that

$$\ln(D_t) = \tilde{\alpha} + \beta' \ln(D_{t-1}) + \gamma' \ln(w_t) + \delta t \quad (2)$$

where $\tilde{\alpha} = \alpha + (\beta_1 + \beta_2 + \dots)g + (\beta_2 + 2\beta_3 + \dots)g \ln(N_1)$ and $\delta = (1 - \beta_1 - \beta_2 - \dots)g \ln(N_1)$. [Kelly and Ó Gráda \(2011\)](#) show that an advantage of this logarithmic specification is that it is robust to systematic under-registration of deaths or mis-measurement of living standards: as long as the measured values are a fairly constant fraction of the true values, the elasticities β and γ will be correctly estimated.

We estimate this regression using deaths imputed above from 1560 to 1664 for the intra-mural, extra-mural, out-parishes, and Westminster in [Table 2](#). In estimating real wages we used the reconstructions for London by [Allen \(2007\)](#) and for English farm labourers by [Clark \(2007\)](#), but the former had no explanatory power and we only report results for the Clark series here. In

	Total	Intra-m	Extra-m	Out-parishes	Westminster
(Intercept)	6.52** (1.25)	5.63** (1.07)	5.59** (1.25)	5.22** (1.23)	0.69 (1.06)
Trend	0.01** (0.00)	0.01** (0.00)	0.01** (0.00)	0.01** (0.00)	0.00 (0.00)
Lag deaths	0.37** (0.09)	0.29** (0.10)	0.42** (0.09)	0.46** (0.09)	0.83** (0.08)
Lag 2 deathg	-0.06 (0.05)	-0.09 (0.05)	-0.03 (0.06)	-0.03 (0.06)	0.03 (0.07)
Wage	-0.37* (0.19)	-0.22 (0.18)	-0.43* (0.21)	-0.47* (0.21)	-0.38 (0.23)
Lag wage	0.21 (0.19)	0.26 (0.19)	0.24 (0.21)	0.16 (0.22)	0.40 (0.24)
Plague year	1.44** (0.10)	1.40** (0.10)	1.51** (0.11)	1.34** (0.11)	1.10** (0.13)
Post-plague year	-0.79** (0.17)	-0.64** (0.17)	-0.90** (0.18)	-0.89** (0.17)	-1.26** (0.16)
R^2	0.83	0.76	0.80	0.87	0.87

Plague years are 1563, 1593, 1603, and 1625

Table 2: Positive Check in London, 1560–1664.

Table 2 it can be seen that mortality is more strongly influenced by current real wages as one moves from affluent to poor areas: current wage has a small and insignificant impact on deaths within the walls or in Westminster, but affects deaths in the extra-mural and out-parishes with an elasticity of 0.4.

Figure 11 shows the relationship between deaths by region and real wages for each year between 1560 and 1664. The major plague years identified in Table 2 are omitted. In each figure there are a cluster of observations to the northeast of the main series, which are labelled in the first panel giving London totals, which correspond to smaller episodes of plague.

The varying impact of living standards on mortality possibly reflects organisation of public charity as well as living standards: the intra- and extra-

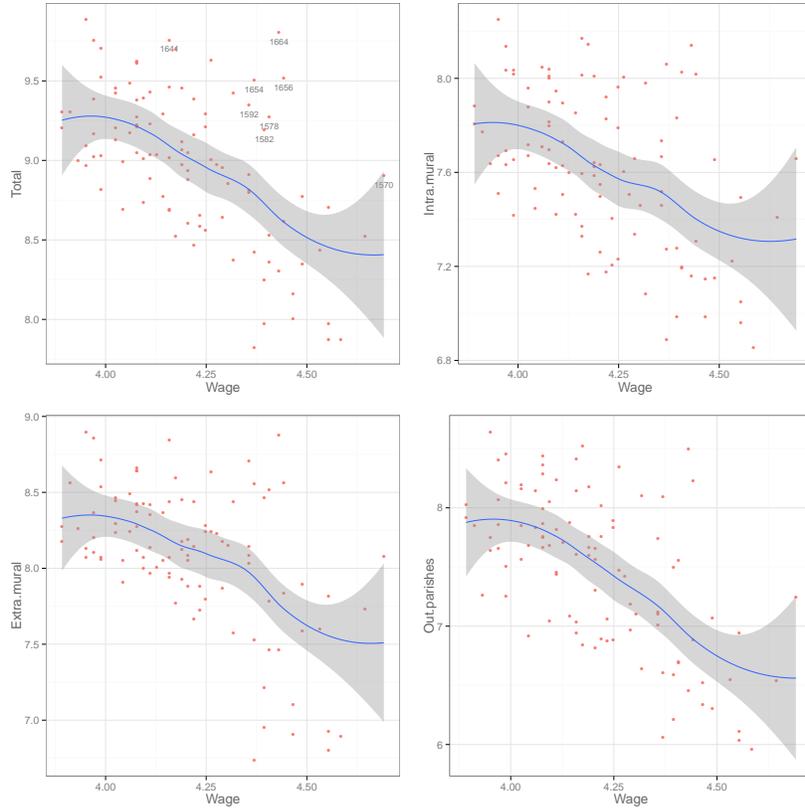


Figure 11: Annual deaths and real wages (in logs) for regions of London, 1560–1664.

mural parishes had a well organized system of public relief with systematic transfers between rich and poor parishes, while the rapidly growing out-parishes were almost entirely reliant on their own resources for poor relief: (Slack, 1989, 182). For rural England between 1600 and 1650, and for London after 1650, Kelly and Ó Gráda (2011) show that mortality is affected by wages with a lag of one year, probably as a result of disease spreading gradually through the population. For the regressions here, by contrast, the impact of wages on mortality is immediate, the same pattern that Kelly and Ó Gráda (2011) find for peasants before the Black Death and for rural England in the late sixteenth century. This immediate response of mortality to

living standards may reflect a large population surviving close to the edge of biological subsistence, or an influx of the rural poor after bad harvests: [Appleby \(1975\)](#) finds a connection between bread prices and mortality from typhus—a disease of filth and over-crowding—during the late seventeenth and early eighteenth centuries. An influx of the rural poor may also explain why Clark’s agricultural labourer wage series is a better predictor of mortality than Allen’s London one.

The close connection between typhus and plague that we noted above raises the possibility that falls in rural wages may have precipitated plague epidemics in London by first increasing the concentration of rural immigrants vulnerable to typhus. However, we can find no simple connection between wage falls and plague outbreaks suggesting that a more complicated dynamic between human lice, typhus and plague is at work.

Whereas the Black Death of the fourteenth century led to large rises in living standards, it is notable that plague mortality has little impact on wages because new migrants rapidly replaced dead Londoners. Looking at the nominal wages of craftsmen and labourers in London around the plagues of 1593, 1603, 1625, 1636, and 1665 [Boulton \(1996\)](#) finds a slight increase for craftsmen after 1593 and 1603; but little overall impact on wages. As [Graunt \(1662\)](#) noted, births, which serve as a measure of population, recovered to pre-plague levels within two years: see [Figure 12](#) below.

7 Imputing Births.

A complication in imputing births is that, unlike deaths, we have no complete set of parish totals for any year: the London Bills only record aggregates over large groups of parishes. In addition the number of children baptised in Anglican churches falls sharply after 1639. We therefore express annual baptisms in each parish as a fraction of known deaths in the parish in 1660. To allow for parishes where no baptismal records survive we impute these

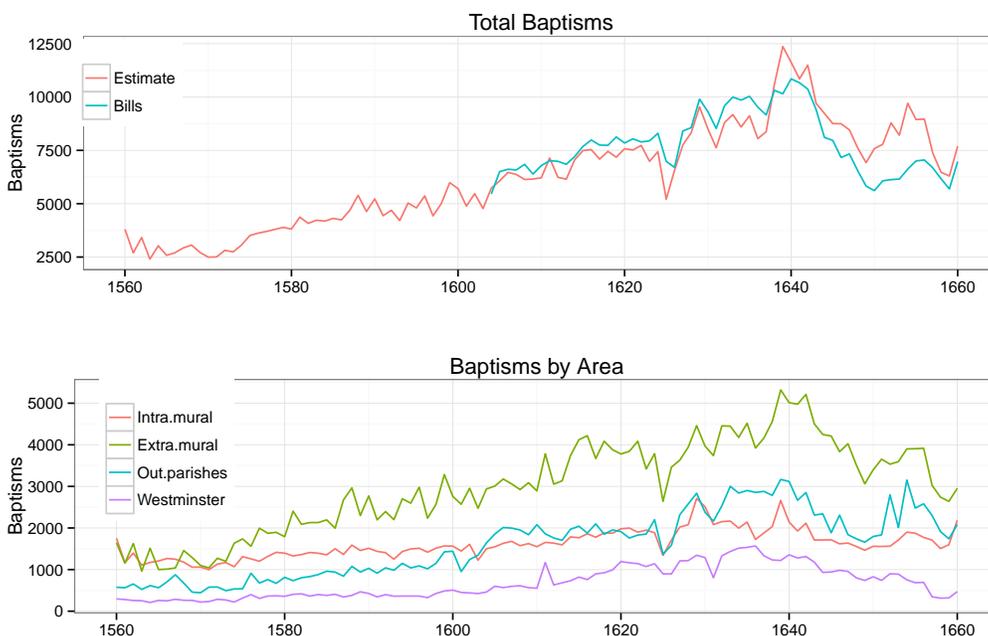


Figure 12: Estimated London baptisms, 1560–1660.

fractions by spatial interpolation for parishes north of the Thames (all southern parishes, including Lambeth, have surviving baptismal records) for 1560 and 1660, using the same nonparametric kernel estimation used for deaths; and include annual estimated totals for the very large missing parishes of St Sepulchre Holborn and St Giles in the Fields. These estimates are included with known totals to impute missing values using the same SVD procedure used for deaths. For the large parish of St James Clerkenwell annual baptismal records are implausibly low, usually one third of recorded burials, but we did not attempt to correct this.

For the seventeenth century, comparing our estimates of baptisms with the total given by Graunt we can see similar trends and levels in both series with a steady rise from around 6,000 around 1605 to 11,000 in 1640. After this the the number of Anglican baptisms falling sharply during the Civil War

and Protectorate, before recovering in the 1660s. For 1578–1582 Creighton’s numbers vary between 3,000 and 3,600 while our totals vary between 3,200 and 3,700.

Looking at the sixteenth century, our results are consistent with the established view that London’s population roughly doubled between 1550 and 1600: our estimate of total baptisms rises from 3,000 to 6,000. However, our results suggest that this rise was not continuous, with most growth occurring in the 1570s and 1580s, with the number of births appearing static during the 1560s and 1590s.

The second panel of Figure 12 shows total estimated baptisms for the four regions of London (with the distant parishes included as out-parishes from the beginning) and shows the slow growth of population inside the walls, with the intra-mural parishes being overtaken by the extra-mural ones by the 1570s, and matched by the out-parishes by the early 1600s. It can be seen that the growth of Westminster only begins around 1600 and that it is still small relative to the other districts by 1640.

Considering the preventive check, we ran similar regressions to those for deaths across the different regions of London, using estimated births from 1560 to the end of reliable registration in 1639, but did not find any large or significant connection with living standards, and do not report the results here.

7.1 Natural Increase.

Figure 13 shows the annual ratio of baptisms to burials from 1560 to the end of informative baptismal records in 1639 for London and its three subdivisions, with the intra-mural parishes again being split into rich and poor based on the proportion of substantial households in 1638. The ratio is computed from the set of parishes in each region and each year that report both baptisms and funerals: we use actual rather than imputed values, and, again, years preceded or succeeded by missing values are also set to missing.



Figure 13: Annual ratio of baptisms to burials in regions of London, 1560–1639

It is immediately apparent that the notion of London as an undifferentiated demographic sink where burials uniformly exceeded baptisms is not sustainable, particularly after the end of the sixteenth century. The marked improvement in the ratio of births to deaths appears to be associated with the disappearance of minor plague outbreaks after 1590 noted above.

Looking at the interquartile range of birth to death ratios, the total for London ran from 0.7 to 0.9: in the median year births were 80 per cent of deaths. However, this interquartile range varied from between 1.0 and 1.3 in the affluent intra-mural parishes, through a range of 0.8 to 1.0 in poorer intra-mural parishes and 0.6 to 0.9 in the extra-mural parishes, to from 0.4 to 0.7 in the out-parishes.¹⁷ When the out-parishes are excluded, the median

¹⁷The relatively favourable demographic regime in the century before 1665 compared with the eighteenth century is also noted by [Razzell \(2011\)](#).

ratio of births to deaths in the intra- and extra-mural parishes is 0.9 with an interquartile range from 0.7 to 1.0.

In other words, the spatial gradient of replacement ratios across London is markedly Malthusian, with prosperous families usually able to reproduce themselves, outside plague years (whose impact, as we have seen, fell markedly in wealthier areas), while households in the poorer suburbs usually suffered a sharp excess of deaths over births, even in intervals between major plagues. The ratio of births to deaths becomes more favourable in the second half of the period, from 1600 to 1639, with a median ratio of 1.1 for the wealthier parishes within the walls, 0.9 for the poorer intra- and extra-mural parishes, and 0.7 for the out-parishes.¹⁸

7.2 Fall in Baptisms in Plague Years.

Faced with plague, the natural reaction of those who were able to was to flee to somewhere safer. Slack (1985, 166–169) argues that flight among the affluent increased as the seventeenth century progressed. The extent of flight may be gauged by the fall in baptisms. We would expect fewer baptisms in plague years because, first, pregnant mothers and newborns would die; and, secondly, some mothers would flee. Given the roughly similar mortality increase in the four big plagues, if we find a higher fall in births in later plagues it would suggest increased flight.

Comparing 1625 with the more severe plague of 1603 we can see support for Slack's view, with a larger fall in births despite lower mortality, indicating population flight. Births fall by less in poor intra-mural parishes and the extra-mural parishes in 1665 than in 1625 but the large fall in rich parishes,

¹⁸The greater natural increase in wealthier areas is also consistent with Sharlin's (1978) view that poorer areas had a greater transient, unmarried population that contributed to deaths but not births. However, it is not immediately apparent that this was the case for London where many wealthier households would have included substantial numbers of unmarried servants and apprentices.

	Intra rich	Intra poor	Extra-m.	City	Out-parishes	Total
1563	1.1	0.8	0.8	0.9	1.3	0.9
1593	0.8	0.9	0.8	0.8	1.1	0.9
1603	0.9	0.7	0.9	0.9	1.1	0.9
1625	0.7	0.7	0.6	0.7	0.8	0.7
1636	0.8	0.9	0.9	0.9	1.0	0.9
1665	0.7	0.9	0.7	0.7	0.9	0.8

Table 3: Births in plague years relative to median over previous five years.

despite their relatively low mortality, is again consistent with a large exodus of population.

8 Conclusions.

While dramatic, the detailed demographic history of London in the late sixteenth and early seventeenth centuries has largely been a mystery. In this paper we analysed a large sample of London parish records, allowing us to reconstruct the spatial and temporal properties of London mortality in the plague era, and to see how these responded to living standards. We found that mortality in the major plagues ran around five to six times normal mortality, while the impact of plague on richer city parishes fell through time and its impact on suburban parishes rose. Looking at the spatial diffusion of plague we find a consistent pattern of crisis mortality first emerging in the poor northern suburbs of St Giles Cripplegate and Shoreditch (until 1665, when it starts in St Giles in the Fields) and spreading over the next 14 weeks around the suburbs, and then inside the walls. Looking at the seasonality of mortality, we found that mortality before 1665 peaks in the autumn as we would expect with plague, but that this pattern persists for several decades after the supposed disappearance of plague, especially in poorer suburbs of the city.

Given the magnitude of the topic, this paper is not intended as a comprehensive or conclusive treatment of London’s demography in the century before the Restoration. In particular, by making our weekly data on burials, baptisms, and marriages for the 130 parishes publicly available in a uniform format, along with other details of the parishes, we hope to encourage others to pursue this research further.

References

- Achtman, Mark. 2012. “Insights from Genomic Comparisons of Genetically Monomorphic Bacterial Pathogens.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 367:860–867. [19](#)
- Allen, Robert C. 2007. *Prices and Wages in London and Southern England, 1259–1914*. <http://www.nuff.ox.ac.uk/users/allen/studer/london.xls>. [29](#)
- Allen, Robert C. 2009. *The British Industrial Revolution in Global Perspective*. Cambridge: Cambridge University Press. [2](#)
- Appleby, Andrew B. 1975. “Nutrition and Disease: The Case of London, 1550-1750.” *Journal of Interdisciplinary History* 6:1–22. [32](#)
- Appleby, Andrew B. 1980. “The Disappearance of the Plague: A Continuing Puzzle.” *Economic History Review* 33:161–173. [4](#)
- Birch, T. 1759. *A Collection of the Yearly Bills of Mortality*. London: A. Millar. [15](#)
- Bivand, Roger S., Edzer J. Pebesma and Virgilio Gomez-Rubio. 2008. *Applied Spatial Data Analysis with R*. New York: Springer. [12](#)
- Boulton, Jeremy. 1987. *Neighbourhood and Society: A London Suburb in the Seventeenth Century*. Cambridge: Cambridge University Press. [2](#), [5](#)

- Boulton, Jeremy. 1996. "Wage Labour in Seventeenth-century London." *Economic History Review* 49:268–290. [32](#)
- Boulton, Jeremy. 2000. London 1540–1700. In *The Cambridge Urban History of Britain*, ed. Peter Clark. Vol. 2 Cambridge: Cambridge University Press. [11](#)
- Boulton, Jeremy and Leonard Schwarz. 2010. "Yet Another Inquiry into the Trustworthiness of Eighteenth-Century London's Bills of Mortality." *Local Population Studies* 2010(85):28–45. [5](#)
- Brett-James, Norman G. 1935. *The Growth of Stuart London*. London: George Allen and Unwin. [20](#)
- Champion, J.A.I. 1995. *London's Dreadful Visitation: The Social Geography of the Great Plague in 1665*. London: Historical Geography Research Group. [24](#)
- Christie. 1893. *Some Account of Parish Clerks, More Especially of the Ancient Fraternity (Bretherne and Sisterne) of S. Nicholas, Now Known as the Worshipful Company of Parish Clerks*. London: Privately Printed. [14](#)
- Clark, Gregory. 2007. "The Long March of History: Farm Wages, Population, and Economic Growth, England 1209-1869." *Economic History Review* 60:97–135. [29](#)
- Cohn, Samuel K. 2002. "The Black Death: End of a Paradigm." *American Historical Review* 107:703–738. [19](#)
- Crawford, Raymond. 1914. *Plague and Pestilence in Literature and Art*. Oxford: Oxford University Press. [19](#)
- Creighton, Charles. 1891. *A History of Epidemics in Britain from A.D. 664 to the Extinction of Plague*. Cambridge: Cambridge University Press. [12](#), [14](#), [15](#)

- Davenport, Romola, Jeremy Boulton and Leonard Schwarz. 2010. Infant and Young Adult Mortality in London's West End, 1750–1824. Working paper Newcastle University: The Pauper Lives Project. <http://research.ncl.ac.uk/pauperlives/infantandchildmortality.pdf>. 5
- Drancourt, Michel, Linda Houhamdi and Didier Raoult. 2006. “Yersinia pestis as a Telluric, Human Ectoparasite-borne Organism.” *Lancet Infectious Diseases* 6:234–241. 19, 20, 24
- Farrington, C. P., N. J. Andrews, A. D. Beale and M. A. Catchpole. 1996. “A Statistical Algorithm for the Early Detection of Outbreaks of Infectious Disease.” *Journal of the Royal Statistical Society. Series A (Statistics in Society)* 159(3):pp. 547–563. 20
- Finlay, Roger. 1981. *Population and Metropolis: the Demography of London, 1580-1650*. Cambridge: Cambridge University Press. 2, 5, 10
- Finlay, Roger and Beatrice Shearer. 1986. Population Growth and Suburban Expansion. In *London 1500-1700: The Making of the Metropolis*, ed. A.L. Beier and Roger Finlay. London: Longman. 5
- Fisher, F. J. 1990. *London and the English Economy, 1500-1700*. London: Hambledon Continuum. 2
- Graunt, John. 1662. *Natural and Political Observations Made Upon the Bills of Mortality*. London: . 12, 24, 32
- Graunt, John. 1665. *London's Dreadful Visitation; or a Collection of All the Bills of Mortality for the Present Year*. London: E. Cores. 22, 24
- Hancock, Thomas. 1821. *Researches into the Laws and Phenomena of Pestilence; Including a Medical Sketch and Review of Plague of London in 1665; and Remarks of Quarantine*. London: William Phillips. 19

- Harding, Vanessa. 1990. “The Population of London, 1550-1700: A Review of the Published Evidence.” *London Journal* 15:111–128. [5](#), [6](#)
- Hayfield, Tristen and Jeffrey S. Racine. 2008. “Nonparametric Econometrics: The np Package.” *Journal of Statistical Software* 27(5).
URL: <http://www.jstatsoft.org/v27/i05/> [13](#)
- Hohle, Michael. 2007. “surveillance: An R package for the Surveillance of Infectious Diseases.” *Computational Statistics* 22:571–582. [20](#)
- Hollingsworth, M. F. and T. H. Hollingsworth. 1971. “Plague Mortality Rates by Age and Sex in the Parish of St. Botolph’s without Bishopsgate, London, 1603.” *Population Studies* 25(131–146). [5](#)
- Houhamdi, L., H. Lepidi, M. Drancourt and D. Raoult. 2006. “Experimental Model to Evaluate the Human Body Louse as a Vector of Plague.” *Journal of Infectious Diseases* 194:1589–1596. [19](#)
- Jones, P. E. and A. V. Judges. 1935. “London Population in the Late Seventeenth Century.” *Economic History Review* 6:45–63. [5](#)
- Keeling, M. J. and C. A. Gilligan. 2000. “Bubonic plague: A Metapopulation Model of a Zoonosis.” *Proceedings of the Royal Society Series B* 267:2219–2230. [24](#)
- Kelly, Morgan and Cormac Ó Gráda. 2011. Living Standards and Mortality in England since the Middle Ages. Working paper School of Economics, University College Dublin. [29](#), [31](#)
- Kitto, J. V. 1936. *The Register of St Martin-in-the-Fields, London. Part II (1619 to 1636)*. London: Harleian Society. [6](#)
- Landers, John. 1993. *Death and the Metropolis: Studies in the Demographic History of London 1670–1830*. Cambridge: Cambridge University Press. [5](#), [6](#)

- Littledale, Willoughby A. 1902. *The Registers of St Vedast, Foster Lane, 1558 to 1836, and St Michael Le Quern, 1685 to 1836. Volume 1.* Vol. 1 Christenings London: Harleian Society. [6](#)
- Littledale, Willoughby A. 1903. *The Registers of St Vedast, Foster Lane, 1558 to 1836, and St Michael Le Quern, 1685 to 1836. Volume 2.* Vol. 2 Weddings and Burials London: Harleian Society. [6](#)
- Lorange, E A, B L Race, F Sebbane and J B Hinnebusch. 2005. “Poor vector competence of fleas and the evolution of hypervirulence in *Yersinia pestis*.” *Journal of Infectious Diseases* 191:1907–1912. [19](#)
- Marshall, John. 1832. *Mortality of the Metropolis.* London: . [12](#)
- Mason, Thomas. 1898. *A Register of Baptisms, Marriages and Burials in the Parish of St Martin in the Fields, 1550-1619.* London: Harleian Society. [6](#)
- Mazumder, Rahul, Trevor Hastie and Robert Tibshirani. 2010. “Spectral Regularization Algorithms for Learning Large Incomplete Matrices.” *Journal of Machine Learning Research* 11:2287–2322. [13](#)
- Monecke, Stefan, Hannelore Monecke and Jochen Monecke. 2009. “Modelling the Black Death. A Historical Case Study and Implications for the Epidemiology of Bubonic Plague.” *International Journal of Medical Microbiology* 299(8):582 – 593. [19](#)
- Murchison, Charles. 1884. *A Treatise on the Continued Fevers of Great Britain.* Third ed. London: Longmans Green. [18](#), [19](#), [27](#)
- Newton, Gill. 2010. “Infant Mortality Variations, Feeding Practices and Social Status in London between 1550 and 1750.” *Social History of Medicine* 24:260–280. [5](#)
- Razzell, Peter. 2011. “Infant Mortality in London, 1538-1850: a Methodological Study.” *Local Population Studies* 87:45–64. [35](#)

- Razzell, Peter and Christine Spence. 2007. "The History of Infant, Child and adult Mortality in London, 1550-1850." *London Journal* 32:271–292. 5
- Sharlin, Allan. 1978. "Natural Decrease in Early Modern Cities: A Reconsideration." *Past and Present* 79:126–138. 36
- Slack, Paul. 1981. "The Disappearance of the Plague: An Alternative View." *Economic History Review* pp. 469–476. 4, 24
- Slack, Paul. 1985. *The Impact of Plague in Tudor and Stuart England*. London: Routledge and Kegan Paul. 2, 5, 10, 16, 36
- Slack, Paul. 1989. *Poverty and Policy in Tudor and Stuart England*. London: Longman. 31
- Southall, H.R. and N. Burton. 2004. *GIS of the Ancient Parishes of England and Wales, 1500-1850*. Colchester: . 6
- Spence, Craig. 2000. *London in the 1690s: A Social Atlas*. London: Centre for Metropolitan History. 5
- Sutherland, Ian. 1972. When was the Great Plague? Mortality in London 1563 to 1665. In *Population and Social Change*, ed. D. V. Glass and R. Revelle. London: Edward Arnold. 5
- Taddy, M.A., R.B. Gramacy and N. Polson. 2011. "Dynamic Trees for Learning and Design." *Journal of the American Statistical Association* 106:109–123. 13
- Twigg, Graham. 1993. Plague in London: Spatial and Temporal Aspects of Mortality. In *Epidemic Disease in London*, ed. J. A. I. Champion. Working Paper Series London: Centre for Metropolitan History. 24
- Webb, Cliff. 2009. London and Middlesex Burials Register Indexes and their Online Availability. Reseach Aids 51 West Surrey Family History Society. 7

- Wood, Simon N. 2006. *Generalized Additive Models: An Introduction with R*. London: Chapman and Hall. [13](#)
- Wrigley, E. A. 1967. "A Simple Model of London's Importance in Changing English Society and Economy 1650-1750." *Past and Present* (37):pp. 44–70. [2](#), [5](#)
- Wrigley, E. A. and R. Schofield. 1981. *The Population History of England, 1541–1871*. London: Edward Arnold. [2](#), [22](#), [27](#)