

Neil Cummins, Morgan Kelly and Cormac Ó Gráda
**Living standards and plague in London,
1560–1665**

**Article (Accepted version)
(Refereed)**

Original citation:

Cummins, Neil, Kelly, Morgan and Ó Gráda, Cormac (2016) Living standards and plague in London, 1560–1665. *Economic History Review*, 69 (1). pp. 3-34. ISSN 1468-0289
DOI: [10.1111/ehr.12098](https://doi.org/10.1111/ehr.12098)

© 2015 Economic History Society

This version available at: <http://eprints.lse.ac.uk/65092/>

Available in LSE Research Online: May 2016

LSE has developed LSE Research Online so that users may access research output of the School. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in LSE Research Online to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain. You may freely distribute the URL (<http://eprints.lse.ac.uk>) of the LSE Research Online website.

This document is the author's final accepted version of the journal article. There may be differences between this version and the published version. You are advised to consult the publisher's version if you wish to cite from it.

Living standards and plague in London, 1560–1665[†]

By NEIL CUMMINS, MORGAN KELLY, and CORMAC Ó GRÁDA*

This article uses individual records of 930,000 burials and 630,000 baptisms to reconstruct the spatial and temporal patterns of birth and death in London from 1560 to 1665, a period dominated by recurrent 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, we find no evidence that plague emerged first in the docks, and in many cases elevated mortality emerges first in the poor northern suburbs. Looking at the seasonal pattern of mortality, we find that the characteristic autumn spike associated with plague continued into the early 1700s. Natural increase improved as smaller crises disappeared after 1590, but fewer than half of those born survived childhood.

The central role of the urban colossus of London in driving Britain's distinctive economic development before the industrial revolution has long been recognized.¹ In an era when population growth in England and Europe generally was slow and London still subject to repeated plague epidemics, the six- or seven-fold rise in the capital's population between the Reformation and the Glorious Revolution was remarkable. Naturally, that growth has attracted scholarly attention. As long ago as the early 1660s John Graunt used London's famous Bills of Mortality to measure the speed of urban 're-peopling' in the wake of plague.² In 1682 Sir William Petty combined fiscal and demographic data to argue that 'London doubles in Forty Years' and to predict that 'the Growth of London must stop of itself, before the Year 1800'.³ Even now, however, the demography of the metropolis is less well understood than that of England and Wales as a whole.⁴ Despite a steady flow of studies in recent decades, consensus is still lacking on London's shifting demographic contours and on what factors caused them to shift.⁵ Uncertainties surrounding the quality of the underlying data,⁶ the shifting determinants

*Author Affiliations: Neil Cummins, LSE—Economic History; Morgan Kelly and Cormac Ó Gráda, University College Dublin—Economics.

[†] We would like to thank Ancestry.com and, in particular, Kim Harrison, for permission to download their parish records, and Jeremy Boulton, Romola Davenport, Gill Newton, Vanessa Harding, John Landers, Paul Slack, and Richard Smith for their advice and comments. The usual disclaimer applies.

¹ Wrigley, 'Simple model'; Fisher, *London*; Allen, *British industrial revolution*, pp. 74–5, 84–90.

² Hull, ed., *Economic writings*, p. 367.

³ *Ibid.*, p. 456.

⁴ On England and Wales the classic source is Wrigley and Schofield's monumental *Population history*.

⁵ Important contributions include Jones and Judges, 'London population'; Glass, ed., *London inhabitants*; Finlay, *Population and metropolis*; Finlay and Shearer, 'Population growth'; Boulton, *Neighbourhood and society*, pp. 13–59; *idem*, 'London'; Harding, 'Population of London', pp. 115–24; *idem*, 'City, capital, and metropolis'; Landers, *Death and the metropolis*.

⁶ For example, Finlay, 'Accuracy'; *idem*, *Population and metropolis*; Boulton and Schwarz, 'Yet another inquiry'; Razzell, 'Infant mortality in London'.

of mortality,⁷ and the demographic impact of plague persist.⁸ Perhaps, as Harding has noted, this is due to the fragmented character and uneven quality of the underlying data sources, which range from lists of communicants to hearth taxes and from marriage duties to the Bills of Mortality.⁹ Yet it is the very richness of another source—the city's parish registers—that has precluded their comprehensive use hitherto. Despite the ravages of the Great Fire of 1666, most of the parish records for mid-seventeenth-century London, including the City, Liberties, and outlying parishes, survive, usually reaching back to the sixteenth century. Several studies have analysed small samples of these records,¹⁰ but no study of them in their entirety has been attempted.

Most of these records are now available online through Ancestry.com. This study uses downloaded records of roughly 930,000 burials and 630,000 baptisms in 118 of the 130 London parishes to reconstruct the spatial and temporal patterns of birth and death in London from 1560 to 1665. We estimate that our sample comprises the individual burial records of over 80 per cent of those 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 impact 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 detect disease outbreaks in real time. 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 recur throughout our period, the frequency and deadliness of smaller crises falls markedly after 1590.

Considering the spread of crisis mortality, in all major plague outbreaks anomalous rises in mortality occur first in the poor northern suburbs although, in two cases, 1603 and 1625, these rises coincide with increases in eastern parishes. In no

⁷ Appleby, 'Nutrition and disease'; Champion, *London's dreaded visitation*, pp. 81–97; Razzell and Spence, 'History'; Newton, 'Infant mortality variations'.

⁸ Creighton, *History of epidemics*, pp. 354, 471–4; Hollingsworth and Hollingsworth, 'Plague mortality rates'; Slack, *Impact of plague*; Twigg, 'Plague in London'; Champion, *London's dreaded visitation*, pp. 55–80; Moote and Moote, *Great Plague*, pp. 177–97, 293–301.

⁹ Harding, 'Population of London', pp. 111–12.

¹⁰ Most notably Finlay, *Population and metropolis*, pp. 20–50, 83–110, 158–67; Slack, *Impact of plague*, pp. 144–72; Boulton, *Neighbourhood and society*, pp. 13–59.

case do we observe crises beginning in the eastern, river parishes and spreading later to other areas, which would be expected, were plague 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.¹¹ However, these discussions ignore a basic diagnostic fact: before the late nineteenth century it was considered difficult, even for professional pathologists, to distinguish isolated adult cases of plague from typhus, which should make us 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 late 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, late 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.

Looking at natural increase, the popular impression is of London as an undifferentiated demographic sink where deaths considerably exceeded births. However, we find that natural increase varied widely across the city in the early seventeenth century, with the wealthier central parishes experiencing a positive natural increase outside plague years, the surrounding poorer parishes suffering an average deficit of 10 per cent, but with average deficits of 30 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 through time) while poor districts suffered a marked excess of deaths over births even between major plagues.

While parish registers rarely give ages, around a half of parishes record that the deceased was the 'son of' or 'daughter of' a householder, allowing us to conclude that the death is of a young person. Deaths of children, so defined, account for 40 to 50 per cent of recorded deaths in our sample. The ratio of child deaths to baptisms gives an approximate estimate of the risk of dying as a child, and this varies from a little under a half in richer parishes to two-thirds in outer suburbs.

Although there are several notable studies of London population for the London Bills period after 1665,¹² detailed studies for our period at the level of parishes are few. These include those by Hollingsworth and Hollingsworth, Finlay, and Boulton, although notable recent contributions include those by Razzell and Spence and by Newton.¹³ However, the monumental study of English plague, to

¹¹ Appleby, 'Disappearance'; Slack, 'Disappearance'.

¹² In particular, Spence, *London*; Boulton and Schwarz, 'Yet another inquiry'; Davenport, Boulton, and Schwarz, 'Infant and young adult mortality'; all deriving from Landers's classic *Death and the metropolis*.

¹³ Hollingsworth and Hollingsworth, 'Plague mortality rates'; Finlay, *Population and metropolis*; Boulton, *Neighbourhood and society*; Razzell and Spence, 'History'; Newton, 'Infant mortality variations'.

which our analysis is deeply indebted throughout, is Slack's *The impact of plague*, most particularly his chapter 6 on metropolitan plague.¹⁴

The rest of the article is as follows. Section I outlines the parish records that we use and compares our estimates of deaths with those of early London Bills. Section II looks at the social geography of London, showing how geographical segregation of the affluent increased between the late sixteenth and early seventeenth centuries. Section III 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 IV uses weekly burials in the parishes in our sample to track the spread of plague epidemics from 1563 to 1665. Section V looks at deaths of children, and section VI looks at the seasonality of deaths in different parts of the city. Section VII imputes the number of births and estimates the rate of natural increase in different parts of London, while section VIII looks at the strength of the positive check in different parts of the city.

I: London parish records

This article uses records of roughly 930,000 burials and 630,000 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.¹⁵ 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 such as Inns of Court or the Tower of London.¹⁶

The record is remarkably complete.¹⁷ We have records for 87 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 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

¹⁴ Slack, *Impact of plague*, pp. 144–72. While our focus is on annual deaths and births, there is an extensive related literature on estimating London's total population beginning with Jones and Judges, 'London population'; continuing through Wrigley, 'Simple model', pp. 45–50; Sutherland, 'When was the Great Plague?'; Finlay and Shearer, 'Population growth'; with a useful survey in Harding, 'Population of London'.

¹⁵ On the changing definition of London, see Harding, 'Population of London', pp. 111–15.

¹⁶ Parish shapefiles are taken from Southall and Burton, 'GIS', with parishes created after 1665 being included in their original parish. Names of the parishes in the map can be found in Landers, *Death and the metropolis*, app. 3, pp. 365–8.

¹⁷ In 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, ed., *Register*, and Kitto and Mason, eds., *Register*), St Clement Danes (from 1538 to 1638 based on facsimiles of the burial register downloaded from findmypast.com), and St Margaret Westminster (from 1538 to 1638 from freereg.org.uk). The freereg series for St Martin-in-the-Fields is considerably lower than the Harleian Society series edited by Kitto and Mason 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 obtained birth and burial records for the fourth largest Westminster parish of St Mary le Strand (starting 1560) from findmypast facsimiles. We have also included birth and death records for the intra-mural parish of St Vedast (from Littledeale, ed., *Registers*). Records for St Giles in the Fields and All Hallows Barking are based on our transcription of microfilm copies in the London Metropolitan Archives, P82/GIS/A/04/001 and P69/ALH1/A/01/001-002.



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

Sources: See n. 17.

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 the small parish of Lambeth (absent from the 1636 Bill, 1 per cent of deaths in 1663) although we have its baptismal records from 1540 onwards. For the five Westminster parishes, we are missing records only for the smallest parish of St Paul Covent Garden (created from St Martin-in-the-Fields in 1645, 0.8 per cent of deaths in 1663). (Figure 1 shows the starting dates of burial records.) Of surviving parish registers for our period listed by Webb, only one extant register is absent from our sample: the tiny All Hallows Bread Street (starts 1538, 0.06 per cent of deaths in 1636).¹⁸

The parishes in our sample therefore account for a substantial proportion of London's population in the early seventeenth century. For 1578, the 73 intra- and extra-mural parishes in our sample account for 80 per cent of deaths recorded in the London Bill. For 1636, the earliest annual Bill that gives reliable deaths by

¹⁸ Webb, 'London and Middlesex', p. 3.

parish, the parishes for which we have data account for 71 per cent of the London total. By region, our parishes account for 66 per cent of 1636 deaths in the intra-mural parishes, 77 per cent in the extra-mural parishes, and 70 per cent in the out-parishes.

We are, in most cases, not using the original registers but downloads of individual records from Ancestry.com. This creates three sources of potential error: the registers 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 registers.¹⁹ We can judge the accuracy of our procedure in two ways: by comparing our 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 1578–82 and the plague years of 1563 and 1593.

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, 1660.²⁰ To prevent small intra-mural parishes clustering indistinguishably around the origin, we use square root axes.

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.

II: The social geography of London

The social geography of mid-seventeenth-century London has been well known since Finlay used the settlement of tithes of 1638 to map the distribution of 'Substantial Householders' (those living in property valued at a rent of £20 or above).²¹ 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 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.²² This view that the social geography of London was relatively fixed during the sixteenth and seventeenth centuries is shared by Boulton.²³

¹⁹ We 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 remains fairly constant, we can trace the spatial and temporal variations in mortality that concern us here.

²⁰ All parish register dates have been shifted 10 days into Gregorian form. Annual London Bills ran from the Thursday before Christmas (Julian Calendar), which is close to the start of Jan. in Gregorian form.

²¹ Finlay, *Population and metropolis*, pp. 70–82.

²² Slack, *Impact of plague*, pp. 170–2.

²³ Boulton, 'London', pp. 327–8.

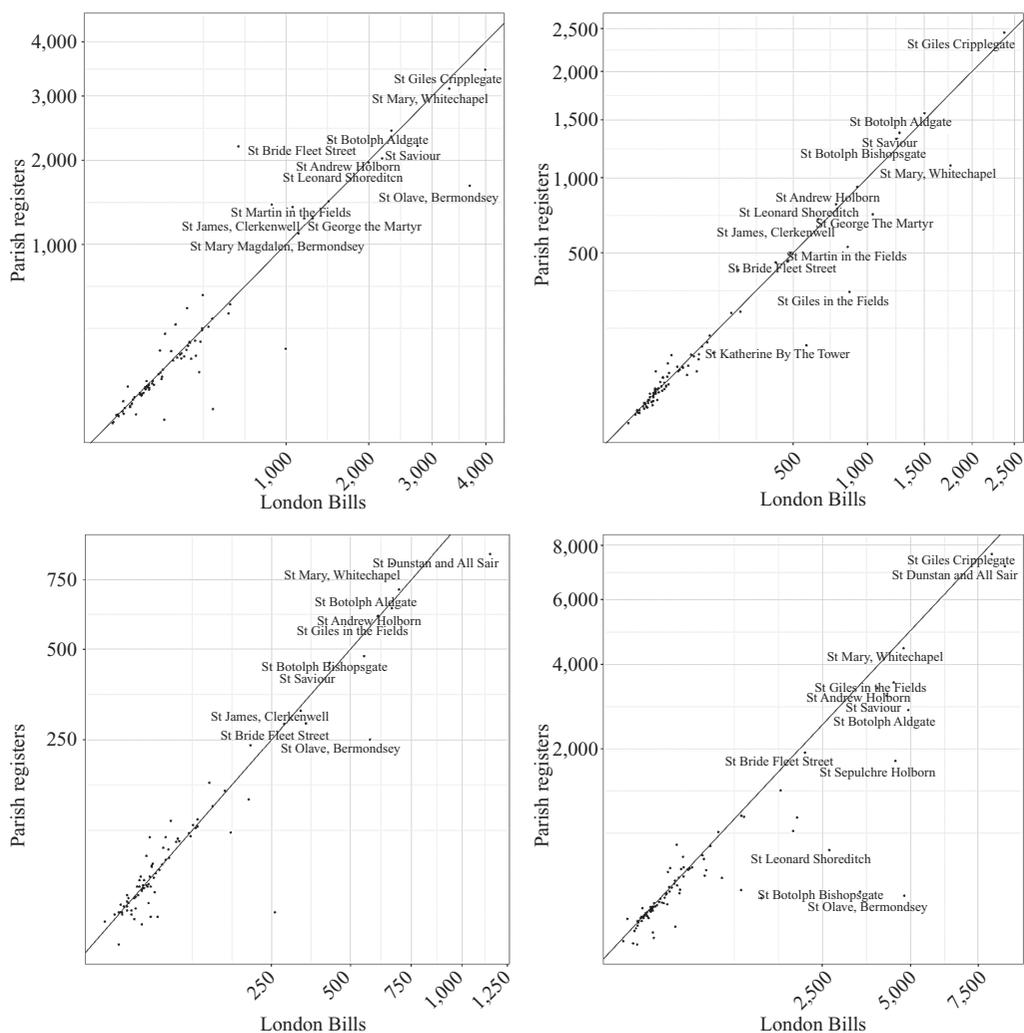


Figure 2. *Recorded deaths in parish registers versus London Bills*

Sources: Our database (see n. 17); Birch, ed., *Collections*.

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.²⁴ Excluding companies, this covers 6,632 individuals and, after leaving out servants of taxpayers, who paid 4d. each, gives a sample of 5,747 taxpayers. The upper panel of figure 3 gives the median tax paid by parish.

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. We shall see below that the trend of increasing

²⁴ This was downloaded from the London Record Society (<http://www.british-history.ac.uk/london-record-soc/vol29>, accessed on 19 Dec. 2014)



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

Sources: See section II.

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.²⁵ 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,

²⁵ Bivand, Pebesma, and Gómez-Rubio, *Applied spatial data analysis*.

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 organization. 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.

III: 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 John Graunt from the London Bills from 1603 to 1642, and from John Marshall 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 also reports weekly mortality from 1578 to 1582, and annual totals for the plagues of 1563 and 1593.²⁶

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 standard approach to such problems, which we will follow here, is to reduce the dimensionality of the problem through a singular value decomposition (SVD) that weights parishes and years separately, analogously to principal components. We tried a variety of SVD algorithms but found that the most reliable performance, particularly for reproducing known death totals from 1578–82, came from the procedure of Mazumder et al.²⁷ implemented in the R package *softImpute*.²⁸ 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.

Figure 4 plots our estimates of annual burials alongside the London Bills totals for three groupings of parishes: the intra-mural parishes, the intra- and extra-mural parishes (that is, 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 1578–82 are close to those recorded by Creighton.²⁹

²⁶ Graunt, *Natural and political observations*; Marshall, *Mortality*; Creighton, *History of epidemics* pp. 341–4.

²⁷ Mazumder, Hastie, and Tibshirani, 'Spectral regularization algorithms'.

²⁸ SVD 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, *Generalized additive models*) and regression trees (Taddy, Gramacy, and Polson, 'Dynamic trees'). When predicting missing values, each produced results close to known totals after 1604, but generated serious overestimates 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.

²⁹ Creighton, *History of epidemics*, pp. 341–4. Creighton does not give a location for these numbers but his total of 6,772 for most of 1582 is close to the 6,930 reported by Christie, *Some account*, p. 135, for the intra- and extra-mural parishes, suggesting that Creighton's numbers are for the intra- and extra-mural parishes.

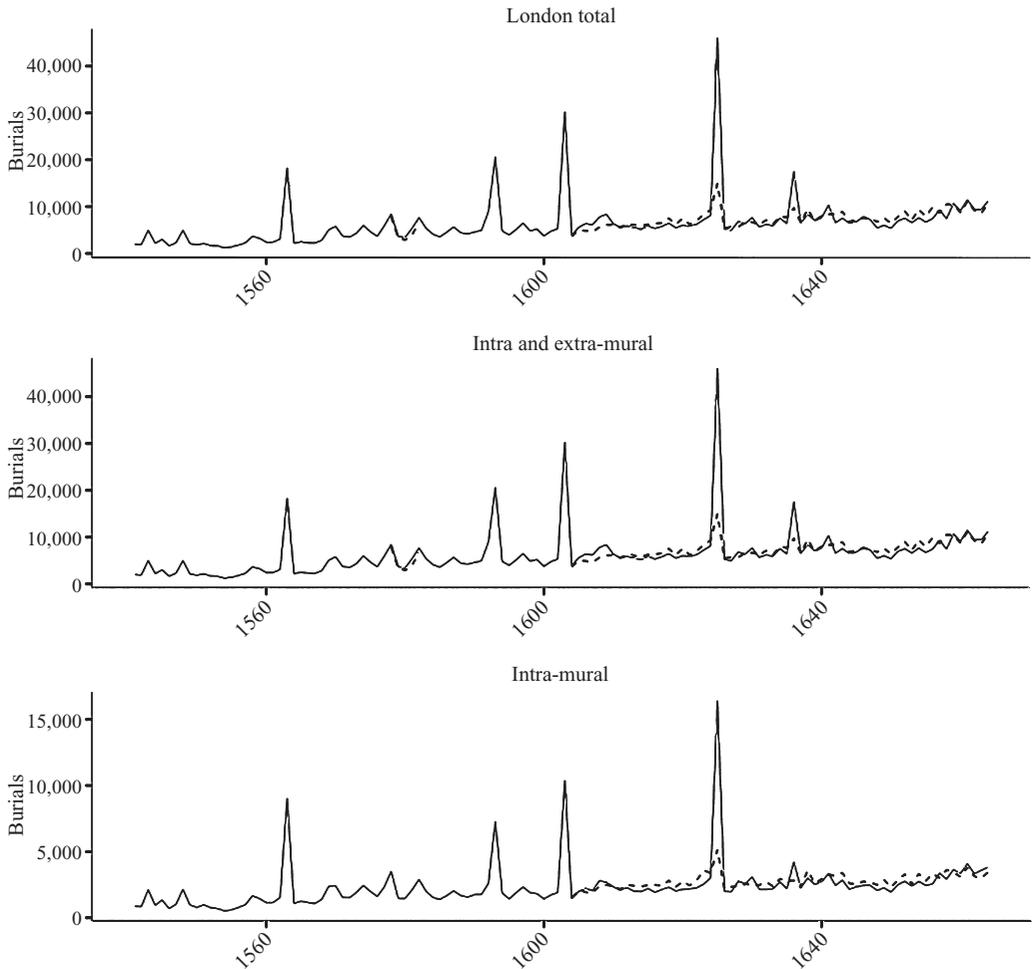


Figure 4. *Estimated (solid line) and recorded (dashed line) burials in groups of London parishes*

Source: Our database (see n. 17); Birch, ed., *Collection*.

Some totals for major sixteenth-century plague years survive. For 1563, Creighton 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 exceeds the 18,000 given by Stow and Graunt,³⁰ 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, even before including estimates for 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

³⁰ Creighton, *History of epidemics*, pp. viii, 18.

to December 1593 in the *Collection of the yearly Bills of Mortality*.³¹ Excluding distant parishes, our estimate for total mortality is 26,000.

III.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 1660–4 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 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, figure 5 shows that the plagues of 1563, 1603, 1625, and 1665 were of roughly equal deadliness, with deaths running from five to six times their usual level; while the plague of 1593 saw deaths running at 4.6 times normal, and in 1636 deaths were 2.3 times normal.

The major trend apparent in figure 5 is the sharp fall in mortality in the central parishes. In 1563 these fared worse than the rest of London but, after 1603, their experience became markedly better than their poorer neighbours, with a rise in mortality in 1665 around half that of the extra-mural parishes. While Slack 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 impact of plague there.³² The largest increase occurs in the rapidly urbanizing out-parishes which go from a plague mortality of 3.5 times normal in earlier major plagues, to six times normal in 1665.

Figure 6 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 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

³¹ Birch, ed., *Collection*, pp. 353–4. This *Collection* also contains a bill purporting to give a breakdown by parish for 1593, but gives the impossible figure 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.

³² Slack, *Impact of plague*, pp. 160–3.

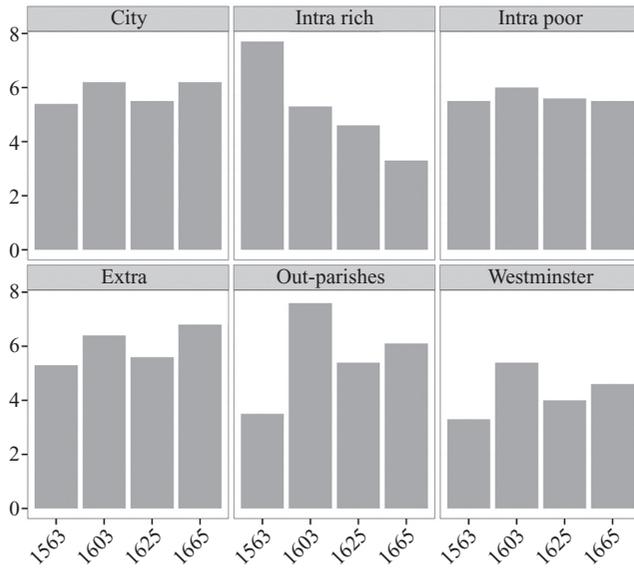


Figure 5. *Mortality in plague years compared with average mortality over preceding five years*

Source: See section III.1.

below at the weekly spread of crisis mortality, we shall see that these northern parishes are always the first (although they sometimes tie with the eastern river parishes) to show unusual rises in mortality.

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 *Encyclopaedia 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’.³³ In the standard Victorian reference on typhus, Charles Murchison 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, agonizing death and the appearance of swollen lymph glands or buboes in typhus is not uncommon.³⁴ Epidemic outbreaks of the two diseases can be distinguished by the fact that typhus rarely kills children, whereas plague kills both adults and children, but telling isolated adult cases apart was almost impossible before improvements in microbiology in the early twentieth century.

While we are agnostic as to the way that plague is transmitted, it is interesting to note that a recent literature based on the experience of French doctors in North Africa between the 1920s and the 1940s has argued that, while rat fleas are the main vector in minor outbreaks, human lice (which spread epidemic typhus) and

³³ *Encyclopedia Britannica* 1902, ‘Plague’ (<http://www.1902encyclopedia.com/P/PLA/plague-03.html>).

³⁴ Murchison, *Treatise*, pp. 200, 518.

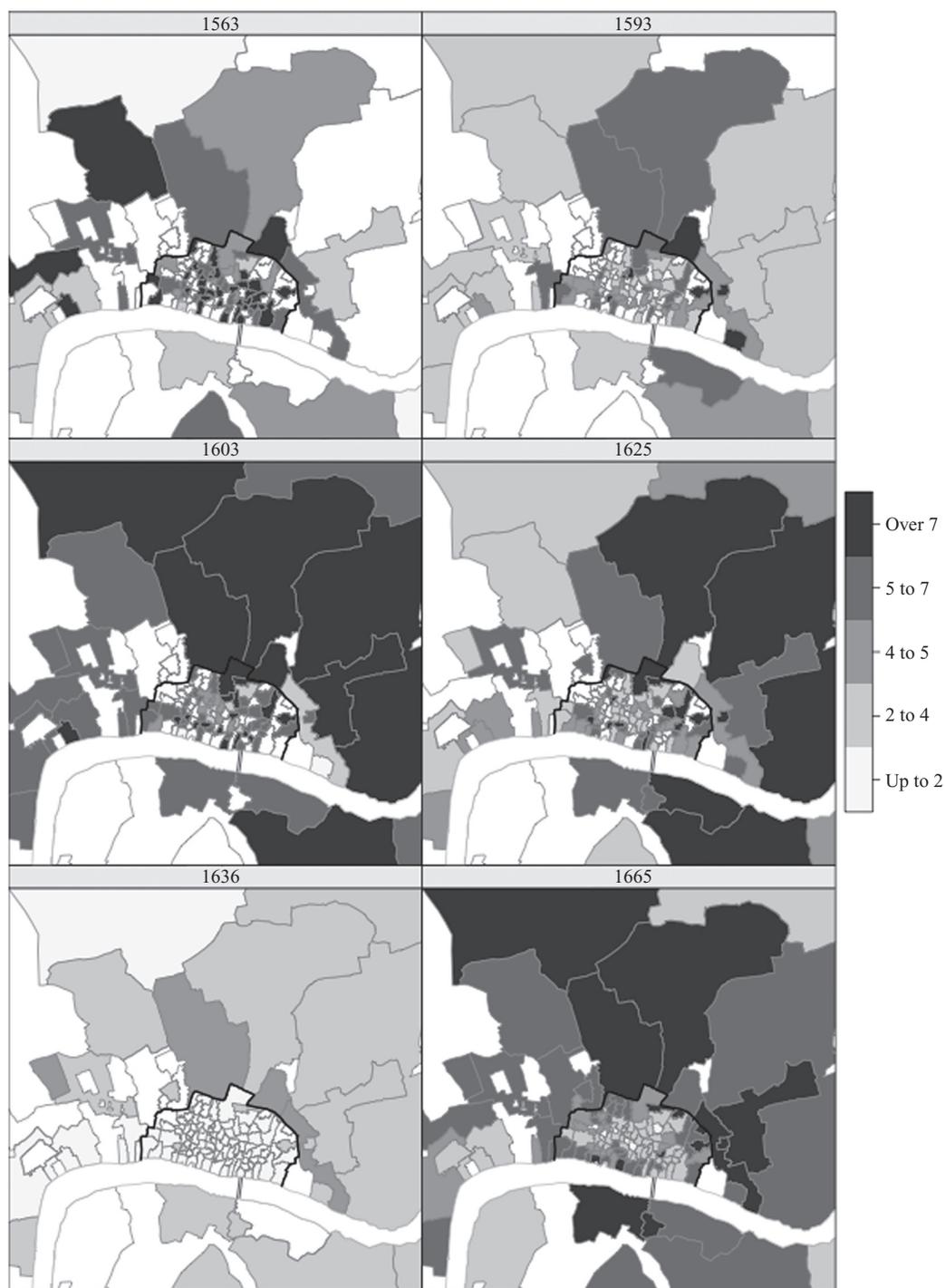


Figure 6. *Mortality in London plague years by parish relative to median mortality in preceding five years*

Source: Our database (see n. 17).

fleas are associated with the spread of major plagues.³⁵ Murchison observes that ‘many epidemics of plague in Europe have been preceded and accompanied by a great prevalence of typhus’; while Raymond Crawford writes that, ‘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’.³⁶

Returning to the falling impact of plague epidemics on wealthier parishes, looking at the 1613 plague in the Saxon town of Freiberg, Monecke et al. 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.³⁷ In the case of London, improved housing in affluent areas—‘from sticks to bricks’, in the words of James I—may have lessened the impact of plague.³⁸ To the extent that serious plague was transmitted by human fleas and lice,³⁹ greater physical segregation of rich from poor would have lessened the force of epidemics among the rich, as would improved personal hygiene.⁴⁰

IV: Mortality crises

We have seen that London mortality until 1665 was characterized by sudden spikes when plague caused deaths to run at five to six times their usual level. 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 for unusual increases in mortality, applying surveillance techniques from epidemiology. The specific algorithm we use is due to Farrington et al., implemented by Höhle.⁴¹ To detect epidemic outbreaks in real time, these compare the 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 five weeks over the three previous years, adjusted for a time trend if necessary. Figure 7 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, defined as the number of deaths each week in excess of the Farrington threshold.

The fundamental change in London mortality after 1665 is immediately evident in the fall in the number of crisis deaths. Between 1560 and 1665, these 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.

³⁵ Drancourt, Houhamdi, and Raoult, ‘*Yersinia pestis*’.

³⁶ Murchison, *Treatise*; Crawford, *Plague and pestilence*.

³⁷ Monecke, Monecke, and Monecke, ‘Modelling the Black Death’.

³⁸ Brett-James, *Growth of Stuart London*, pp. 15, 67.

³⁹ Drancourt et al., ‘*Yersinia pestis*’.

⁴⁰ However, to judge from Pepys, lice remained a problem even among the affluent. For example, 23 Jan. 1699: ‘I am louzy, having found in my head and body above 20 lice, little and great’; *Diary of Samuel Pepys*, <http://www.pepysdiary.com/diary/1669/01/23/>.

⁴¹ Farrington, Andrews, Beale, and Catchpole, ‘Statistical algorithm’; Höhle, ‘Surveillance’. Using other standard surveillance algorithms from Höhle gave almost identical results and they are not reported here.

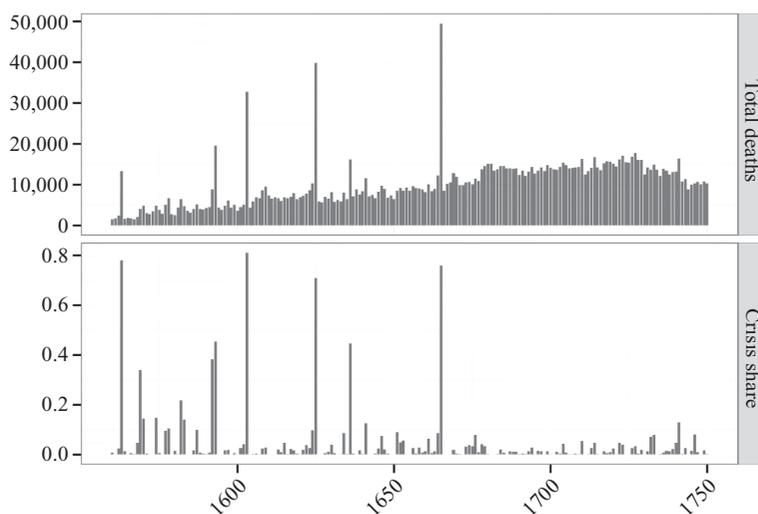


Figure 7. *Annual deaths, and proportion of deaths in excess of the Farrington threshold, 1560–1750*

Source: Our database (see n. 17).

However, what is less immediately evident but more interesting is that there is a marked reduction in the number of smaller mortality crises from the 1590s onwards: from 1563 to 1593, there are 10 years when crisis mortality exceeded 10 per cent of deaths, but from 1594 to 1665 there are only five years. In other words, there appears to be a disappearance of smaller crises from 1590 onwards.

IV.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 survive, we can compare the timing and pattern of crises detected by the surveillance algorithm with official notifications of plague deaths.

Figure 8 shows snapshots of the weekly mortality by parish in the four major plagues. The value for each parish is the number of deaths each week relative to its Farrington threshold. In each case, the map starts in week 17, except in 1563, when sustained, elevated mortality is not apparent until week 26.

What is notable about each map is that mortality first becomes entrenched in the poor northern suburbs, before spreading around the walls, and then into the intra-mural parishes. In two cases (1603 and 1625) mortality spikes in these parishes coincide with increased mortality in the dockland parish of Stepney (in the extreme east, just above the river), but in no case do we see the pattern of rising mortality appearing first in the docks, that we might expect if plague were arriving from foreign ports. The possible endemicity of plague is further supported by the seasonality of mortality (see section VI below) where mortality shows the characteristic autumn spike associated with plague, even in years with few recorded plague deaths.

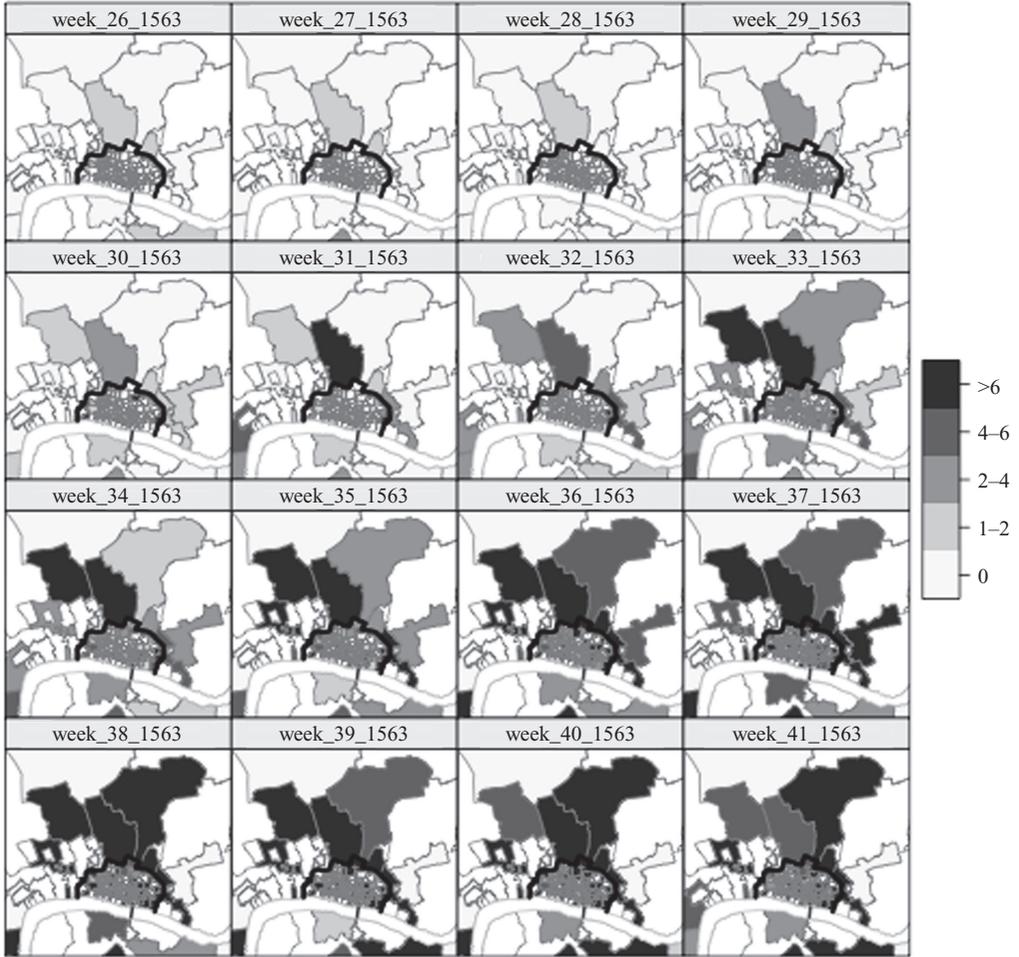


Figure 8. *Weekly spread of crisis mortality in London parishes: 1563, 1603, 1625, and 1665*

Source: Our database (see n. 17).

For 1665 we have weekly data for all London Bills parishes compiled by Graunt.⁴² 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 year t , weekly burials in that parish follow a Poisson distribution with parameter $d_{it}/52$.⁴³ 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

⁴² Excellent earlier studies of 1665 include Twigg, 'Plague in London', and Champion, *London's dreaded visitation*, both of which focus, as we do, on spatial and temporal aspects of the plague.

⁴³ Allowing the Poisson parameter to show a seasonal trend of the sort outlined in section VI did not change the results in any way.

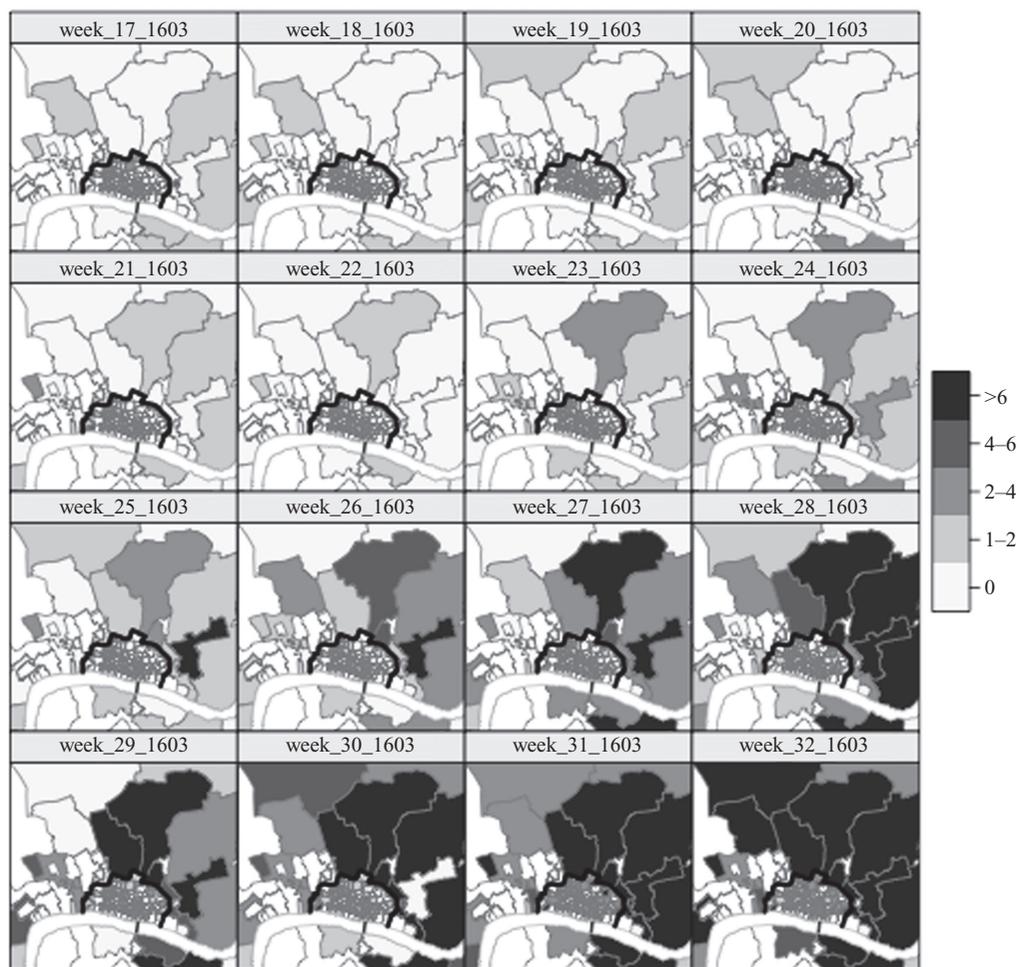


Figure 8. *Continued*

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 through the northern parishes over the next eight weeks. This south-westerly shift in the 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.

The geographical spread of plague across London is not supportive of the idea that plague was imported through the docks in the east of the city from foreign ports. That plague is generated internally in response to local conditions rather than spreading in international waves is suggested further by Biraben's data on the number of cities reporting plague each year.⁴⁴ If plague spread from the Mediterranean, we would expect Italian outbreaks to precede those in Spain and France,

⁴⁴ Biraben, *Les hommes et la peste*, vol. 2, pp. 377–88.

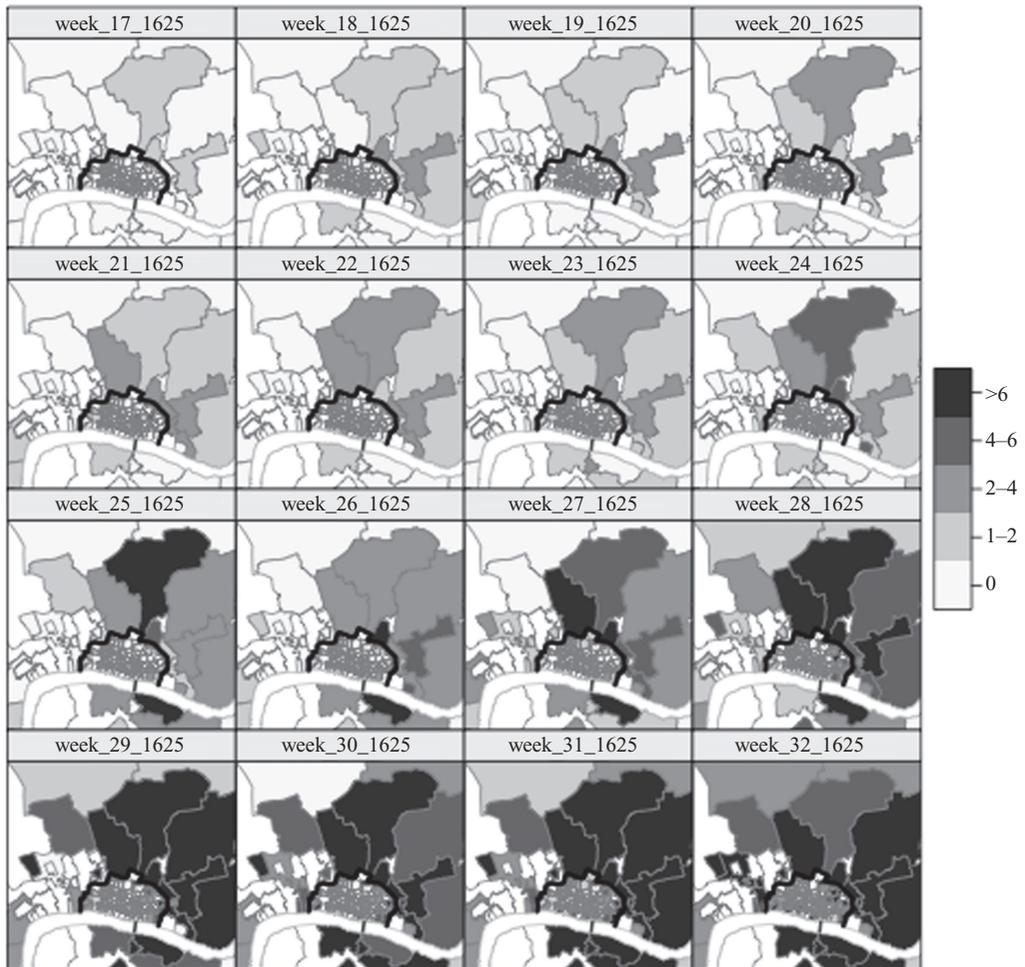


Figure 8. *Continued*

with the Netherlands and England following. However, as figure 9 shows, there are few cases after 1347–8 where spikes coincide across Europe.

V: Child deaths

With rare exceptions, registers do not record age at death. However, for about half the parishes in our sample, the register records some burials as ‘son of’ or ‘daughter of’, allowing us to conclude that the deceased was young, probably under 15 years of age. We can therefore look at how the share of child deaths, so defined, varied spatially and through time. Figure 10 shows child deaths as a fraction of baptisms in the same parishes.⁴⁵

⁴⁵ For this calculation we only included parish-year combinations where at least one burial was recorded as ‘son of’ or ‘daughter of’. A full list of the parish-years used is available at <http://neilcummins.com/ChildNcrosstab.xlsx>.

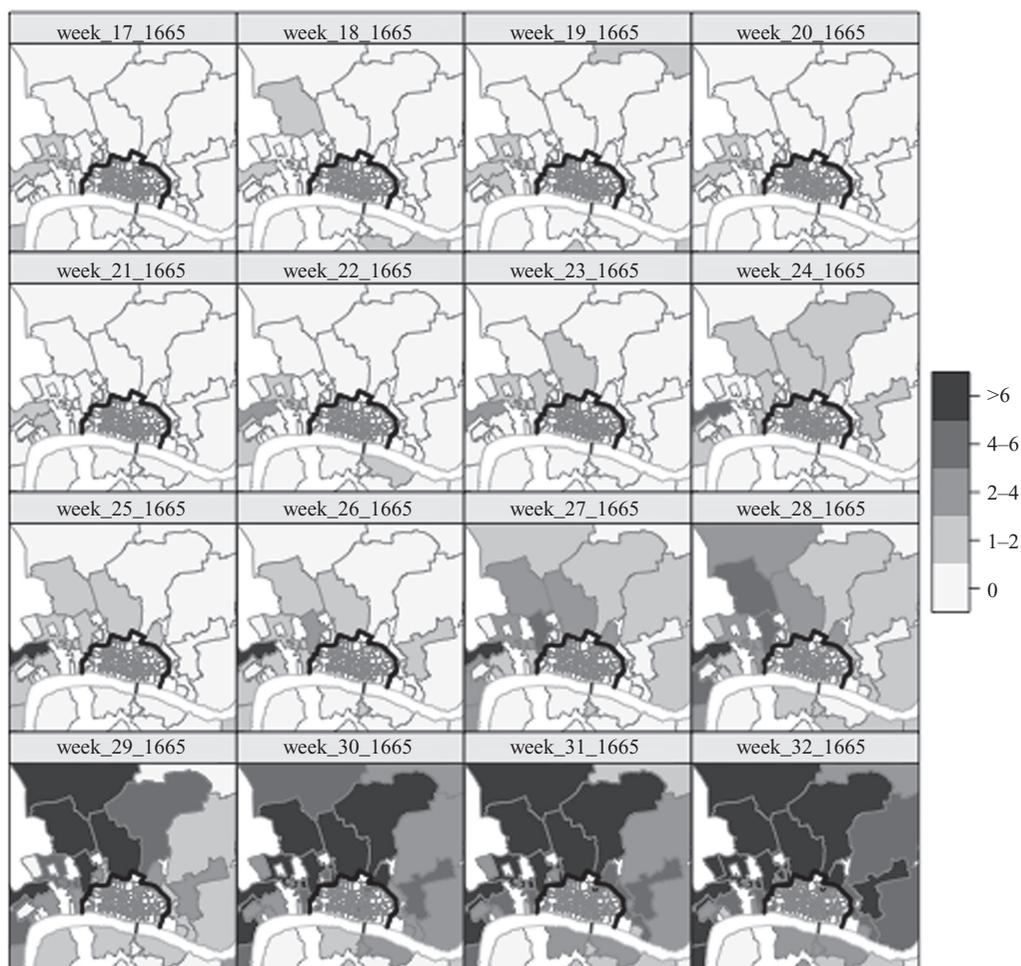


Figure 8. *Continued*

Looking at child deaths as a share of total deaths in the upper panel, it can be seen that the fraction is fairly similar across regions, with the share of children in total deaths rising from around one-third in the 1560s to nearly one-half in the mid-seventeenth century. This share falls markedly in the plague years of 1625 and 1665, indicating that registration of child deaths fell in the latter parts of these years as mortality rose. Newton shows that the low mortality of the wealthiest Cheapside parishes is explained by the practice of sending infants out to wet nurses, so that their deaths are recorded elsewhere.⁴⁶ However, the fact that child deaths as a share of total deaths are not appreciably lower in the central intra-mural parishes than elsewhere suggests that this practice was not widespread outside the very wealthiest parishes and does not affect overall child mortality of the region materially.

⁴⁶ Newton, 'Infant mortality variations'.

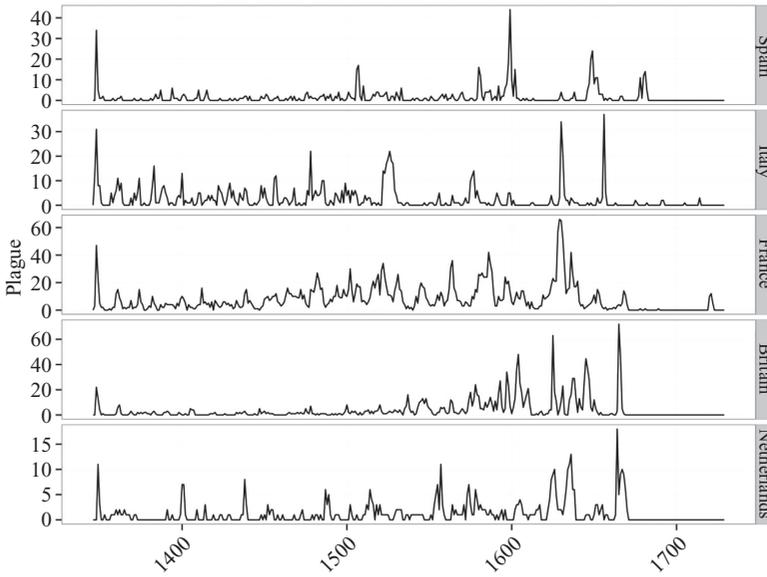


Figure 9. *Cities reporting plague across Europe, 1346–1730*

Source: See n. 44.

The rising share of children in recorded deaths between the late sixteenth and mid-seventeenth centuries does not appear to indicate a worsening mortality experience for children: in the lower panel we can see that the ratio of children’s deaths to baptisms at this time remains fairly stable, rising in the 1640s and 1650s as the share of children being baptized falls; while the ratio of births to total deaths improves (figure 10). This suggests that the benefits of the mortality improvement in the early seventeenth century went disproportionately to adults or that children constituted a larger share of the population.

Across regions, the bottom panel of figure 11 shows that the central parishes had a consistently lower ratio of child deaths to baptisms compared with the extra-mural and out-parishes. To a first approximation this annual ratio of child deaths to births gives the probability of dying during childhood.⁴⁷ For the inter-plague period 1605–24 we find that roughly half of those born survived childhood: the ratio of child deaths to baptisms is 0.45 in both rich and poor intra-mural parishes, and 0.55 in extra-mural and out-parishes. These rates are similar to estimates for four parishes by Finlay.⁴⁸ For the sixteenth century, looking at the inter-plague period 1565–92, intra-mural parishes again record a child-death to baptism ratio of 0.45, but the extra-mural and out-parishes together have a ratio of 0.67. Over

⁴⁷ Suppose that p_i is the fraction of children born in a year who die at age i . We suppose that, outside plague years, this is fairly constant from year to year. It follows that child deaths in year t $D_t = \sum_{i=0}^{\infty} p_i B_{t-i}$, where B_t is births in year t . Assuming that annual births increase at constant rate g , it follows that the ratio of child deaths to births $D_t/B_t = \sum_{i=0}^{\infty} p_i (1+g)^{-i} \approx \sum_{i=0}^{\infty} p_i$ when g is small or when most child deaths occur at low ages, as was the case in London. For St Botolph Bishopsgate in 1603, Hollingsworth and Hollingsworth, ‘Plague mortality rates’, tab. 8, p. 144, calculate that the annualized death rate for children under 1 was 314 per thousand, 40 for those aged 1–5, and 10 or below after this. For 1728, the earliest Bill giving mortality by age group, of deaths under age 20, 69% were under 2, and 17% aged 2 to 5.

⁴⁸ Finlay, *Population and metropolis*, pp. 83–110.

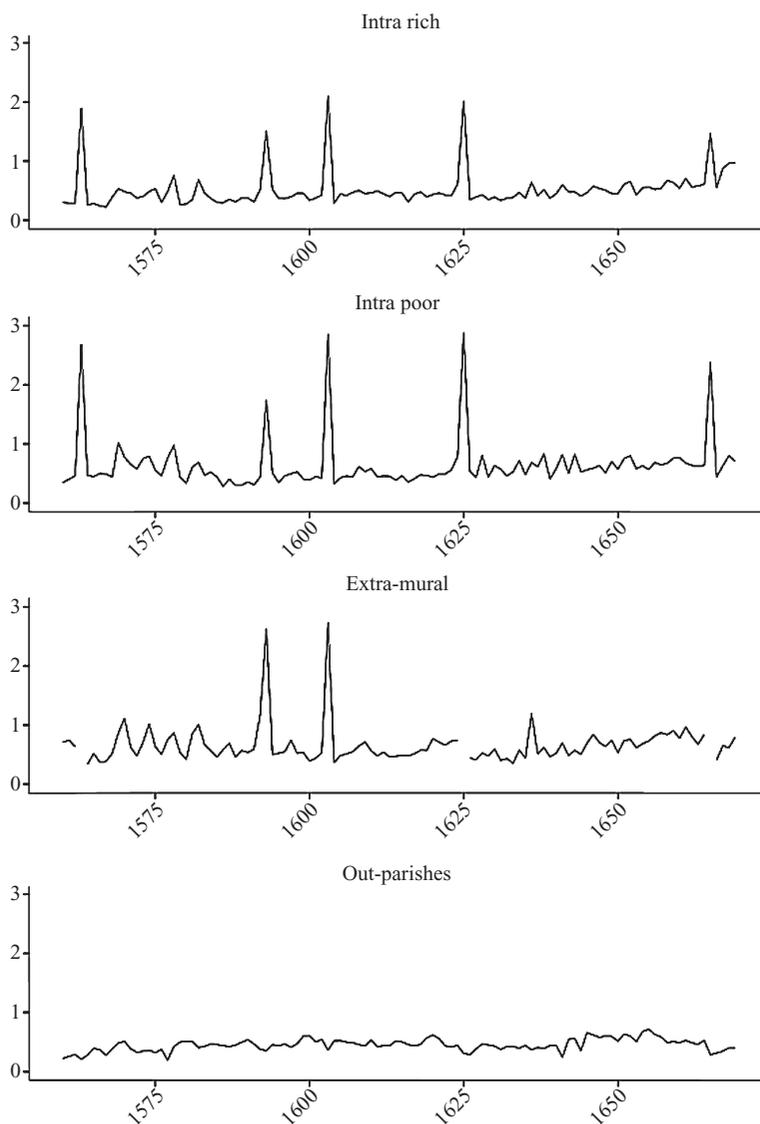


Figure 10. *Ratio of child deaths to baptisms, in regions of London, 1560–1669*

Source: Our database (see n. 17).

the entire period 1560 to 1624, the ratios are 0.47 and 0.55 for the rich and poor intra-mural parishes respectively, and 0.66 for the extra-mural and out-parishes. The markedly worse experience of children in poorer areas is at odds with Sharlin's conjecture that the worse rates of natural increase in poor areas simply reflect a higher transient population that added to deaths but not to births.⁴⁹

⁴⁹ Sharlin, 'Natural decrease'.

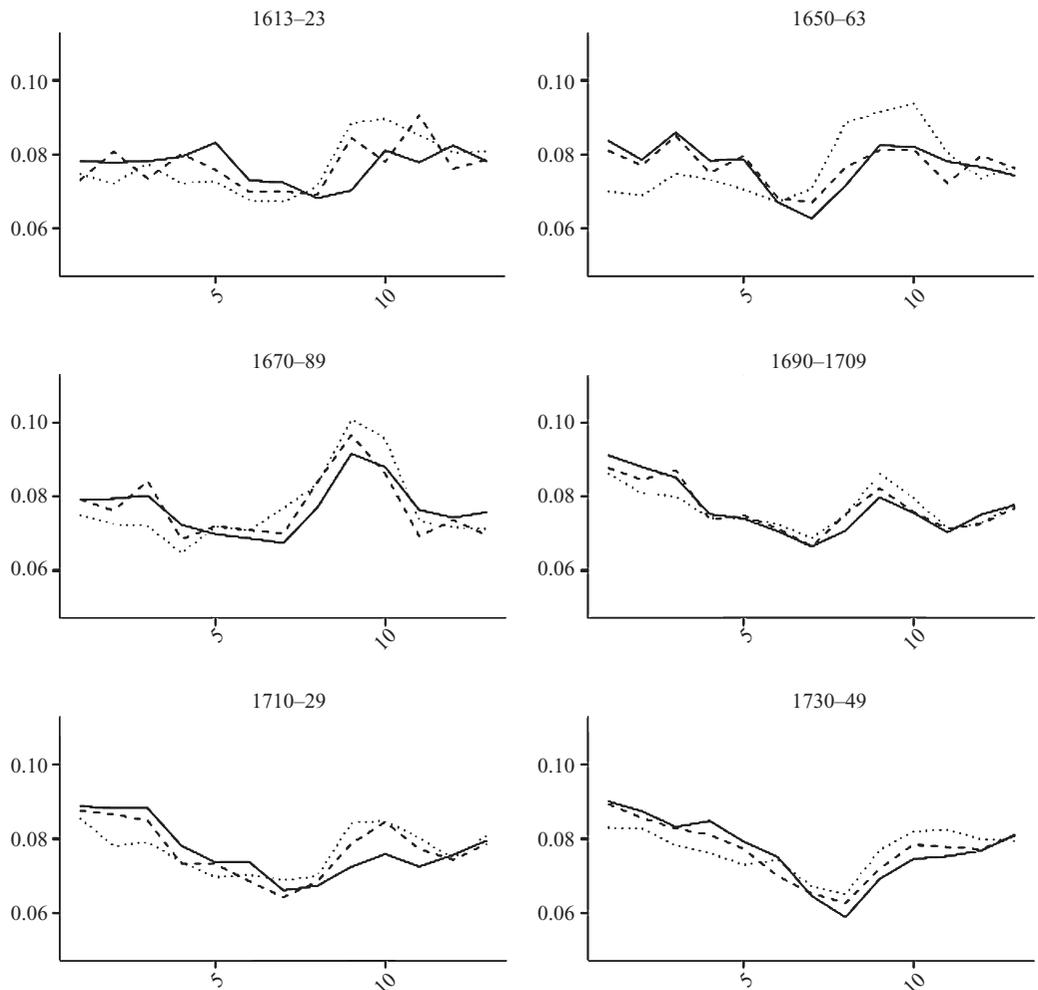


Figure 11. *Share of deaths by months in intra-mural, extra-mural, and out-parishes*
 Note: The solid line refers to intra-mural parishes, the dashed line to extra-mural parishes, and the dotted line to out-parishes.

Source: Our database (see n. 17).

VI: Seasonality

How did mortality vary during the year? For rural England at this time, Wrigley and Schofield show that mortality peaked in March and reached a minimum in July.⁵⁰ 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.⁵¹

⁵⁰ Wrigley and Schofield, *Population history*, pp. 293–6.

⁵¹ Murchison, *Treatise*, p. 77.

Figure 11 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 solid, dashed, and dotted lines 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 nine and 37 plague deaths per year out of a total ranging from 7,500 to 11,000) and 1650–63 (with four 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 show 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 1650–63, 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 11, for 1670–89, 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 1710–29, the intra-mural area has reached the standard v-shaped mortality profile but the extra-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.

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.⁵² This seasonality is consistent with the continued presence of plague (although its lengthy persistence without a major epidemic outburst is puzzling) but could, of course, be associated with some other autumn disease, perhaps dysentery. However, it is notable that the elevated mortality continues into the cool weather of October, and 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. However, the absence of any major epidemics in this long period does argue against this interpretation.

VII: Baptisms

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 baptized in Anglican churches falls sharply after 1639. However, we can still assess the accuracy of our baptismal totals by comparing them with annual totals recorded by Graunt. Another reliability check comes from comparing ratios of baptisms to burials,

⁵² Landers and Mouzas, 'Burial seasonality', note the autumn peak in mortality after 1665, which they attribute to 'convulsions', smallpox, and fever (p. 66), but they do not note its similarity to earlier intra-plague periods.

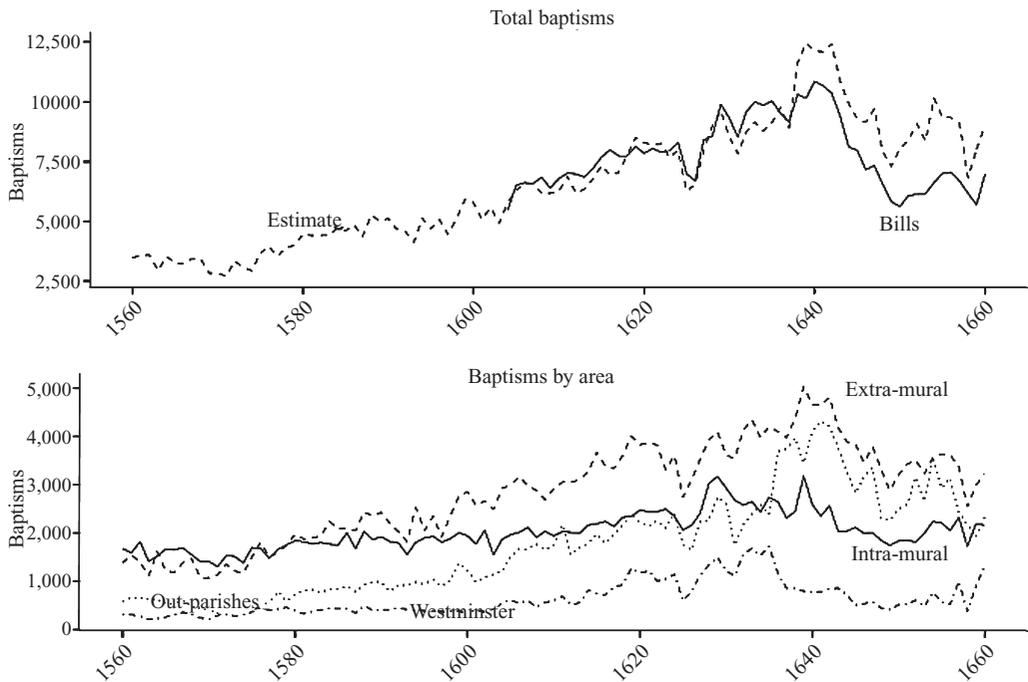


Figure 12. *Estimated London baptisms, 1560–1660*

Source: Our database (see n. 17).

which are roughly similar in every parish with the exception of St James Clerkenwell, where recorded baptisms run consistently around one-third of burials.

To impute births, we took the ratio of baptisms to burials in parishes with surviving records across each area of the city (intra-mural, extra-mural, out-parishes, and Westminster) and assumed that missing parishes had the same ratio. We used this ratio times imputed deaths from above to estimate missing baptisms (figure 12).

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 number of Anglican baptisms fell sharply during the Civil War and Protectorate, before recovering in the 1660s. For 1578–82 Creighton's numbers vary between 3,200 and 3,600 and are almost identical to our estimates, except for 1581 where he reports the implausibly low figure of 2,900 even though deaths are not elevated, while our estimate is 3,700.⁵³

Looking at the sixteenth century, our results are consistent with the established view that London's population roughly doubled between 1560 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.

⁵³ Creighton, *History*, pp. 341–5.

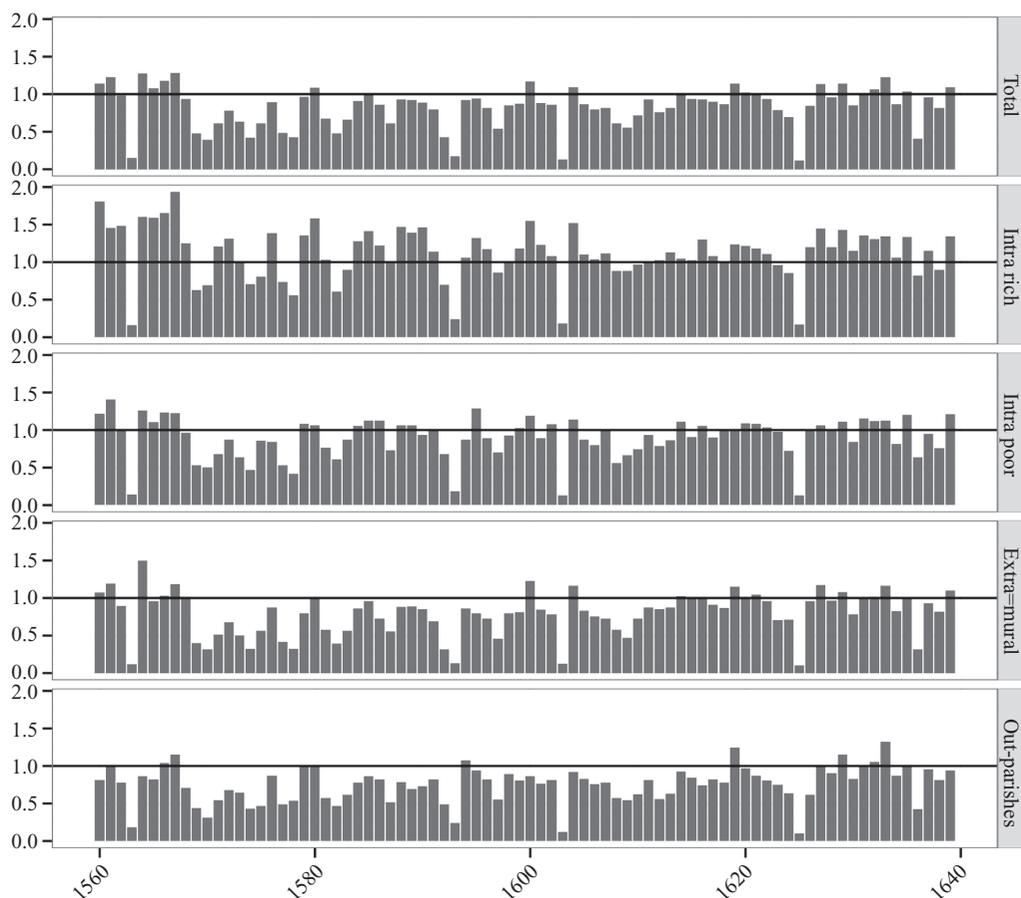


Figure 13. *Annual ratio of baptisms to burials in regions of London, 1560–1639*

Source: Our database (see n. 17).

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.

VII.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 sub-divisions, with the intra-mural parishes again 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 burials: we use actual rather than imputed values, and, again, years preceded or succeeded by missing values are also set to missing.

It is immediately apparent that the notion of London as an undifferentiated demographic sink where burials uniformly exceeded baptisms is not sustainable, particularly after 1600. The marked improvement in the ratio of births to deaths appears to be associated with the disappearance of smaller 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 0.8–1.0 in poorer intra-mural parishes and 0.6–0.9 in the extra-mural parishes, to 0.4–0.7 in the out-parishes.⁵⁴ When the out-parishes are excluded, the median 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.

Looking at absolute numbers across the 130 parishes, we estimate that the average annual deficit of deaths over births was 2,000 in the 1560s, 2,700 in the 1570s, 1,500 in the 1580s, 3,800 in the 1590s, 5,100 in the 1600s, 900 in the 1610s, 6,500 in the 1620s, and 1,900 in the 1630s. It is notable that our estimated deficits match fairly well with those for London provided by Wrigley and Schofield.⁵⁵

VII.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, and Slack argues that flight among the affluent increased as the seventeenth century progressed.⁵⁶ The extent of flight may be gauged by the fall in baptisms: given the roughly similar mortality increase in the four major plagues, if we find a higher fall in births in later plagues it would suggest increased flight. Comparing the affluent central parishes in 1625 and 1665 in figure 14, we can see support for Slack's view, with a constant fall in births despite lower mortality in 1665, indicating population flight.

VIII: Positive checks

To what extent did London deaths respond to living standards? Kelly and Ó Gráda show that England, outside London, saw the disappearance of the positive check during the early seventeenth century, while London after 1665 showed a con-

⁵⁴ Razzell, 'Infant mortality in London', has also noted the relatively favourable demographic regime in the century before 1665 compared with the eighteenth century.

⁵⁵ Wrigley and Schofield, *Population history*, pp. 166–70.

⁵⁶ Slack, *Impact of plague*, pp. 166–9.

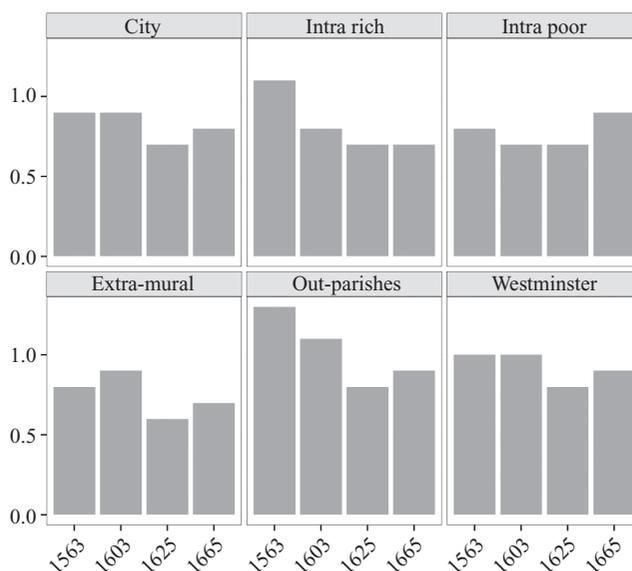


Figure 14. *Number of baptisms in major plague years relative to the average of the preceding five years*

Source: Our database (see n. 17).

tinued strong positive check until the early eighteenth century.⁵⁷ Like Kelly and Ó Gráda, 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 is annual deaths, N is population, and 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 show that an advantage of this logarithmic specification is that it is robust to systematic under-registration of deaths or mis-measurement of

⁵⁷ Kelly and Ó Gráda, 'Living standards', pp. 369–72.

Table 1. *The positive check in London, 1560–1664*

	<i>Total</i>	<i>Intra-mural</i>	<i>Extra-mural</i>	<i>Out-parishes</i>	<i>Westminster</i>
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 deaths	-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

Notes: Plague years are 1563, 1593, 1603, and 1625; standard errors in parentheses. ** indicates significant at 1%.

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.⁵⁸

We estimate this regression using deaths imputed above from 1560 to 1664 for the intra-mural, extra-mural, out-parishes, and Westminster in table 1. In estimating real wages, we tried the reconstructions for London by Allen and for English farm labourers by Clark, but the former had no explanatory power and we only report results for the latter series here.⁵⁹ In table 1 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 15 shows the relationship between deaths by region and real wages for each year between 1560 and 1664. The major plague years identified in table 1 are omitted. In each figure there is a cluster of observations to the north-east 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 organization of public charity as well as living standards: the intra- and extra-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.⁶⁰ For rural England between 1600 and 1650, and for London after 1650, Kelly and Ó Gráda 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 find for peasants before the Black Death and for rural England in the late sixteenth century.⁶¹ This immediate response of mortality to living standards may reflect a large population surviving close to the edge of biological subsistence, or immigration of the rural poor after bad harvests: Appleby finds a connection between bread prices and mortality from typhus—a disease of filth and overcrowding—during the late seventeenth and early eighteenth century,⁶² with Gal-

⁵⁸ Kelly and Ó Gráda, 'Living standards,' p. 365.

⁵⁹ Allen, 'Prices and wages'; Clark, 'Long march of history', pp. 131–4.

⁶⁰ Slack, *Poverty and policy*, p. 182.

⁶¹ Kelly and Ó Gráda, 'Living standards,' pp. 369–70.

⁶² Appleby, 'Nutrition and disease', p. 13.

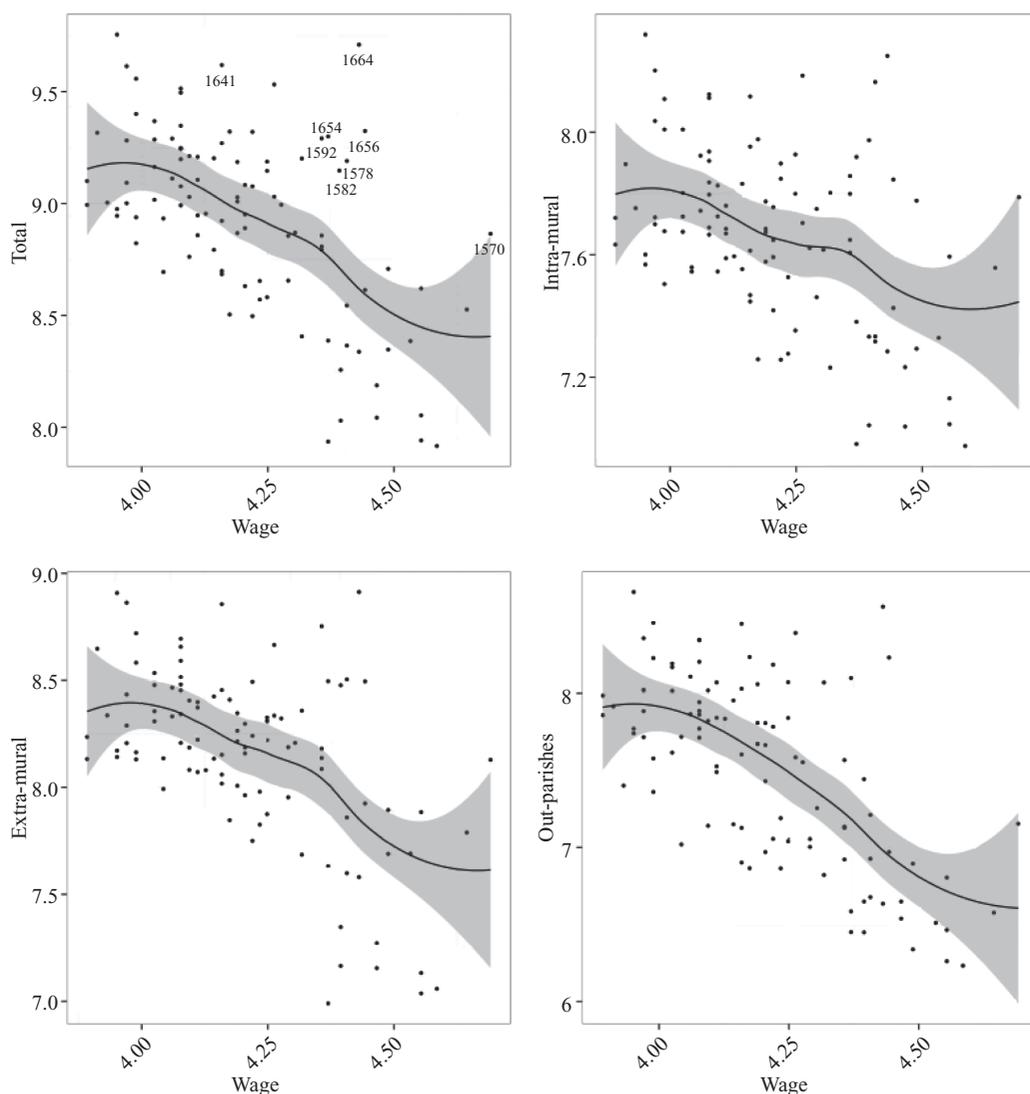


Figure 15. *Annual deaths and real wages (in logs) for regions of London, 1560–1664*
 Source: Our database (see n. 17); Clark, ‘Long march’.

loway and Landers and Mouzas finding similar results.⁶³ Such 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 and smallpox. However, we can find no simple connection between wage

⁶³ Galloway, ‘Annual variations’, pp. 495–500; Landers and Mouzas, ‘Burial seasonality’, pp. 61–4, 69–80.

falls and plague outbreaks, suggesting that a more complicated dynamic between human lice, typhus, and plague was at work.

Whereas the Black Death of the fourteenth century led to large rises in living standards, it is notable that plague mortality had 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 finds a slight increase for craftsmen after 1593 and 1603; but little overall impact on wages.⁶⁴ As Graunt noted, births, which serve as a measure of population, recovered to pre-plague levels within two years (see figure 12).⁶⁵

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.

IX: Conclusions

While dramatic, the detailed demographic history of London in the late sixteenth and early seventeenth centuries has largely been a mystery. In this article 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 at 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, although this sometimes coincided with its emergence in eastern parishes. Looking at the seasonality of mortality, we found that mortality before 1665 peaked in the autumn as we would expect with plague, but that this pattern persisted for several decades after the supposed disappearance of plague, especially in poorer suburbs of the city.

Given the magnitude of the topic, this article 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.⁶⁶

<i>Date submitted</i>	<i>31 July 2013</i>
<i>Revised version submitted</i>	<i>31 July 2014</i>
<i>Accepted</i>	<i>19 August 2014</i>

DOI: 10.1111/ehr.12098

⁶⁴ Boulton, 'Wage labour', pp. 288–9.

⁶⁵ Graunt, *Natural and political observations*, pp. 367.

⁶⁶ The data are available at http://neilcummins.com/CKOG_LondonData_2014.zip.

Footnote references

Allen, R. C., 'Prices and wages in London and southern England, 1259–1914' (2007), <http://www.nuff.ox.ac.uk/users/allen/studer/london.xls> (accessed on 19 Dec. 2014).

- Allen, R. C., *The British industrial revolution in global perspective* (Cambridge, 2009).
- Appleby, A. B., 'Nutrition and disease: the case of London, 1550–1750', *Journal of Interdisciplinary History*, VI (1975), pp. 1–22.
- Appleby, A. B., 'The disappearance of the plague: a continuing puzzle', *Economic History Review*, 2nd ser., XXXIII (1980), pp. 161–73.
- Biraben, J.-N., *Les hommes et la peste en France et dans les pays méditerranéens*, 2 vols. (Paris, 1975–6).
- Birch, T., ed., *A collection of the yearly Bills of Mortality* (1759).
- Bivand, R. S., Pebesma, E. J., and Gómez-Rubio, V., *Applied spatial data analysis with R* (New York, 2008).
- Boulton, J., *Neighbourhood and society: a London suburb in the seventeenth century* (Cambridge, 1987).
- Boulton, J., 'Wage labour in seventeenth-century London', *Economic History Review*, XLIX (1996), pp. 268–90.
- Boulton, J., 'London 1540–1700', in P. Clark, ed., *The Cambridge urban history of Britain, 2: 1540–1840* (Cambridge, 2000), pp. 315–46.
- Boulton, J. and Schwarz, L. D., 'Yet another inquiry into the trustworthiness of eighteenth-century London's Bills of Mortality', *Local Population Studies*, 85 (2010), pp. 28–45.
- Brett-James, N. G., *The growth of Stuart London* (1935).
- Champion, J. A. I., *London's dreaded visitation: the social geography of the Great Plague in 1665* (1995).
- Christie, J., *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* (1893).
- Clark, G., 'The long march of history: farm wages, population, and economic growth, England 1209–1869', *Economic History Review*, 60 (2007), pp. 97–135.
- Crawford, R., *Plague and pestilence in literature and art* (Oxford, 1914).
- Creighton, C., *A history of epidemics in Britain from AD 664 to the extinction of plague* (1965).
- Davenport, R., Boulton, J., and Schwarz, L. D., 'Infant and young adult mortality in London's West End, 1750–1824' (2010), www.geog.cam.ac.uk/people/davenport/davenport2.pdf (accessed on 19 Dec. 2014).
- Drancourt, M., Houhamdi, L., and Raoult, D., 'Yersinia pestis as a telluric, human ectoparasite-borne organism', *Lancet Infectious Diseases*, 6 (2006), pp. 234–41.
- Farrington, C. P., Andrews, N. J., Beale, A. D., and Catchpole, M. A., 'A statistical algorithm for the early detection of outbreaks of infectious disease', *Journal of the Royal Statistical Society. Series A (Statistics in Society)*, 159 (1996), pp. 547–63.
- Finlay, R. A. P., 'The accuracy of the London parish registers, 1580–1653', *Population Studies*, 32 (1978), pp. 95–112.
- Finlay, R., *Population and metropolis: the demography of London, 1580–1650* (Cambridge, 1981).
- Finlay, R. and Shearer, B., 'Population growth and suburban expansion', in A. L. Beier and R. Finlay, eds., *London 1500–1700: the making of the metropolis* (1986), pp. 37–59.
- Fisher, F. J., *London and the English economy, 1500–1700* (1990).
- Galloway, P. R., 'Annual variations in deaths by age, deaths by cause, prices and weather in London, 1670 to 1830', *Population Studies*, 39 (1985), pp. 487–505.
- Glass, D. V., ed., *London inhabitants within the walls* (1966).
- Graunt, J., *Natural and political observations made upon the Bills of Mortality* (1662), in C. H. Hull, ed., *The economic writings of Sir William Petty* (Cambridge, 1899), vol. 2, pp. 315–435.
- Harding, V., 'The population of London, 1550–1700: a review of the published evidence', *London Journal*, 15 (1990), pp. 111–28.
- Harding, V., 'City, capital, and metropolis: the changing shape of seventeenth-century London', in J. F. Merritt, ed., *Imagining early modern London: perceptions and portrayals of the city from Stow to Strype, 1598–1720* (Cambridge, 2001), pp. 117–43.
- Höhle, M., 'Surveillance: an R package for the monitoring of infectious diseases', *Computational Statistics*, 22 (2007), pp. 571–82.
- Hollingsworth, M. F. and Hollingsworth, T. H., 'Plague mortality rates by age and sex in the parish of St Botolph's without Bishopsgate, London, 1603', *Population Studies*, 25 (1971), pp. 131–46.
- Hull, C. H., ed., *The economic writings of Sir William Petty: together with the observations of the Bills of Mortality more probably by Captain John Graunt* (Cambridge, 1899; repr. New York, 1969).
- Jones, P. E. and Judges, A. V., 'London population in the late seventeenth century', *Economic History Review*, 2nd ser., VI (1935), pp. 45–63.
- Kelly, M. and Ó Gráda, C., 'Living standards and mortality since the middle ages', *Economic History Review*, 67 (2014), pp. 358–81.
- Kitto, J. V. and Mason, T., eds., *A register of baptisms, marriages, and burials in the parish of St. Martin in the Fields, in the county of Middlesex* (1937).
- Landers, J., *Death and the metropolis: studies in the demographic history of London 1670–1830* (Cambridge, 1993).
- Landers, J. and Mouzas, A., 'Burial seasonality and causes of death in London 1670–1819', *Population Studies*, 42 (1988), pp. 59–83.
- Littledale, W. A., ed., *The registers of St Vedast, Foster Lane, 1558 to 1836, and St Michael Le Quern, 1685 to 1836*, 2 vols. (1902–3).
- Marshall, J., *Mortality of the metropolis* (1832).

- Mason, T., ed., *A register of baptisms, marriages and burials in the parish of St Martin in the Fields, in the county of Middlesex, from 1550 to 1619* (1898).
- Mazumder, R., Hastie, T., and Tibshirani, R., 'Spectral regularization algorithms for learning large incomplete matrices', *Journal of Machine Learning Research*, 11 (2010), pp. 2287–322.
- Monecke, S., Monecke, H., and Monecke, J., 'Modelling the Black Death: a historical case study and implications for the epidemiology of bubonic plague', *International Journal of Medical Microbiology*, 299 (2009), pp. 582–93.
- Moote, A. L. and Moote, D. C., *The Great Plague: the story of London's most deadly year* (Baltimore, Md., 2004).
- Murchison, C., *A treatise on the continued fevers of Great Britain* (1862).
- Newton, G., 'Infant mortality variations, feeding practices and social status in London between 1550 and 1750', *Social History of Medicine*, 24 (2011), pp. 260–80.
- Razzell, P., 'Infant mortality in London, 1538–1850: a methodological study', *Local Population Studies*, 87 (2011), pp. 45–64.
- Razzell, P. and Spence, C., 'The history of infant, child and adult mortality in London, 1550–1850', *London Journal*, 32 (2007), pp. 271–92.
- Sharlin, A., 'Natural decrease in early modern cities: a rejoinder', *Past and Present*, 92 (1981), pp. 175–80.
- Slack, P., 'The disappearance of the plague: an alternative view', *Economic History Review*, 2nd ser., XXXIV (1981), pp. 469–76.
- Slack, P., *The impact of plague in Tudor and Stuart England* (1985).
- Slack, P., *Poverty and policy in Tudor and Stuart England* (Harlow, 1988).
- Southall, H. R. and Burton, N., 'GIS of the ancient parishes of England and Wales, 1500–1850' (2004), <http://discover.ukdataservice.ac.uk/catalogue?sn=4828> (accessed on 19 Dec. 2014).
- Spence, C., *London in the 1690s: a social atlas* (2000).
- Sutherland, I., 'When was the Great Plague? Mortality in London, 1563 to 1665', in D. V. Glass and R. Revelle, eds., *Population and social change* (1972), pp. 287–320.
- Taddy, M. A., Gramacy, R. B., and Polson, N. G., 'Dynamic trees for learning and design', *Journal of the American Statistical Association*, 106, 493 (2011), pp. 109–23.
- Twigg, G., 'Plague in London: spatial and temporal aspects of mortality', in J. A. I. Champion, ed., *Epidemic disease in London* (1993), pp. 1–17.
- Webb, C., 'London and Middlesex burials register indexes and their online availability' (2009), <http://www.wsfhs.org/assets/documents/researchaids/RA51.pdf> (accessed on 19 Dec. 2014).
- Wood, S. N., *Generalized additive models: an introduction with R* (2006).
- Wrigley, E. A., 'A simple model of London's importance in changing English society and economy 1650–1750', *Past and Present*, 37 (1967), pp. 44–70.
- Wrigley, E. A. and Schofield, R. S., *The population history of England, 1541–1871: a reconstruction* (1981).