Abstract
Urban centres exerted a powerful influence on mortality trends in early modern England. The high mortality rates of urban areas created a constant need for new immigrants, drawn from rural populations, and the size and trading functions of towns meant that they functioned as periodic sources of epidemic diseases among the non-urban majority of the population. It is possible that much of the rise and fall of mortality at the national level over the seventeenth and eighteenth centuries reflects the waxing and waning of mortality in urban centres. However our understanding of this process remains very limited, due to the difficulties of working with historical urban sources. As a counterweight to these problems, the Bills of Mortality produced by many towns and cities provide information not available for other sectors of the population, and the individual-level records that underlie the Bills compilations provide extraordinary insights into epidemiological processes in this key period of urban demography. This paper will illustrate the potential of these sources using evidence of smallpox burials from the large London parish of St. Martin-in-the-Fields, and the collegiate church of Manchester.

English mortality patterns 1541-1850.
Thanks largely to the work of Tony Wrigley and colleagues at the Cambridge Group for the History of Population and Social Structure, we now have a fairly clear picture of mortality trends in England over the course of the last half millenium. Historically favourable levels of life expectancy prevailed in sixteenth and early seventeenth centuries, punctuated by subsistence and epidemic crises and especially by soaring mortality rates during plague outbreaks. From the mid-sixteenth century the amplitude of these crises diminished, and plague disappeared after the 1660s. However as mortality fluctuations dampened, the average level of mortality actually rose. Life expectancy was lowest in the early eighteenth century before recovering to sixteenth century levels by

1 This work is funded by the Economic and Social Research Council and the Wellcome Trust: see http://research.ncl.ac.uk/pauperlives/ for details of the projects.
2 Senior Research Associate, Cambridge Group for the History of Population and Social Structure, Dept of Geography, Downing Place, Cambridge, CB2 3EN
3 Professor of Urban History, University of Newcastle.
the turn of the nineteenth century. Life expectancy then stagnated in the middle quarters of the nineteenth century before embarking on a secular decline that has continued almost uninterrupted to the present. The extent to which these trends were typical of other European populations remains unclear in the absence of comparable long-run series for other national populations. However there is substantial evidence of widespread improvements in life expectancy in the late eighteenth century in most of north-western Europe, where data are available. In Scandinavian countries improvement continued virtually uninterrupted throughout the nineteenth century, but in societies with higher levels or rates of urbanisation the mid-nineteenth century was marked by a period of stagnation similar to that observed in England.

Two features of the course of mortality change in England were particularly striking. First, the contribution of ‘crisis’ events to overall mortality levels was slight (around 5% of total mortality in the period 1600-1750, by Wrigley and Schofield’s definition of crisis). Moreover as mortality crises diminished in the seventeenth and eighteenth centuries, ‘background’ mortality rose. This contradicted earlier models that assumed a dominant role for crises in overall mortality, and associated mortality decline with reductions in volatility of mortality (Flinn, 1981). A second surprising finding was the apparent independence of mortality rates from living standards, narrowly defined as real wages. Although burials rose in response to hikes in food prices (Wrigley and Schofield, 1989), over the longer run, life expectancy did not rise with real wages, but showed if anything an inverse relationship, being lowest in periods of highest real wages (Wrigley, 2004). Thus Wrigley and Schofield characterised mortality as largely exogenous to economic factors, narrowly construed. The Malthusian positive check appeared to be weak in early modern England, and absent after about 1750.

Wrigley & Schofield (1989) initially interpreted the recovery of life expectancy in the eighteenth century as marking simply a return to earlier conditions. However more detailed evidence of age-specific mortality rates, derived from family reconstitution studies, indicated that profound changes in the structure of mortality underlay these apparently unremarkable changes in life expectancy (Wrigley et al., 1997). Adult survival improved from the early eighteenth century, in parallel with a worsening of mortality in children. From the mid-eighteenth century survival rates improved for older children and infants, but mortality in early childhood remained higher at the end of the century than it
had been in the sixteenth century. Wrigley et al. attributed these age structural changes to epidemiological processes accompanying the increasing economic integration of the English population. Dearth-related mortality, a minor contribution to mortality in any case, diminished progressively with increasing agricultural productivity, increasing market integration, and greater market access through Poor Law schemes. However increased economic exchanges between towns and regions also increased the circulation of infectious diseases. Epidemic diseases which had occurred at irregular intervals in small towns and rural settlements became more frequent, raising the level of disease exposure and mortality. In the case of diseases where infection conferred long-lasting immunity on survivors (such as smallpox, measles, scarlet fever and other ‘childhood’ diseases), occasional epidemics tended to affect adults as well as children, but with increasing epidemic frequency most adults had acquired immunity through epidemics experienced in childhood, and these diseases increasingly became childhood diseases. Thus as epidemics became more regular they also became less devastating, and epidemic cycles became shorter and of lower amplitude. In the early phases of this process of endemicisation, greater exposure of previously unexposed populations raised mortality at all ages, but as epidemic frequency increased then adults experienced a reduction in risk, as infection became concentrated in children. Although the increased circulation of infectious diseases may have raised mortality rates especially in early childhood, any negative effect on life expectancy was apparently offset by an improvement in survival of neonates. This apparent paradox, of improving survival in early infancy as infection rates intensified, can be explained within Wrigley’s model as an effect of improving maternal health, since reductions in maternal infections would have had positive effects on foetal and neonatal health.

This hypothesis, that increasing economic integration of the English population led to the progressive endemicisation of many infectious diseases, accounts both for the observed changes in the age structure of mortality in the English population, and for the progressive dampening of the volatility of mortality. Mortality crises were provoked both by subsistence crises and by autonomous epidemic cycles, and both these factors were similarly affected by the process of economic and epidemiological integration that unfolded over the seventeenth and eighteenth centuries.
This model has particular implications for the roles of urban centres. Wrigley et al. provided a very spare account of the epidemiological changes that might have occurred in the English population in the seventeenth and eighteenth centuries, with minimal assumptions about the process of endemicisation. However the basic model fits that proposed by William McNeill (1977; 1980). McNeill proposed that certain types of infectious diseases would progressively endemicise within large populations, becoming established first in dense urban populations where re-introduction was frequent, contact rates were high, and where birth rates were sufficient to maintain a constant stream of new susceptible individuals. With increasing population size and contact with other populations, urban centres would experience increasingly frequent epidemics, producing high levels of immunity amongst adults. In less densely populated and more remote areas, epidemics would remain infrequent, resulting in large numbers of immunologically 'naïve' adults. McNeill’s hypothesis applies only to those diseases which are transmitted directly from person to person and which confer long-lasting immunity on survivors (such as smallpox and measles). A consequence of McNeill’s argument is that, during this phase of endemicisation, rural migrants to urban areas would be at high risk of epidemic disease relative to the native-born population, amongst whom such diseases would have become confined mainly to childhood. As population densities rose and contacts between rural and urban areas increased then the frequency of epidemics would increase nationally, until these epidemic diseases became endemic diseases of childhood throughout the population.

*The transformation of the urban mortality regime*

The preceding paragraphs sketched the basic outline of changes in life expectancy in England between the sixteenth and early nineteenth centuries, and the dominant hypothesis to explain these changes. However in addition to changes in age structure and volatility of mortality, a third major change in mortality took place in the eighteenth century, that was of much greater magnitude than changes at the national level, and which could not be mistaken for a return to earlier conditions. This was a dramatic reduction in mortality in urban areas.

Figure 1 presents estimates of infant mortality rates (IMR) for other cities and towns in England, together with rates for the London Quakers, and for two rural parishes with long-run series (derived from Galley and Shelton, 2001). Three aspects are immediately
apparent. First, trends in urban mortality followed the national pattern in highly exaggerated form. Both small and major urban centres in England seem to have experienced a rise in infant and child mortality in the late seventeenth century, with IMR in London reaching perhaps as much as 400-450/1000 in the 1740s. After 1750 the modest improvements at the national level were accompanied by spectacular declines in urban mortality, so that by the 1820s London’s IMR was comparable to the national average, at around 160/1000. Although infant mortality varied widely by settlement type and location in the nineteenth century, there was nonetheless a substantial convergence in rates between the eighteenth and the nineteenth centuries. Second, as Galley and Shelton have argued, infant mortality was apparently very high in even quite small urban settlements in the seventeenth and eighteenth centuries. York had a population of approximately 12,000 through the seventeenth century, and barely grew over the period, yet its infant mortality rates appear to have exceeded those of even Liverpool in the mid-nineteenth century, when the Liverpool population exceeded a quarter of a million, and was the most notorious mortality blackspot of the period. Market towns of several thousand inhabitants in the eighteenth century, such as Banbury, similarly rivalled the infant mortality rates of the great industrial cities of the nineteenth century. A third point is that infant mortality seems to have changed relatively little (either absolutely or proportionately) in those settlements that remained rural. This raises the possibility that the changes in mortality rates observed in the national aggregate may reflect mainly the vicissitudes of mortality in urban and urbanising areas, with relatively little change in rural populations. Unfortunately trends in mortality for individual parishes within the twenty-six parish sample used by Wrigley and colleagues in their national analysis have been published for only a few of the parishes (Banbury, Colyton and Hartland in Figure 1). Colyton and Hartland were relatively remote parishes, and the trajectory of mortality in rural communities in closer contact with urban centres remains unclear.

The vicissitudes of mortality in urban populations influenced mortality trends in the national population in a number of ways. As suggested above, most of the change in mortality rates at the aggregate level may have been a consequence of the contribution of urban populations. Although the urban population was relative small in the seventeenth century (de Vries gives an estimate of 8.8% of the population of England and Wales living in urban settlements of 2500+ in 1600), urbanisation proceeded relatively rapidly across the period, to incorporate half of the population by 1850 (de
Therefore an ever-increasing proportion of the population was subject to urban mortality regimes. In addition, urban centres influenced the rural population in a number of ways. First, cities and towns acted as reservoirs or entrepots of infections that then circulated through rural areas in epidemic form. One consequence of this is that the progressive integration of rural areas into a national economy may have increased the circulation of infectious diseases in rural areas. Secondly, the very high death rates in urban areas before the late eighteenth century meant that cities and towns required a constant flow of immigrants, derived mainly from the rural population, even to maintain the urban population, as well as to drive any expansion of the urban sector. Wrigley famously estimated that half the natural growth of the English population (births in excess of deaths) was consumed by London’s mortality regime in the seventeenth and early eighteenth centuries (Wrigley, 1967). These rural migrants to urban areas are considered to have comprised mainly young unmarried adults, although this profile may be more typical of long-term economic migrants than of casual (seasonal or subsistence) migrants, of whom less is known. Crucially, until the late eighteenth century at least, the urban environment seems to have been particularly lethal to new migrants, who may have lacked immunity to the diseases that were endemic in urban areas but still rare in rural populations.

**Testing the ‘endemicisation hypothesis’**

To investigate the relationship between the disease environments of urban centres and the larger rural population requires several approaches. Richard Smith, Gill Newton and Peter Kitson of the Cambridge Group are currently funded by the Wellcome Trust to investigate changes in the volatility of burial series for 500+ parishes, rural and urban, across England from the sixteenth to the mid-nineteenth century. The intention is to test whether there is evidence of a convergence in mortality patterns (either in the synchronicity or the periodicity of burial peaks), that would be consistent with an increasing epidemiological integration of the national population (see [http://www.geog.cam.ac.uk/research/projects/epidemiologicaltransition/](http://www.geog.cam.ac.uk/research/projects/epidemiologicaltransition/)).

In this paper I wish to discuss a complementary approach to the question of the inter-relationship of disease patterns in urban and rural populations, that relies mainly on evidence from urban Bills of Mortality and their underlying sources. While urban populations are notoriously difficult to study in the absence of census-type information
on the age structure of the population, on the positive side, almost all we know of causes of death in England before the mid-nineteenth century derives from urban areas, because a number of towns produced Bills of Mortality, that listed the causes of death and/or ages of burials within the town. This information is of great interest not only for the study of urban mortality, but also for our understanding of rural populations, since the often large numbers of rural migrants that contributed to the Bills of Mortality provide some insight into the epidemiology of their places of origin. By contrast, rural burial registers rarely recorded age or cause of death, although this type of evidence does become more common from the 1770s. In addition, the Bills themselves were compiled from individual records of burials in each parish. In many cases the requirement to report information to the Bills seems to have resulted in remarkably detailed accounts of the age of the decedent as well as cause of death and sometimes occupation and/or burial fee. This information was sometimes recorded in parish registers, but probably was often recorded separately in ‘day books’ or other sources less likely to survive. While Bills of Mortality recorded counts of burials by age and by cause of death, this information was not cross-tabulated. Therefore the Bills themselves do not permit us to examine the age structure of particular causes of death, nor the importance of particular diseases to a given age group. However where both age and cause of death were recorded for individual burials, such records provide much greater insight into the structure of mortality in early modern cities and towns, as well as some indication of the disease environments of their migrant hinterlands.

The value of these records is best illustrated with respect to smallpox. Smallpox was one of the most readily identified of the diseases of early modern London, and there is relatively little controversy over the meaning of the term in the Bills (Meier, 2009). Smallpox appears to have risen from a relatively minor cause of death in the sixteenth century to become probably the most lethal single disease in eighteenth century London (Figure 2). The cause of this apparent rise in importance as a cause of death remains unclear, but has been argued to reflect the increasing circulation of a more virulent strain of smallpox, variola major (that may have displaced the more benign variola minor strain (Carmichael and Silverstein, 1987). Infection with smallpox confers lifelong immunity on survivors. Therefore smallpox has the characteristics of the type of immunising disease that might be expected to show a transition from an occasional epidemic disease affecting adults as well as children, to an endemic childhood disease, to which only
immigrants from remote areas outside the region of endemicity would be susceptible to in adulthood. Indeed smallpox is generally considered to exemplify the type of disease behavior predicted by McNeill’s model. However smallpox differed from some of the more classic ‘childhood’ diseases, such as measles and scarlet fever, in both its transmission patterns, and its susceptibility to preventative measures. Although often described as highly infectious, smallpox was much less infectious than some other ‘childhood’ diseases including measles (Anderson & May, 1998; Gani & Leach, 2001). Moreover, the smallpox virus is comparatively stable, and can be transmitted through infected objects (including clothing and bedding) as well as person-to-person. Artificial immunization against smallpox was introduced into England in the early eighteenth century, through the practice of deliberate infection with a very low dose of (possibly attenuated) smallpox (a process known as inoculation). Inoculation appears to have gained in popularity especially in rural areas after the introduction of cheaper and safer techniques in the 1760s. Vaccination with a related but relatively benign virus, cowpox, was developed by Edward Jenner in 1896 and widely used from the last years of eighteenth century, with dramatic effects on smallpox infection rates. Therefore the epidemiology of smallpox is complicated both by its complex transmission dynamics, and by changing levels of artificial immunization.

Smallpox epidemics appear to have increased in both frequency and amplitude over the period 1660 to 1770 in London. Burials were reported in most weeks, and epidemics occurred every 3-4 years in the seventeenth century, increasing to 2-3 intervals in the period 1700-1800 (Duncan et al., 1993; Krylova, 2011). Using the weekly Bills Krylova (2011) has shown that these longer cycles were superimposed on an annual season pattern of smallpox epidemics in late summer, that became particularly pronounced after 1770. Smallpox mortality may have peaked in London around 1770, with smallpox burials accounting for around ten percent of all burials in the capital, before declining gradually in the last quarter of the eighteenth century. Epidemics diminished dramatically in magnitude and frequency after 1801.

\[4 \text{ Gani & Leach (2001) estimate a basic reproductive number (the theoretical number infected by a single infective individual at the beginning of an outbreak in a completely susceptible population) of perhaps 4-5, compared with around 10 for measles}\]
We know relatively little of smallpox in London in the sixteenth and seventeenth centuries, and few individual-level records of cause of death with age indicators survive for the period. Those that do have been analysed by Henry Meier (Meier, 2009). He found that 16% of smallpox burials were aged ten and over in St. Botolph Aldgate, 1583-1600, and 33% in St. Martin-in-the-Fields, 1685 – 1703. In St. Giles Cripplegate smallpox was very much a disease of childhood in the decade before 1666, with only 7% of smallpox burials identified as adults in the period 1654-66. However plague (1665) and the Great Fire (1666) seem to have produced a dramatic turnover of population, and the influx of many susceptible adults into the parish, producing a significant hike in both smallpox burial numbers and the proportion of these that were adult (to 21% in the years 1667-77). These fragmentary data suggest that a substantial proportion of adults may have been susceptible to smallpox, at least in parts of London. That these were probably mainly migrants is suggested by the sudden increase in adult victims in St. Giles Cripplegate following the increase in immigration that followed the events of 1665-66. This intriguing glimpse indicates the complexity of London’s demography in this period, when repeated epidemics of plague may have influenced the dynamics of other diseases through the recruitment of distinct cohorts of new immigrants.

Individual-level records that include cause of death and age are more common in the eighteenth century. The sextons’ burial books of St. Martin-in-the-Fields survive for most of the period 1752-1824 and record age, cause of death, street address and the fee paid for burial in most years. In the mid-eighteenth century smallpox accounted for 7-12% of burials in the parish, and twenty percent of these were adult (Table 1). St. Martin-in-the-Fields was a relatively wealthy parish with large numbers of female domestic servants. Although we don’t know the age and sex structure of the population before 1821, it is likely that the population structure resembled a lopsided hourglass, with a distinctive bulge of young adults, a majority of them female. However the frequency of adult smallpox burials is not simply a function of the unusual age structure of the parish (an age structure that was probably typical of towns in this period). On the assumption that most children in the parish were London-born, then the age pattern of smallpox burials aged under ten indicates that smallpox exposure was high in early childhood, and only a small proportion of London-born adults would have escaped infection and (therefore immunisation) in childhood. Therefore the majority of adult smallpox burials are likely to
be of recent migrants to the city, who had lived hitherto in areas where smallpox was not endemic.

What else can the burial records tell us about the identity of adult smallpox victims in mid-eighteenth century London? In St. Martin’s males predominated amongst adult victims, despite the excess of young women in the population and amongst non-smallpox burials (Davenport et al., 2011). Evidence of migration patterns suggests that female migrants to may have migrated shorter distances on average than males. Therefore an excess of male smallpox victims may indicate that most domestic servants, drawn from closer to London, had acquired immunity to smallpox in childhood, and that many of the adults dying of smallpox in London had come from more remote parts of the country, where smallpox remained an infrequent disease. Landers hypothesised that the periodic demobilisation of soldiers following wars may have accounted for some of the more severe smallpox epidemics in the eighteenth century (Landers, 1993). Soldiers tended to be drawn from a wider geographical area than most migrants, and this may explain to some extent the preponderance of males amongst adult victims. Unfortunately the St. Martin’s records do not indicate the occupation of decedents, so we can’t test this hypothesis directly. The St. Martin’s records also indicate that while the distributions of fees paid for child burials were similar for smallpox and other burials, amongst adults those dying of smallpox were less likely to be accorded pauper burials, but were also rarely amongst the most expensive burials (resembling the case in the late seventeenth century; Meier, 2009). Therefore at least in St. Martin’s adult smallpox victims were not in general subsistence migrants driven into the city by high food prices.

The most striking evidence from the St. Martin’s records is a dramatic drop in the number of adult smallpox victims, from sometime around 1770. This sudden decline in the proportion of smallpox victims that are adults, occurred not only in St. Martin’s in western London, but in the East London parish of St. Dunstan Stepney, and in St. Mary, Whitechapel (Figure 3). There is no evidence of any shift in the age structure of other burials that might indicate a change in the age structure of the St. Martin’s population, and the change seems in any case to be too widespread to be attributable to this type of change. Rather it seems likely that the decline in the number of adult smallpox victims reflects an increase in immunity to smallpox amongst migrants. This increase in immunity may have arisen as a consequence of the spread of new cheaper and safer
methods of smallpox inoculation (that is, deliberate infection with a small dose of attenuated smallpox). Or there may have been a change in the infectiousness of the smallpox virus itself, that increased circulation of smallpox within the national population. In any case, there was a dramatic reduction in the risk to young adult migrants of smallpox in London. Smallpox accounted for almost a quarter of all burials of males between ages 15 and 29 in St. Martin’s between 1752 and 1767, and this reduced to 3% of burials after 1770 (comparable figures are 12% and 3% for females). Therefore smallpox appears to have been a significant risk especially to young male migrants to London, and London became a substantially safer place for rural migrants in the last quarter of the eighteenth century.

The evidence from St. Martin-in-the-Fields suggests that while many migrants to mid-eighteenth century London were susceptible to smallpox in adulthood, these migrants were not typical of the majority of migrants to St. Martin’s, who were more likely to be female (and to be accorded a pauper burial at death). Therefore it seems likely that smallpox was a childhood disease by the mid-eighteenth century in much of London’s migrant hinterland, but that smallpox was still rare in some rural areas from which migrants were drawn.

We have only begun to probe the geography of smallpox in Britain. Creighton, writing in the late nineteenth century proposed a north-south divide of the country with respect to smallpox, considering the disease to be endemic even in very rural northern areas with dispersed populations, but still occasional and epidemic in rural southern areas (Creighton, 1894). His impression was based mainly on evidence from the late eighteenth century, when smallpox appears to have become much more widespread, by natural or artificial means, within the national population. Peter Razzell reached a similar conclusion regarding the early endemicisation of smallpox in northern England, but again most of his data for northern populations is post-1770. The evidence for widespread vulnerability of adults in southern Britain is also rather slight. However even Burford, a market town on a major transport route, experienced a devastating smallpox epidemic in 1758, in which perhaps half the victims were adults (Razzell, 2003). Further evidence, especially for the period before 1780, are clearly required to determine the extent, and geographical heterogeneity, of smallpox transmission outside London.
To address this issue we have begun to investigate the sextons’ registers of the collegiate church of Manchester, which provide information on cause of death and age from 1753. Manchester comprised a single very large parish, and although there was a proliferation of other churches and chapels, the right of the collegiate (parish) church to fees for marriage, baptism and burial meant that a relatively high proportion of Anglican events was registered at the church throughout the eighteenth century, and the collegiate church formed the sole basis of the Manchester Bills of Mortality until the nineteenth century. Manchester grew rapidly from less than 20,000 in the mid-eighteenth century to around 250,000 by 1851. At present we have extracted only the smallpox and measles burials, for the period 1753-1790, and a sample of the complete register, for the year 1760. As in St. Martin’s the recording of age is very detailed, with infant ages at burial recorded in months (and even weeks and days in St. Martin’s).

Smallpox dominated mortality in Manchester to a much greater extent than London, accounting for around twenty percent of burials in the second half of the eighteenth century (compared with 6-10 percent for London). Extraordinarily, even in the mid-eighteenth century nearly 95% of smallpox burials in Manchester were children (Table 1). This implies a remarkably high level of endemicity, not only within Manchester, but also in the rural areas which supplied migrants to Manchester, and contrasts starkly with the 15 - 20% of smallpox burials that were adult in London in this period (Table 1). The difference in the proportions of adult smallpox burials in the two cities is unlikely to be a function of large differences in their age structures. Manchester grew proportionally more rapidly than London after 1750, and most of this growth was probably fueled by migration. A survey in 1773 indicated that 51% of the population of Manchester was aged between 15 and 49 years (Percival, 1789), a figure very similar to the 55% in this age group in London in the 1821 census, and much higher than the 29% of the English population in this age group in 1821. Smallpox was clearly endemic in the Manchester population by the mid-eighteenth century, and smallpox burials occurred in every month. At present we have only a short time series, but it appears that smallpox epidemics may have increased in frequency over the last half of the eighteenth century, assuming a two yearly cycle after around 1770, with a smaller annual cycle of autumnal epidemics. Thus the periodicity of epidemics in Manchester was very similar to that in London, despite the

---

5 The Bills of Mortality themselves have not survived in any numbers for Manchester.
great difference in the size of the populations (London’s population was close to a million by 1801).

Apart from the striking difference in the level of adult smallpox burials, the patterns in Manchester were remarkably similar to those we observed in St. Martin-in-the-Fields. As in London, there was a drop in the proportion of adult burials sometime between 1763 and 1771, and only 1 – 1.5 % of smallpox burials were aged ten and over after 1771 (Table 1). This proportion was the same in the periods 1772-78 and 1785-89, indicating that the change in age distribution occurred fairly abruptly in the gap 1763-71. Again, as in London, this drop in the proportion of adult smallpox burials was accompanied by a change in the sex ratio of adult smallpox burials. In St. Martin-in-the-Fields smallpox burials were biased towards males in the period before the 1770s, but assumed a normal sex ratio in the last quarter of the eighteenth century (Davenport et al., 2011). The bias towards males in the earlier period suggested that a higher proportion of male migrants to London may have derived from more remote areas than was the case for female migrants. In Manchester, a similar male bias was observed before the 1770s, with males accounting for 75 – 83% of adult smallpox burials in the period 1753-62. By 1772 adult smallpox burials were distributed almost equally between males and females. One cause of the high sex ratio in the first period was the high proportion of soldiers amongst adults recorded as dying of smallpox (12 of 32 adult burials). This finding is consistent with John Landers’ hypothesis that smallpox epidemics were often associated with demobilisation, although the dates of the soldier burials do not coincide with periods of major demobilisation, and may instead reflect the geographical origins of troops stationed around Manchester. Occupation was not generally recorded in the sextons’ books of St. Mary’s in this period, except in the case of soldiers. After 1771 only two adult smallpox burials were described as soldiers.

Coincident with the decline in adult smallpox burials in Manchester there was a reduction in the average age of child smallpox victims after 1770, very similar to that observed in London (Table 2). Consistent with the remarkable endemicity of smallpox suggested by the paucity of adult smallpox burials in Manchester, the age distribution of child smallpox victims was much younger than in London, suggesting that smallpox was indeed a

---

6 The percentage depends on whether the few burials where sex was not clear were all assumed to be female, or were distributed equally by sex.
disease of early childhood even by the mid-eighteenth century. However there was a further concentration of smallpox mortality at the youngest ages in the last quarter of the century, and the shift seems to have occurred in the period between 1763 and 1772. Smallpox accounted for 25 – 30 % of burials aged under two in Manchester in the period 1753-90, but for less than ten percent of burials in this age group in London 1752-1799. While this may reflect the greater burden of other diseases of infancy in London, smallpox also seems to have been more lethal in Manchester. We can estimate smallpox mortality rates amongst infants using smallpox burials aged under one, and baptisms in the same period as the denominator. According to this measure, infant smallpox mortality ranged from 10-30 per thousand in London, compared with around 100/1000 in Manchester.7 Notably, there was no evidence of any decline in smallpox mortality amongst children aged under two in either London or Manchester over the period in which adult mortality declined in both cities. Therefore while smallpox inoculation could have played an important role in reducing the susceptibility of rural populations, and the migrants deriving from them, there is little evidence of any impact of urban inoculation in reducing smallpox mortality in urban-born populations, where very young children were the main victims.

Our evidence from Manchester provides some support for the thesis that smallpox was a childhood disease in much of northern England. Very few of the adult migrants to Manchester in the second half of the eighteenth century were susceptible to the disease, and the disease seems to have circulated more rapidly within Manchester than within London’s much larger population. These findings are very interesting with respect to models of smallpox transmission. In the case of a highly infectious and immunizing disease such as measles, epidemics tend to be rapid and to burn themselves out as the number of non-immune ‘susceptibles’ dwindles. Therefore measles requires a relatively large population (of around a quarter of a million, in twentieth century England and the USA) to be maintained without repeated introduction. Accordingly, measles appears to have been endemic in eighteenth century London, but to have appeared only

7 Baptisms are not a reliable indicator of births in this period. There is evidence of significant under-recording of births in St. Martin’s. Births were doubtless also under-reported in Manchester, but the monopoly of the collegiate church on fees probably means that the population baptizing at the church was larger than that burying at the church (because the church was more constrained in its capacity to bury bodies than to baptize infants). Therefore infant mortality rates are probably over-estimated for St. Martin’s, and underestimated in Manchester, and any correction should serve to raise further infant mortality rates in Manchester in comparison with London.
occasionally in epidemic form in Manchester, which was too small to sustain measles transmission. However smallpox was apparently sustained in endemic form in both Manchester and London, and may have circulated as a frequent disease of childhood in many of the rural communities in the migrant hinterlands of both cities, and especially Manchester. This capacity of smallpox to sustain transmission at relatively low densities of susceptible hosts suggests that transmission via infected objects may have been an important mechanism, perhaps especially in rural areas. It is possible for instance that the ‘putting out’ system in Lancashire, where much of the cloth production was conducted in rural communities via urban distribution centres, may have facilitated the sustained circulation of smallpox in small communities.

**Conclusion**

This paper sought to demonstrate the potential of the burial records underlying the Bills of Mortality for the study of both urban mortality and of the disease environment of urban hinterlands. Fortuitously, smallpox was one of the most lethal diseases of the eighteenth century, and also one of the most reliably identified in contemporary records, making it possible to study its epidemiology in some detail. However while smallpox appears superficially to conform to the type of immunizing disease that should show the classic pattern of progressive endemicisation and migrant vulnerability proposed by William McNeill, examination of the evidence for late eighteenth century London and Manchester suggests a more complex picture. Superficially, the increasing frequency of epidemics and the rising importance of smallpox as a cause of death over the seventeenth and eighteenth centuries in London suggest a process of progressive endemicisation as the city grew. However evidence of very rapid smallpox circulation and higher smallpox mortality in the much smaller population of eighteenth century Manchester (and perhaps its rural hinterlands) suggest that population size and density may not have been the critical drivers of smallpox endemicisation in English towns. Although current models of smallpox transmission include only person-to-person transmission, the peculiar ability of smallpox to sustain transmission within relatively small populations suggests that other modes of infection may also have been important in historical populations. The relative importance of these different modes of transmission in different settings may explain some of the apparent geographical heterogeneity of smallpox epidemics, which, if real, is otherwise difficult to account for using classical models of the transmission of immunizing ‘crowd’ diseases. These unusual characteristics could have favoured the
early endemicisation of smallpox in market towns as well as cities, and may explain much of the peculiar lethality of early modern towns in England. The causes of the decline in adult smallpox victims after around 1770 remain obscure, but the phenomenon accords with the pattern of all cause mortality observed at the national level, where adult mortality improved while mortality in late infancy and early childhood did not. By the nineteenth century there was a relatively clear positive relationship between urban size and density on the one hand and mortality on the other (often described as Farr’s Law), but it is possible that this relationship was rather different in the eighteenth century. The advent of widespread vaccination and the decline of smallpox as a cause of death may have acted to alter dramatically urban mortality regimes, as other diseases more responsive to factors such as population size and crowding came to dominate child mortality.

References
Wrigley EA (1967) ‘A simple model of London’s importance in changing English society and economy 1650-1750’ *Past and Present*, 37, pp. 44-70
Figure 1. Long-term trends in infant mortality in England and Wales, London, and selected parishes and registration districts (Galley & Shelton, 2001, Figure 3)

Figure 2. Smallpox as a percentage of all burials.
Source: Marshall, Mortality, unpaginated tables; Sextons’ day books of St. Martin-in-the-Fields.
Figure 3. Adult smallpox burials (aged ten and over) as a percentage of all smallpox burials.
*Source:* Sextons’ day books of St. Martin-in-the-Fields, and St. Dunstan’s, Stepney; Razzell (2011).
Table 1. Age distributions of smallpox burials in St. Martin-in-the-Fields, London, and the collegiate church, Manchester

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>13.7</td>
<td>23.3</td>
<td>20.1</td>
<td>27.6</td>
<td>27.5</td>
</tr>
<tr>
<td>1-4</td>
<td>54.5</td>
<td>61.5</td>
<td>67.3</td>
<td>68.1</td>
<td>68.3</td>
</tr>
<tr>
<td>5-9</td>
<td>10.9</td>
<td>9.4</td>
<td>7.6</td>
<td>3.3</td>
<td>2.7</td>
</tr>
<tr>
<td>10-19</td>
<td>4.6</td>
<td>1.8</td>
<td>2.1</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>20-49</td>
<td>15.6</td>
<td>3.5</td>
<td>2.9</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>50+</td>
<td>0.7</td>
<td>0.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>% aged &lt;10</td>
<td>79.1</td>
<td>94.2</td>
<td>95.0</td>
<td>99.0</td>
<td>98.5</td>
</tr>
<tr>
<td>N</td>
<td>1083</td>
<td>2022</td>
<td>725</td>
<td>1717</td>
<td>1067</td>
</tr>
</tbody>
</table>

Table 2. Age distributions of smallpox burials aged under ten years of age, St. Martin-in-the-Fields, London, and the collegiate church, Manchester

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>17.3</td>
<td>24.7</td>
<td>21.2</td>
<td>27.9</td>
</tr>
<tr>
<td>1</td>
<td>21.8</td>
<td>25.6</td>
<td>31.3</td>
<td>36.2</td>
</tr>
<tr>
<td>2</td>
<td>18.0</td>
<td>18.5</td>
<td>18.6</td>
<td>19.8</td>
</tr>
<tr>
<td>3</td>
<td>17.0</td>
<td>12.9</td>
<td>11.8</td>
<td>9.7</td>
</tr>
<tr>
<td>4</td>
<td>12.1</td>
<td>8.3</td>
<td>9.1</td>
<td>3.3</td>
</tr>
<tr>
<td>5-9</td>
<td>13.8</td>
<td>10.0</td>
<td>8.0</td>
<td>3.1</td>
</tr>
</tbody>
</table>