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Title: Neonatal mortality in the workhouse of St. Martin-in-the-Fields, 1725-1824

Running title: neonatal mortality in a Georgian workhouse

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Abstract

The first stage of the mortality transition can be traced to the late eighteenth century in north-western Europe. Falls in mortality were particularly spectacular in urban areas, and amongst neonates, but few sources provide insight into these processes. The records of the workhouse of the London parish of St. Martin-in-the-Fields provide detailed evidence of age at death and maternal characteristics for pauper infants born in the workhouse 1725-1824. Neonatal mortality was extremely high as a consequence of workhouse conditions and high illegitimacy rates. However improvements in survival of workhouse neonates coincided with trends outside the workhouse, and in maternal mortality. The time-course of mortality in the workhouse indicated high levels of infectious diseases contracted during or shortly after delivery, and suggested the involvement of neonatal sepsis and possibly tetanus. Reductions in exposure or susceptibility to infectious diseases may have played a key role in improving neonatal survival in this period.

Keywords: epidemiological transition; mortality transition; demographic transition; neonatal; mortality; infant; London; eighteenth century; workhouse; illegitimate

Introduction

An outstanding puzzle in historical demography is the dramatic decline in urban mortality across north-western Europe in the period 1750-1820. In the seventeenth and early eighteenth centuries European cities operated as 'urban graveyards', with death rates so high as to require a net flow of in-migrants even to maintain their population size. 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 this period (Wrigley, 1967). Kuznets and de Vries have argued that excessive urban mortality rates precluded modern economic growth, with its concomitant rapid urbanisation, because no population could produce a rural population surplus sufficient to maintain a very large urban component (Kuznets, 1960; de Vries, 1984). However in the last half of the eighteenth century a dramatic change occurred, and baptisms began to exceed burials from around 1770 in a large number of towns and cities in north-western Europe. Indeed it is likely that most of the relatively modest improvement in life expectancy over the eighteenth century in the English population is attributable to improvements in mortality in urban populations (Wrigley et al., 1997: 307-22; Galley & Shelton, 2001), in contrast to the braking function of urban death rates on life expectancy in both the seventeenth and nineteenth centuries (Woods, 1985, 2000; Wrigley, 1990). Neonates experienced the most dramatic fall in mortality (from a peak of 110 deaths per thousand births in the period 1675-99 to 57/1000 by 1800-24), and accounted for almost all the reduction in infant mortality in the English population in this period (Wrigley et al., 1997: 236-7). In London improvements in survival were particularly spectacular, and infant mortality fell from a peak of around 340-450 deaths per thousand births in the mid-eighteenth century to the national average of c.160/1000 by 1825 (Landers, 1997: 136, 170; Laxton & Williams, 1989). Amongst London Quakers, where infant age at death was recorded, improvements were greatest in the first three months of life, and neonatal mortality fell from 125/1000 in the first quarter of the eighteenth century to 40/1000 by the first quarter of the nineteenth (Landers, 1997: 136).

Urban areas are particularly difficult to study, because there are few census-type data giving the age and sex structure, or even the size, of the population, and urban dwellers were usually highly mobile, and not very amenable to event history techniques such as family reconstitution. On the plus side, British cities often kept Bills of Mortality, which recorded burials by age and sex, and burials by cause. In London the Bills of Mortality recorded burials by age, and dividing burials aged under two years by the baptisms recorded in the same years gives a rough estimate of trends in infant mortality. However these data rely on counts of baptisms and burials rather than births and deaths, and both sources are subject to under-recording to different extents. To circumvent these problems Landers reconstituted several London Quaker chapters, whose members recorded births and deaths rather than baptisms and burials (Landers, 1990, 1993). Landers found that infant mortality amongst the Quakers appeared to follow trends and levels similar to those of the London Bills population, with falls from 340/1000 in the period 1700-49 to 150/1000 by the second quarter of the nineteenth century. The Quakers were relatively affluent compared with the London Bills population as a whole, and the similarity in infant mortality rates suggested that wealth may have conferred little advantage in this period, at least in childhood. Levene's estimates of mortality of infants abandoned at the London Foundling Hospital also suggest a decline in mortality amongst some of the most disadvantaged children in London, although her rates refer mainly to the experience of children at nurse outside London (Levene, 2005a; 2007). Razzell and Spence (2007) reported similar levels and trends in infant mortality between 'elite' and non-elite families in several London sources, but the numbers involved were small and the quality of the sources problematic. It remains unclear to what extent the dramatic decline of infant mortality after 1750 was shared across social classes in the metropolis.

To investigate the decline of mortality in London we are exploiting the very rich sources for the West End parish of St. Martin-in-the-Fields. In addition to burial records that detail age and cause of death, we have records for the poorest section of the parochial population that allow us to calculate very robust mortality rates, albeit under rather peculiar circumstances. These are the records of the parochial workhouse. The workhouse registers recorded dates of admission and discharge or death, and other details of inmates including age at admission and sometimes the reason for admission or discharge. Births and deaths were recorded, rather than baptisms and burials, and the records of entry and discharge make it possible to calculate the number of person-years at risk, and to convert deaths in the workhouse into mortality rates. Twenty percent of burials in the parish were attributed to the workhouse, and this proportion remained remarkably stable throughout the period 1750-1824 (the evidence for the parish as a whole covers the period 1752-1824, while the workhouse records span the years 1725-1824). The workhouse records therefore make it possible to estimate mortality levels and trends amongst paupers, and to ask whether declines in mortality within the workhouse reflected changes in health of the wider metropolitan population, or rather were the result of changes specific to the workhouse, such as changes in the composition of the workhouse population, or improvements in workhouse conditions. We assess our results with respect to three main explanations proposed to account for the decline in infant mortality in the period 1750-1820: (1) an increase in the prevalence or duration of breastfeeding (e.g. Fildes, 1980; Landers, 1993: 152; Edvinssson et al., 2008); (2) exogenous changes in pathogen characteristics or climate (Fridlizius, 1984; Perrenoud, 1997); (3) improvements in maternal health, via improved nutrition (e.g.

Fogel, 1986; Hart, 1998; Floud et al., 2011) or a reduction in infections (Wrigley et al., 1997; Smith & Oeppen, 2006; Woods, 2009).

The workhouse of St. Martin-in-the-Fields

Under the English 'old' poor law, parishes were required by law to provide various types of economic and medical support for those poor who qualified as members of the parish. Residential workhouses were introduced in some parishes from the early eighteenth century, although outside urban areas most were established only after the reform of the poor laws in the 1830s. Workhouses were designed to recoup some of the cost to the parish of poor relief, by putting able-bodied paupers to work within the confines of an institution. Where residence in the workhouse was a condition of the welfare provision, workhouses were also intended to act as a deterrent to those seeking relief. Hitchcock has argued that the intention to deter and to recoup costs was never realised in the eighteenth century, and instead urban workhouses found themselves overwhelmed with sick paupers seeking medical aid, and were forced to assume a major medical function (Sienna, 2004).

London parishes were precocious in the establishment of workhouses, many opening in the 1720s. St. Martin's workhouse opened in 1725 and was the third largest of London's workhouses by 1803. It was enlarged in 1772, raising its capacity from perhaps 400 to around 700 inmates, and further extended in 1783. The St. Martin's workhouse quickly assumed an important medical function for the poor of the parish (Boulton et al., in press).

Consistent with its hospital function, the workhouse clearly operated partly as a delivery ward, with over 30 per cent of women giving birth admitted 'In Labour'. It accounted for between three and seven per cent of all baptisms in the parish, depending on the year (Figure 1). The number of births in the workhouse rose sharply after the extension of the workhouse in 1772, but fell back to earlier levels in the 1790s. The workhouse accounted for ten per cent of all infant burials recorded in the period 1747-1824, but the workhouse proportion of infant burials fell sharply in 1783, and this coincided with the opening of a new labour ward, as will be discussed below. After birth most surviving infants and mothers spent at least three weeks in the workhouse before being discharged. With the exception of the period of the General Reception at the London Foundling Hospital (1756-60), the timing of discharges was fairly stable. By the end of the first month ten to fifteen per cent of surviving infants had left the workhouse, and so the analysis of mortality amongst those born in the workhouse was restricted to the first month of life, when most infants remained in observation.

Figure 1

Neonatal mortality in the workhouse

Figure 2 presents rates of neonatal mortality for infants born in the workhouse. Stillborn and first day deaths were excluded from analyses, to reduce the impact of the recording of some very early neonatal deaths as stillborn, and effects of changing definitions of stillbirths in the workhouse (from a category including many live births to one approximating ‘dead-born’) (see below). Figure 2 also excludes the period of the General Reception at the London Foundling Hospital (1756-60). During the General Reception infants were accepted into the Hospital without restriction, and of 113 infants born in the workhouse in this period 39 were sent to the Foundling Hospital, many within a few days of birth. This had strong effects on the composition and mortality of the remaining infants, and space precludes a detailed analysis of this period here.

Figure 2

The impression conveyed in Figure 2 is both of excessive mortality of infants in the workhouse (with more than half of all day-old newborns dying within a month, in the 1740s), and of remarkable improvements over time. Improvement was most marked in the late neonatal period, where the chances of dying between days 7 and 28 after birth fell 10-fold, from 35-45 per cent to 2-5 per cent.

The peculiar lethality of the workhouse, and the scale of improvements, is also evident in Figure 3, which presents mortality rates calculated by day of life in the first month. In most populations mortality is highest on the first day of life, and declines with age throughout the first week. The workhouse pattern was aberrant in two respects, before 1783. Firstly, the first day rate was implausibly low, because very early deaths of live-born infants were often classified as stillborn (Davenport, unpubl.). Second, mortality appeared to rise after the first week of life. In the earliest period, 1725-49, mortality was excessive in the second and third weeks of life. In the period 1750-1782 this excess mortality became concentrated in the second week of life, in a pattern very typical of neonatal tetanus, also called 'eight day sickness' or 'nine day fits'. After 1783 the age pattern of neonatal mortality assumed a more 'normal' pattern, for two reasons: first day mortality rose (as a consequence of changes in the definitions of still- and live-born); and the 'hump' of mortality in the second week disappeared. While under-recording of early neonatal deaths could produce these patterns (of apparently excess mortality later in the neonatal period), it is unlikely that infant deaths occurring after the day of birth were significantly under-recorded. Baptism was rapid in the workhouse, often occurring on the day of birth, and any baptised infant that died subsequently would have been classified as live-born (Davenport, unpublished). Moreover, although changes in the recording of stillborns in 1783 affected first day mortality rates, there was no evidence of any discontinuities in rates on subsequent days (Figures 3, 4a).

Figure 3

The pronounced rise in mortality rates with infant age in the first two weeks of life, if real, indicates a very significant involvement of infectious diseases. Neonatal mortality is usually considered to be dominated by ‘endogenous’ causes of death, arising from genetic or *in utero* circumstances (especially prematurity), or from difficulties and accidents during the birth process. The effect of these endogenous causes is usually greatest in the first hours and days of life, and accounts for the mortality maximum at birth. However there are also a number of infectious diseases that exert their greatest effect in the neonatal period, and which therefore would be included in ‘endogenous’ mortality as usually calculated (using the biometric or Bourgeois-Pichat technique). The main causes in this category are neonatal tetanus and neonatal sepsis, which still account for very significant proportions of neonatal deaths in high mortality populations (Lawn et al., 2005). Mortality from both causes rises over the first week of life, reflecting the tendency for infection to occur during or shortly after birth, and the lag between infection and clinical symptoms. Other infectious diseases with very significant impact in the first month of life include diarrhoeal and respiratory diseases, but these causes are often associated with absence or early cessation of breastfeeding, and are not concentrated in the neonatal period but are of major importance throughout infancy.

Figure 4

Most suggestive in terms of infectious disease mortality in the workhouse is the peak of mortality at 8-9 days of age, that emerged in the period 1750-1780 (Figure 3).

Such a peak corresponds very closely to age patterns of neonatal tetanus mortality established from clinical diagnoses in both hospital and community settings (Stanfield & Galaska, 1984; Boerma & Stroh, 1993; Roper et al., 2007). Neonatal tetanus is usually caused by infection of the umbilical stump due to contamination during cutting, or by application of infected ointments. Historically, case-fatality rates approached 100 per cent. Neonatal tetanus is still a significant cause of neonatal mortality in developing country populations with low levels of skilled attendance at birth (Roper et al., 2007), and was recognised as a major cause of infant mortality in some historical populations (Clarke, 1789; McMillen, 1991; Vasey, 1997; Stride, 2008). Boerma and Stroh (1993) demonstrated using a range of evidence that the ratio of mortality at ages 4-14 and 15-28 was usually close to one in populations with low rates of neonatal tetanus, but that mortality at ages 4-14 days significantly exceeded that at ages 15-28 days where neonatal tetanus was prevalent. Figure 4a explores the relationship between these age groups over time amongst infants born in the workhouse. It shows five year moving means of probabilities of dying at ages 1-3, 4-14 and 15-27 days (the day of birth, age 0 days, is omitted). While there was a rapid improvement at all ages in the 1740s, the trend in mortality at ages 4-14 days diverged from that at other ages after 1750, and remained consistently above that at ages 15-27 days between 1750 and 1780. From 1780 mortality fell dramatically in both age groups, but mortality at ages 4-14 days again exceeded mortality at ages 15-27 days substantially in the periods 1785-95 and 1800-07. However, while these age patterns of neonatal mortality are suggestive of a significant contribution of neonatal tetanus, they do not accord with the more striking patterns presented by Boerma and Stroh (1993). In the workhouse mortality at ages 4-14 days was roughly double that at ages 15-27 days in the period 1750-1780, considerably lower than the four- to five-fold ratios typical where neonatal tetanus was a major cause of death (Boerma & Stroh, 1993; Reid & Garrett, in press). Therefore, while the pronounced peak in mortality at day eight, peculiar to neonatal tetanus, suggests a role for neonatal tetanus (especially in the period 1750-80), it is likely that other factors also contributed to the pattern of excess mortality after the first week of life.

Neonatal sepsis (or septicaemia) is caused by infection by a very wide variety of bacterial pathogens. It is usually fatal in the absence of antibiotic treatment (Edmond & Zaidi, 2010). ‘Early onset’ cases, usually defined as manifesting within the first few days of life, are generally attributed to ‘vertical’ infection from the mother during birth, but poor hygiene after birth is also implicated (Zaidi et al., 2009). Premature and low birth-weight neonates are at higher risk of neonatal sepsis. At present group B streptococci, acquired from infected mothers, dominate cases of early neonatal sepsis in low mortality populations, but the profile of causal pathogens varies substantially by region and study (Vergnano et al., 2005; Zaidi et al., 2009). Group A streptococci are sometimes implicated in late onset neonatal sepsis (with onset after the first days or week of life) (Vergnano et al., 2005), but are considered to have been the major cause of neonatal sepsis in now-developed countries before the introduction of antibiotics (Freedman et al., 1981; Nizet & Klein, 2011).

An important question is whether the curious age patterns observed in the workhouse were also evident in the St. Martin’s population as a whole. Unfortunately this is difficult to determine, because the evidence for the rest of the parish consists of age at death information, which although usually reported in days or weeks for young infants, nevertheless shows significant heaping on ages such as ‘fourteen days’ and ‘two weeks’. This produces artifactual peaks that obscure underlying patterns in daily rates. In contrast, the workhouse reported dates of birth and death, rather than age of neonatal deaths, and so age-heaping was not a problem. Figure 4b shows mortality rates for the non-workhouse population. Burials aged ‘14 days’ and ‘two weeks’ were distributed equally between the age categories 4-14 days and 15-27 days, and the latter category included half of the small number of deaths at age ‘one month’. These rates are much less reliable than those for the workhouse population, because they are calculated from baptisms and burials rather than births and deaths. There is good reason to think that births were under-registered in the parish in this period, and that the extent of under-registration increased over the late eighteenth century. Therefore the non-workhouse rates presented here probably overestimate the level of infant mortality, and underestimate the extent of improvements. However burial registration seems to have been relatively complete, except in the case of very early neonates, which were often recorded as stillborn (Davenport, unpubl.). Deaths on the day of birth were omitted from the rates in Figure 4b, but the deficit of very early neonates means that rates for 1-3 day olds are particularly unreliable. With these caveats in mind, the ratio of deaths at days 4-14 to days 15-27 did not suggest that neonatal tetanus caused significant mortality in the first two weeks of life in the non-workhouse population (although the ratio could also be affected by high mortality at ages 15-27 days: Boerma & Stroh, 1993). Nevertheless, both sources were quite similar in their age-specific trends, and indicated little improvement between 1750 and 1780, a period of major and rapid mortality decline in the 1780s, and a transient worsening around 1800.

The unusual age pattern of neonatal mortality in the workhouse was also superficially similar to maternal mortality patterns. Figure 5 shows the time course of maternal mortality in the workhouse. These rates were calculated including women delivered of stillbirths, however the first day rate is probably an underestimate, because many stillbirths are likely to have gone unrecorded, especially before 1783. The rates include all maternal deaths and therefore overestimate mortality due specifically to pregnancy and childbirth. However although ‘background’ mortality undoubtedly played a part in the high mortality amongst mothers in the workhouse, it could not account for the timing of mortality evident in Figure 5. Amongst workhouse inmates as a whole mortality fell precipitously with duration of stay in the workhouse for most age groups (Boulton et al., in press), in contrast to the rise in mortality over the first week after delivery amongst women giving birth (the majority of whom were resident in the workhouse before delivery). The cause of the rise in mortality was probably puerperal fever, which had a characteristic time course of mortality (in twentieth century populations), shown in Figure 5 for Scotland, 1929-33 (Loudon, 1992: 55). Puerperal fever was a very major cause of maternal mortality before effective antibiotic treatment, and was probably caused mainly by Group A streptococcal infections. DeLacy and Loudon have argued that Group A streptococci were responsible for epidemics of puerperal fever (especially in institutions) and for most of the mortality associated with puerperal fever (deLacy, 1989; Loudon, 1992: 77-80). Seligman (1991) argued that Group B streptococci were the main cause of 'endemic' levels of puerperal fever, with lower levels of mortality.

Figure 5

Cox regression analysis of neonatal mortality

In order to explore further the causes of mortality, and its decline, in the workhouse, neonatal mortality was modelled using Cox regression analysis, a technique which takes into account the age pattern of deaths, and changes in the population at risk as individuals enter, and die or leave. A key assumption of Cox proportional hazards models is that the relationship of independent variables to the risk of dying is proportional at all ages (for example, the risks associated with being a twin should not vary with age). Proportionality tests suggested that the independent variables differed in their effects at different ages within the first month of life, and that neonatal mortality could not be modelled using a conventional division into early and late neonatal periods, but that the age groups 1-3, 4-14 and 15-27 days provided a better basis for analysis.

The basic characteristics of the dataset are described in Table 1, and the variables are described together with results in the results section. Only infants for whom full maternal details were available (including date of delivery) were included in the regression analysis (see Table 1). The impact of changing definitions of stillbirths (from a category including many live births to one approximating 'dead-born') was reduced by exclusion of all stillborns and first day deaths from the following analysis. The General Reception period (1756-60) was also excluded.

Table 1

Results

The analysis reported here had two aims: to determine the causes of excessive neonatal mortality in the workhouse, and to test whether improvements in neonatal mortality were a function primarily of factors specific to the workhouse and its inmates, or also reflected changes in the broader population. We first consider the causes of high neonatal mortality in the workhouse, and the major risk factors in each age group. We then evaluate the extent to which changes in the composition of the workhouse population and workhouse conditions could account for the observed reductions in neonatal mortality within the workhouse. The effect of each variable on neonatal mortality was modelled over the full period 1725-1824 (Table 2) and for the period when the marital status of most mothers was known (1752 – 1824: Table 3). In most cases results were broadly similar for both periods, except in the case of maternal age, where the inclusion of marital status in the period 1752-1824 had substantial effects on the results of multivariate analysis. Therefore results are discussed only with reference to the shorter period 1752-1824, except in the case of period effects, or where univariate analyses indicated a substantial difference between the two periods as a consequence of the different periods covered. Regression results are reported as odds ratios, that is, the multiplicative risk of death compared with the baseline category. The relationship of each variable to neonatal mortality was considered alone (univariate analysis) and in the presence of the other variables (multivariate analysis). The very short interval associated with ages 1-3 days and the small number of events in this age range made it difficult to determine any but the strongest associations in this age group.

Tables 2,3

Maternal age. Age of workhouse inmates was recorded at admission in exact years. The age distribution of women giving birth in the workhouse was younger than was probably the case for the parish population, due to the predominance of unmarried mothers in the workhouse. Unmarried women were significantly younger than married women (Figure 6). The age distribution of mothers whose marital status was unknown was intermediate between those of married and unmarried mothers, and this distribution could be approximated best by assuming that married women comprised around 55 per cent of the unknown status group (a higher proportion than their share of the known status sample). The age distribution of the sample in the period 1725-51 was almost identical to that after 1751, suggesting that the ratio of married to unmarried women may have been fairly constant in all periods.

Although maternal age usually has a U-shaped relationship to infant mortality, with infants of women in their twenties at lowest risk, in the workhouse maternal age showed no significant association with neonatal mortality, either alone or in multivariate models (when marital status was included: Table 3). Inclusion of interactions between maternal age and marital status in the analysis indicated that the effects of maternal age did not differ significantly by maternal marital status (results not shown).

Figure 6

Legitimacy status. Most illegitimate births in the parish occurred in the workhouse, and unmarried women constituted the majority of women giving birth in the workhouse. After 1751 legitimacy status could be assigned to 89 per cent of births, and of these 74 per cent were illegitimate (Table 1). Maternal marital status was not given routinely in the workhouse registers, and so this was established in most cases by linking infants to their baptism records, which recorded parental details. This method of assigning legitimacy status was not practical before 1752, and so analysis of illegitimacy was restricted to the period 1752-1824.

Illegitimacy usually carried a severe mortality penalty in historical populations, which was evident in the neonatal as well as post-neonatal periods (Registrar-General, 1877: l-li; Kitson, 2004: 231; Reid, 2005). In the workhouse illegitimacy was associated with significantly higher risk only in neonates aged 4-14 days (hazard ratio of 1.89 relative to legitimate infants, multivariate analysis, Table 3).

Absence of legitimacy information was associated with higher risk in the first two weeks of life, but again the association was statistically significant only at ages 4-14 days. The unknown status group comprised both legitimate and illegitimate infants, and it was possible that deaths were concentrated amongst the illegitimate-born in this group. However the age distribution of mothers of unknown marital status whose infants died in the neonatal period was very similar to that of all mothers of unknown marital status, suggesting that the inclusion of illegitimate infants was not the primary reason for the high risk associated with this group. Rather the higher risk in this group was probably attributable to two shortcomings of the database itself. First, the use of baptism records to establish legitimacy omitted those infants who died before baptism, and so although baptism was rapid in the workhouse, a proportion of very early neonatal deaths could not be assigned legitimacy status. In addition, many infants could not be assigned legitimacy status because of episodic linkage failures between the workhouse and the parochial baptism registers. This problem was greater in the period before 1790, when mortality was higher, and this probably contributed to the apparently higher risk of infants of unknown status.

Illegitimacy was clearly a major factor accounting for the excessive neonatal mortality in the workhouse. While a mortality disadvantage of illegitimacy is a consistent historical finding, the nature of the disadvantage has remained largely elusive (Levene, 2005b; Reid, 2005). Levene (2005b) suggested that unmarried mothers may have experienced greater poverty and ill-health, and a higher incidence of primiparity, that may reduced the viability of their offspring compared with legitimate-born infants. While a higher incidence of prematurity or low birth-weight could have raised infectious disease rates in these infants at ages 4-27 days, these disadvantages would be expected to have their greatest effect in the earliest days of life, where illegitimacy seems to have conferred no disadvantage in the workhouse. It is possible that women and infants were transferred out of labour wards at some point after delivery, and that married and unmarried women were sorted to different wards, with differing infectious disease risks. Alternatively or additionally, although women were not sorted to delivery wards on the basis of marital status, it is possible that marital status influenced their treatment within the same wards. Eden reported in 1797 that 'each married lying-in woman [was allowed] one pot of porter for caudle the first 9 days and a pint for 7 days after; others half that quantity" (Eden, 1797), and 'bastard-bearers' were required to wear a distinctive blue and yellow uniform, at least in some periods (Mackay, 1995). Other, unknown forms of discrimination may also have operated to the disadvantage of illegitimate infants. The tetanus-causing pathogen *Clostridium tetani* is ubiquitous in soil and is carried in human and animal faeces. Delivery on straw may be a risk factor, or wrapping the infant in infected cloth before the umbilical stump has healed (Bennett et al. 1996). These conditions would also influence exposure to other pathogens. If married women were more likely to bring in clean linen for their newborns, or to be given better beds within the workhouse, then this may have reduced infection rates amongst legitimate neonates relative to their illegitimate peers.

Maternal survival. Maternal death posed a very high risk to infants in historical populations. Amongst workhouse neonates, 88 per cent of infants whose mothers died in the first month after birth also died in the workhouse, three quarters of these within the first month. Maternal survival was modelled as survival to the end of the age interval under analysis. The number of maternal deaths occurring to infants aged under four days was too small for analysis, once deaths on the day of delivery were excluded (Table 1). However maternal death was associated with a six-fold increase in risk of neonatal death amongst older neonates (Table 3).

Infant sex. Males are usually at a disadvantage in infancy, and male excess may be particularly marked in the early neonatal period (Waldron, 1983). Surprisingly, in the workhouse male sex was associated with significantly higher risk only at ages 4-14 days (1.64 times the risk of females). Excess male mortality is a common finding in studies of both neonatal tetanus and sepsis, although it remains unclear whether this male excess reflects a gender bias in seeking medical attention or recall of infant deaths, or represents a genuine biological susceptibility (Roper et al., 2007).

Obstetric risk factors: admission in labour, and multiple births. Many entries recorded women as 'Brought in labour' to the workhouse. Women were also considered as admitted in labour if they were admitted less than three days before delivery.

Being in labour at admission was associated with a 2.23-fold increase in the risk of early neonatal death (adjusted for other factors), compared with women admitted before labour (ages 1-3 days, Table 3). To test further the possibility that the workhouse catered especially for 'emergency' deliveries we examined the frequency of multiple births, which are often accompanied by difficult labours that may have induced a woman to seek recourse to the workhouse during her labour. Multiple births were associated with a dramatic elevation of risk relative to singleton births in the workhouse (over 26 times the risk of singleton infants at ages 1-3 days, and 4.7 times higher risk later in the neonatal period: Table 3). However multiple births were not in excess of the numbers expected (2.75 per cent of all births including those reported as stillborn, and 2.46 per cent of those reported liveborn, compared with 2.7 per cent of live births in the Cambridge Group national reconstitution sample: Wrigley et al.,1997: 243). Therefore the evidence that the workhouse catered for a population at relatively high obstetric risk was equivocal.

Workhouse factors: ward type, and crowding. The unusual age patterns of neonatal mortality in the workhouse suggested high levels of infectious disease mortality, with particular impact after the first week of life. We lacked direct evidence of workhouse conditions and policies, however we were able to use ward type as a proxy for some of these effects. The admissions registers indicate the ward each infant was born in, and it is possible from the age and sex structure of the ward inmates, and occasionally their reasons for admission, to determine the type of ward. The workhouse introduced a labour ward in the 1730s, and between the 1730s and 1783 an increasing proportion of infants were born into labour wards rather than general wards (which could contain children and women of all ages and sometimes adult males). Assignment to a labour ward was apparently independent of marital status. After a major rebuilding in 1772 the workhouse was expanded further in 1783, when the roof was raised to provide space for a charity school and extra wards. From mid-

1783 almost all recorded births took place in a single ward, ward 4, which did not appear in earlier records (it may have been a new ward, but renumbering of an old ward is also a possibility). This ward was clearly a labour ward, inhabited only by women of reproductive age and infants. Ward type was modelled as a binary distinction between being born in a general or a labour ward. In addition we included an interaction term in our multivariate regression models, representing the effects of being born in a labour ward after 1782.

The workhouse population roughly doubled after the rebuilding in 1772, and then contracted again in the 1780s. Crowding was modelled as the annual numbers of births. These followed annual admissions trends and served as a proxy for the size of the workhouse population, which could have affected disease exposure.

'Crowding' was generally positively associated with mortality, however the association was statistically significant only when the full period 1725-1824 was considered, suggesting that 'crowding' may have been most lethal in the earliest period (1725-49). Crowding effects may help to explain the relative healthiness of summer for neonates (see below), because summer was the period of lowest workhouse residency. However while the confinement of women and newborns to an exclusive ward should have resulted in lower exposure to the diseases rife amongst other inmates of the workhouse, birth in a labour ward *per se* seems to have conferred little advantage before 1783 (Table 3). However being born into the post-1783 labour ward was associated with a 41% reduction in risk at ages 1-3 days compared to birth in a general ward before 1783 (1.66 x 7.11 x 0.05 = 0.59), and a halving of risk at ages 15-27 days (0.88 x 4.42 x 0.13 = 0.51), but was not associated with a significant improvement at ages 4-14 days. This accords with the evidence from Figure 4a, where the drop in mortality at ages 15-27 days appeared to coincide with the opening of the new labour ward in 1783 (allowing for the imprecision introduced by the use of five year moving means), whereas the fall at ages 4-14 days began slightly earlier, around 1780.

What were the changes in workhouse practices around 1783, that might account for the improvements in neonatal mortality from this date? We don't know the location of the post-1783 labour ward, but it may have been a newly-built room, which could have improved hygiene levels. In addition it appears that there was substantial reform of practices surrounding birth registration. Before 1772 stillbirths were recorded frequently, and this practice coincided with a pronounced deficit in deaths of very young neonates. After 1772 no stillborns were recorded until 1783, when there was a sudden leap in both stillborns and first day deaths (evident in the anomalous rise in the death rate of youngest infants in the period 1783+ in Figure 3), suggesting that both stillborn and live-born early neonatal deaths were recorded with new rigor, and a more stringent definition of stillborn was adopted. The evidence points to some overhaul of policies towards labour and birth in 1783, that improved both early and late neonatal mortality. Unfortunately the workhouse records don't indicate the motive for these changes, nor how they were enacted. In a tantalising coincidence, a similar fall in neonatal mortality was reported in the Dublin Lying-in Hospital from 1784. Dr Joseph Clarke, who took over management of the hospital in 1783, attributed excessive rates of neonatal mortality in the hospital to nine day fits, and claimed that he was able through improved ventilation to cut dramatically the incidence of both nine day fits and infant mortality (Clarke, 1789). However although Clarke was in correspondence with medical practitioners in England, the coincidence in timing seems too close for an improvement in Dublin to have driven changes in St Martin's, and in any case Clarke's remedy was unlikely to prevent neonatal tetanus.

Season of birth. Dates of birth were aggregated into annual quarters; winter (December-February) spring (March-May) summer (June – August) and autumn

(September – November). There was little seasonality in workhouse births, in contrast to admissions in other age groups (which peaked in winter, and were lowest in summer).

Season of birth had little effect on mortality amongst workhouse-born infants, except for a pronounced spring excess at ages 15-27 days, suggesting the involvement of specific infectious diseases in this age group (Table 3). Summer was a relatively healthy season to be born in, although the association was statistically significant only when the full period 1725-1824 was considered. The relative lack of seasonality within the workhouse was in stark contrast to the pattern outside the workhouse, where neonatal burials peaked in the summer months (Figure 7). A similar pattern of excessive summer mortality prevailed amongst London Quaker neonates (Landers, 1993: 146) and neonates in York, 1561-1700 (Galley, 1998: 102). Landers attributed this pattern to very early weaning or absence of breastfeeding amongst the Quakers, which exposed infants to particular risk of diarrhoeal diseases in summer when foods and liquids were most liable to contamination. Strikingly, in both St. Martin's and amongst London Quaker neonates, this seasonal pattern of high summer risk persisted, despite large falls in neonatal mortality. Landers suggested that such a pattern reflected the increasing concentration of mortality amongst a diminishing proportion of families where hand feeding persisted. Alternatively, improvements in neonatal mortality may not have been a function of changes in feeding practices. Interestingly, infants brought into (not born in) the workhouse in the first month of life did show a summer excess of mortality, but this pattern was almost entirely attributable to the inclusion of foundlings in this group, who were presumably hand-fed not wet-nursed (analysis not shown). Neonates brought in with their mothers showed an aseasonal pattern of risk similar to the workhouse-born infants. The healthiness of summer amongst workhouse infants compared with the parochial population suggests high rates of breastfeeding in this pauper population, and indicates one pathway that may have diminished differences in infant mortality by social status.

Figure 7

Period of birth and change over time. Decade of birth was used to estimate period effects. Birth in the period 1810-24 was used as the baseline category, because it contained a large sample compared with some of the earlier, incomplete decades (Table 1).

Infant mortality fell dramatically in London over the century covered by the workhouse records, and survival gains were even more extraordinary amongst infants born in the workhouse (Figure 2 and univariate analyses, Table 2). Mortality decline in the workhouse clearly occurred partly through changes in the composition of the workhouse population (including falls in admissions in labour, and in maternal mortality) and, more significantly, improvements in workhouse conditions, reflected most obviously in the effects of the reform of policies towards neonates associated with the post-1783 labour ward. In the case of very early neonatal mortality (ages 1-3 days), there was no evidence for a significant decline in mortality, once these factors were adjusted for. This reflects in part the small numbers of deaths in this age range (Table 1). However, after adjustment for known maternal characteristics and workhouse conditions, then a consistent pattern of improvement remained at ages 4-27 days (Tables 2,3).

Period effects are best considered over the full dataset 1725-1824: the similarities in the size of period effects from 1760 in Tables 2 and 3 are sufficient to make the comparision valid. At ages 4-14 days time trends in mortality in the baseline group (male singleton infants born in a general ward in winter, to mothers aged 20-24 not in labour and who survived the first month after delivery), differed very little from unadjusted trends for all neonates in this age range (compare univariate and multivariate analyses in Tables 2 and 3). Mortality at ages 4-14 days roughly halved between the second and third quarters of the eighteenth century. Rates then stagnated in the third quarter before more than halving between 1770 and the 1790s, and halving again in the early nineteenth century. This pattern accords fairly closely with trends in rates amongst the non-workhouse population of St. Martin-in-the-Fields after 1750 (Figure 4). Although the data for the non-workhouse population are much less reliable than those for workhouse neonates, the two sources were subject to very different types of biases and recording errors, suggesting that similarities in time trends between the two series may reflect genuine correspondences in the causes of mortality decline.

Mortality of workhouse-born infants at ages 15-27 days was clearly influenced by conditions in delivery wards, but when these effects were adjusted for then mortality in the baseline group within this age range appeared to decline fairly smoothly over time after 1750 (Figure 8).

Taken together, mortality at ages 4-27 days among workhouse-born neonates declined substantially over the second half of the eighteenth century even after adjustments for workhouse-specific factors. This accorded with evidence of improvements in survival of parish neonates born outside the workhouse, and also echoes the rapid improvements in neonatal and endogenous infant mortality amongst London Quakers and the national population at the end of the eighteenth century. The ubiquity of mortality decline in these populations suggests the possibility that similar, unobserved, forces drove mortality decline in all groups.

The relationship of period of birth to neonatal mortality in the workhouse was necessarily estimated as a residual, after known factors were adjusted for, and our data provide few clues as to the nature of this change over time. The only known factor in our dataset that changed over time with a trend similar to that of neonatal mortality was maternal mortality (Figure 8). Although these maternal mortality rates are based on very few deaths, they are in broad agreement with trends in maternal mortality in London estimated from 'Childbed' burials in the London Bills of Mortality, and with maternal mortality in the national family reconstitution sample (Wrigley et al., 1997: p.314), although the *levels* of mortality were much higher in the workhouse. Given the evidence for high levels of infectious disease mortality amongst mothers in the workhouse (Figure 5), it is likely that the large declines in maternal mortality there involved substantial reductions in puerperal infection.

Figure 8

Trends in maternal and neonatal mortality were also very similar in the English family reconstitution sample over the period 1650-1837, leading Wrigley et al. (1997) to speculate on the possibility of a causal mechanism linking the two phenomena. Even in the workhouse maternal mortality was not high enough to be a direct determinant of trends in survival rates amongst neonates (at worst no more than 3-5 per cent of neonates lost their mother in the period 1725-49, when over half of all neonates died). Wrigley et al. (1997: 307-22) demonstrated that improvements in maternal survival kept pace with improvement in the survival of male spouses in the English population, and therefore were more likely to have occurred as a function of wider improvements in adult health, rather than of specific improvements in obstetric practice. Instead they suggested that the falls in adult mortality over the late seventeenth and eighteenth centuries reflected greater childhood exposure to immunising infectious diseases, which raised mortality in late infancy and early childhood, but reduced adult disease rates. Greater maternal immunity to a range of diseases would have improved maternal resistance to infection during pregnancy and after childbirth, and improved foetal health (Smith & Oeppen, 2006). More recently, Woods argued that reductions in stillbirth rates may have been driven by reductions in infectious disease incidence during pregnancy, as a result of rising immunity to specific diseases (such as smallpox) (Woods, 2009; Davenport et al., 2011). Alternatively, maternal health may have improved as a consequence of improvements in diet and nutritional status (Fogel, 1986).

Space precludes a detailed analysis of maternal mortality within the workhouse. However the evidence presented here raises the (highly speculative) possibility that changes in exposure or susceptibility to specific diseases exerted similar effects on both neonatal and maternal mortality in the workhouse and perhaps the parish of St. Martin's as a whole. One possibility is that certain pathogens underwent independent changes in virulence, that reduced infection or mortality rates in the human population. Alternatively, falling maternal and neonatal rates of infection could result from increasing levels of immunity amongst pregnant women to pathogens present in the urban environment, as a consequence of increasing exposure to similar diseases in childhood. This would have improved foetal health, but could also have protected neonates from very early infection through the transfer of specific maternal antibodies *in utero.* While this mechanism would not have operated in the case of tetanus (where the pathogen is ubiquitous, and exposure often lethal), it is a plausible scenario with respect to some of the bacteria implicated in neonatal sepsis, such as Group B streptococci (where maternal immunisation is now routinely employed), and possibly Group A streptococci (where both cross-immunity via infection with different strains and changes in virulence are also likely). While Loudon (1992) and Wrigley et al. (1997) dismissed the possibility that declines in puerperal fever amongst women could have been associated with significant improvements in neonatal survival, the possibility deserves further attention. Semmelweiss, who first discovered the link between puerperal fever and streptoccal infections of other tissues in the mid-nineteenth century, noted the high rates of puerperal fever deaths amongst infants of infected women (Semmelweis, 1983; Raju, 1999). Group A streptococcal infection was probably the major cause of neonatal sepsis before antibiotic therapy in now-developed country populations (Freedman et al., 1981), and neonatal mortality, which apparently improved little after 1840, declined dramatically and in tandem with maternal mortality after the introduction of the anti-streptococcal sulphonamides in the late 1930s (Loudon, 1992). Thus streptococcal infections may have played a major role in neonatal as well as maternal mortality before antibiotic therapy, and these pathogens could have exerted similar effects independently on both age groups, or their effects may have been mediated by maternal exposure to similar pathogens in childhood. If maternal immunity were implicated then this would probably have conferred advantages on infants born to mothers of longer residence in the city (who would have greater prior disease exposure and immunity). If unmarried mothers were more likely than married women to be recent migrants to the city, then this might explain some of the disadvantage to illegitimate neonates that emerged only after the first few days of birth.

Conclusions.

The rich sources for the parish of St. Martin-in-the-Fields provide a great deal of insight into pauper mortality within the workhouse. Infants born in the workhouse clearly suffered extreme levels of mortality in the first month of life. Part of this excessive mortality was attributable to the concentration of illegitimate births in the workhouse, which carried a higher risk especially in the second week of life. However the most obvious cause of the high mortality in the workhouse in the late neonatal period appeared to be a high incidence of infection acquired during birth or shortly after, possibly caused by unhygienic delivery and postnatal environments, and especially lethal to illegitimate infants. Reforms in policies regarding stillbirth registration and neonatal care seem to have had a dramatic effect on neonatal survival in the first days after delivery and in the second half of the neonatal period (ages 15-27 days), indicating the peculiar lethality of the workhouse environment itself. However these policies apparently did not influence neonatal mortality in the age range 4-14 days, where infectious diseases specific to the neonatal period, such as neonatal sepsis and tetanus, exert their greatest effect, and where trends in mortality were most similar to those in the non-workhouse population.

Neonatal mortality in the workhouse followed trends in the parochial population in exaggerated form, suggesting that mortality improvements in the workhouse population may have been coupled to some extent to improvements in the health of infants of other status groups, at least in the first month of life. The question remains what these improvements may have been. Three possibilities are often suggested: an increase in the prevalence and/or duration of breastfeeding; exogenous changes in climate or pathogen properties; and improvements in maternal health. With respect to breastfeeding, the differences in the seasonality of neonatal mortality between workhouse infants and the non-workhouse population, and the persistence of a strong summer penalty in the latter, suggested that breastfeeding was much more prevalent in the workhouse population than in the parish as a whole, and that this pattern did not alter substantially in the late eighteenth and early nineteenth centuries. Therefore changes in breastfeeding patterns seem unlikely to explain improvements in mortality amongst either pauper neonates (where breastfeeding was apparently very widespread) or non-workhouse infants (where there is no evidence for an increase in breastfeeding). An autonomous change in pathogen virulence remains a plausible if residual explanation of mortality decline, given the potential importance of early neonatal infections in both the workhouse and the parish as a whole, and the synchronicity of improvements in both neonatal and maternal mortality. Finally, the evidence for improvements in the survival of the poorest infants and their mothers indicates that any substantial changes in maternal health that might have driven these improvements must have been very widespread and relatively egalitarian in their effects. On balance, if one accepts that improvements in the health of infant paupers and their mothers kept pace with other income groups, then changes of an epidemiological type seem more plausible than a rise in living standards.

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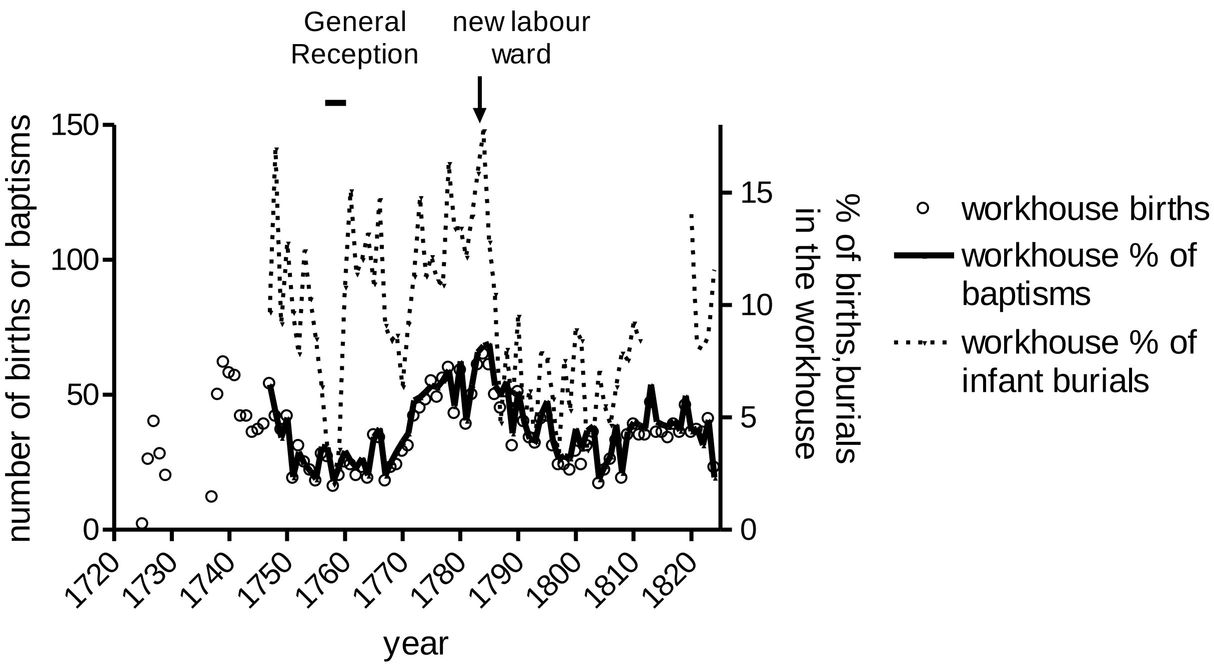

Figure 1. Annual births, and percentage of parochial baptisms and infant burials, in the workhouse of St. Martin-in-the-Fields.
Sources: Admissions register of the workhouse, baptism registers and sextons' burial registers of St. Martin-in-the-Fields.

Figure 2. Early and late neonatal mortality rates in St. Martin-in-the-Fields workhouse, five year moving means (excluding the day of birth, and the period 1756-60).
Source: Admissions register of the workhouse of St. Martin-in-the-Fields.

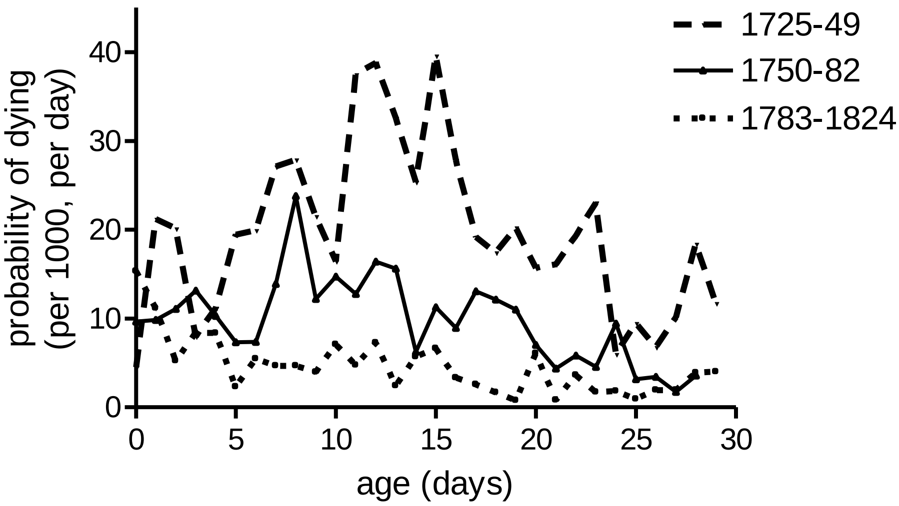

Figure 3. Daily mortality rates by neonatal age in the workhouse of St. Martin-in-the-Fields.
Source: Admissions register of the workhouse of St. Martin-in-the-Fields.

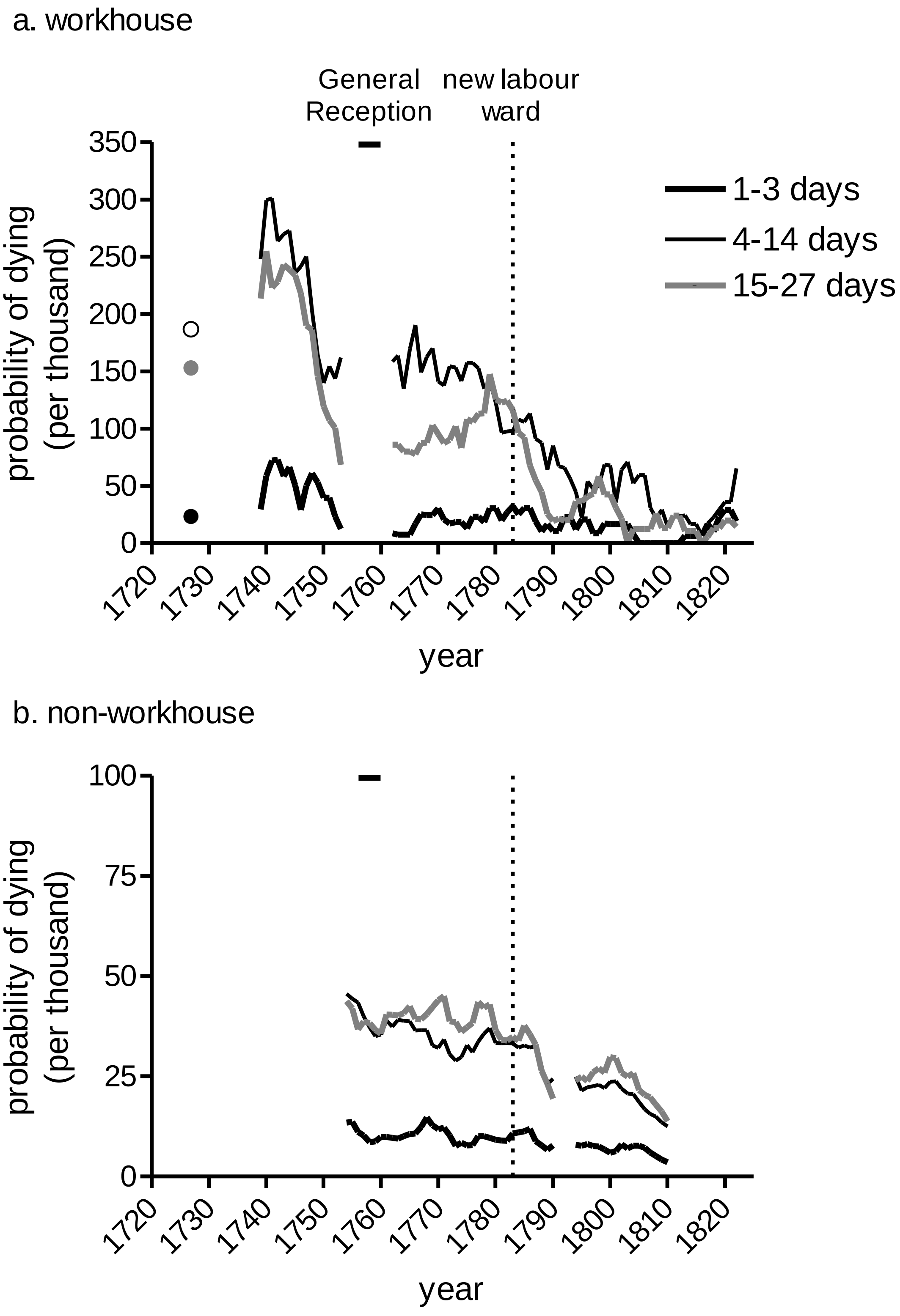

Figure 4. Mortality rates by age of neonate in the workhouse (a) and non-workhouse (b) populations of St. Martin-in-the-Fields, five year moving means. The day of birth, the General Reception period in the workhouse (1756-60), and periods of poor recording, are excluded.
Sources: Admissions register of the workhouse, baptism registers and sextons' burial registers of St. Martin-in-the-Fields.

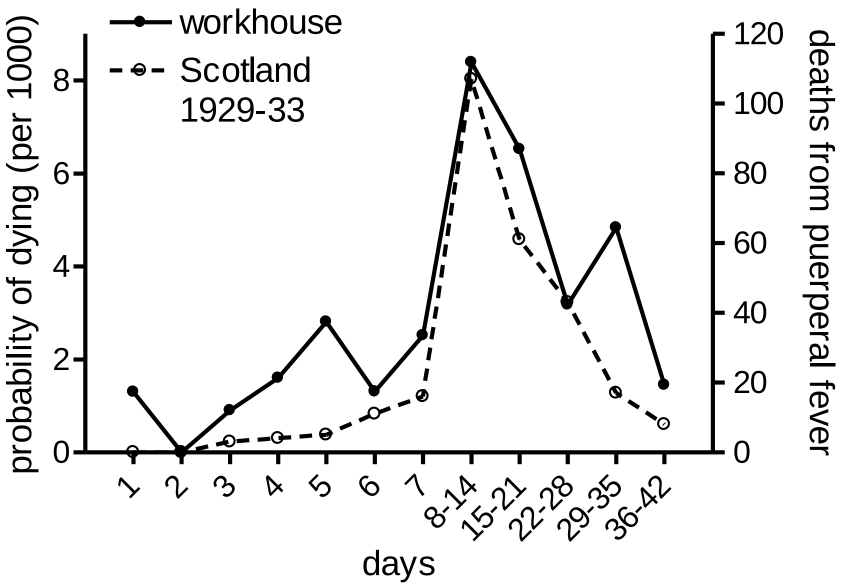

Figure 5. Maternal mortality rates in the workhouse of St. Martin-in-the-Fields (1725-1824), and deaths from puerperal fever in Scotland (1929-33).
Sources: Admissions register of the workhouse of St. Martin-in-the-Fields all maternal entries, including maternal deaths associated with stillbirths); Loudon, (1992, p. 55)

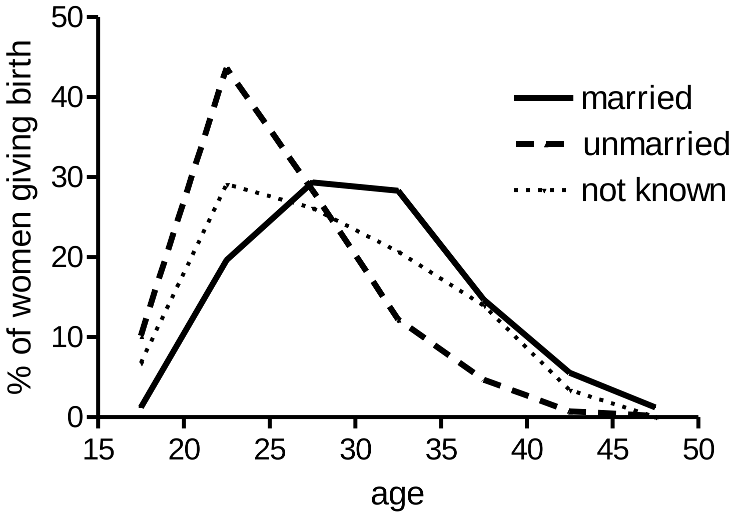

Figure 6. Age distributions of women giving birth in the workhouse of St. Martin-in-the-Fields, 1752-1824 (including only those included in regression analyses – see Table 1).
Sources: Admissions register of the workhouse of St. Martin-in-the-Fields.

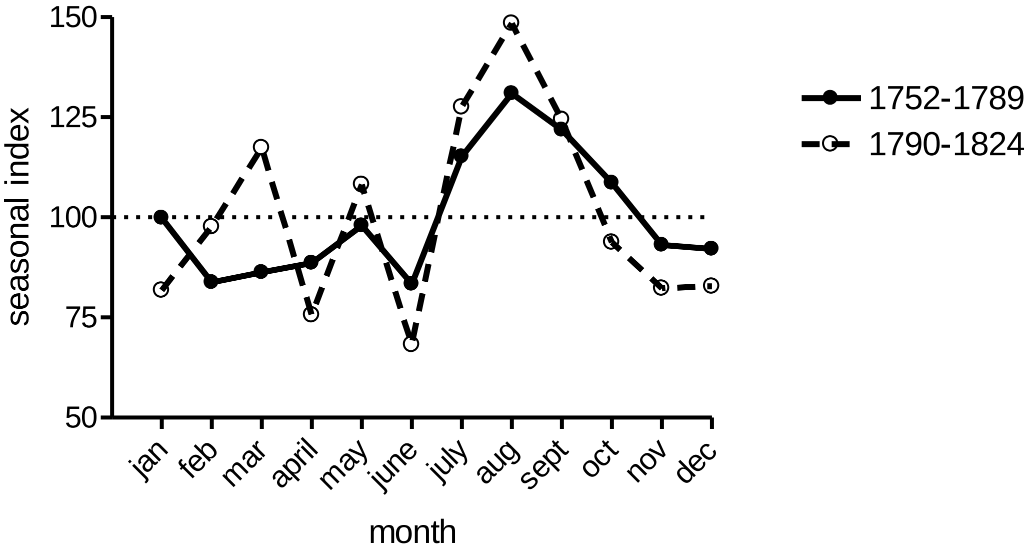

Figure 7. Seasonality of neonatal mortality in the non-workhouse population of St. Martin-in-the-Fields (adjusted for seasonality of births and length of month).
Sources: Baptism registers and sextons' burial registers of St. Martin-in-the-Fields (note that baptism registers included date of birth).

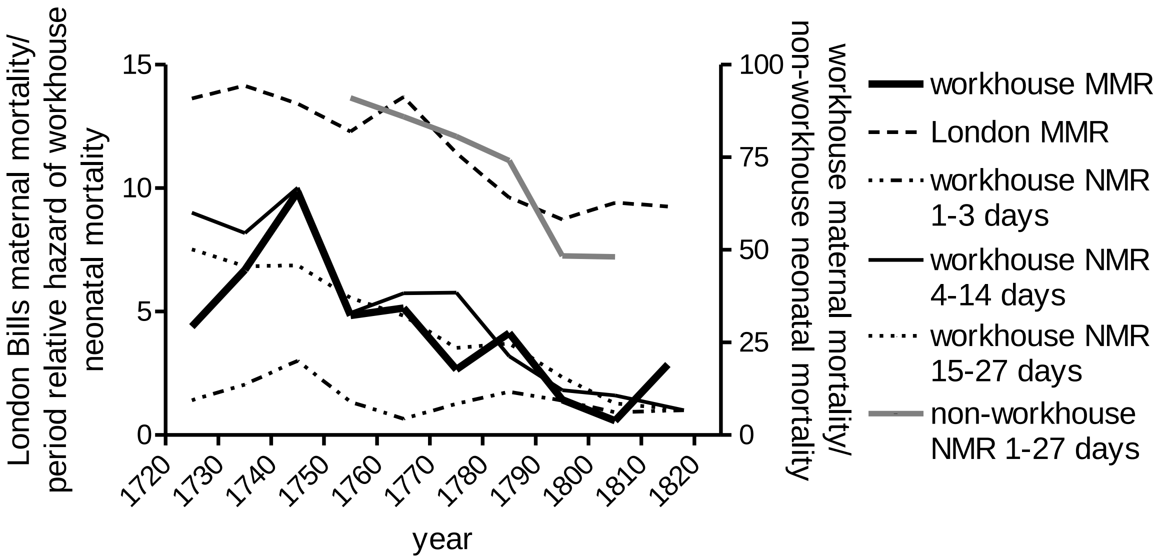

Figure 8. Maternal (MMR) in the workhouse of St. Martin-in-the-Fields and the London Bills of Mortality (decadal averages), neonatal mortality in the non-workhouse population and relative risk of baseline group by decade of birth for neonates (estimated by Cox regression) in the workhouse of St. Martin-in-the-Fields.

Sources: Admissions register of the workhouse of St. Martin-in-the-Fields (maternal deaths weeks 1-4 after delivery); childbed burials in the Bills of Mortality, divided by the sum of baptisms and stillborn burials in the same decade, from Marshall (1832: unpaginated tables); sextons' books of St. Martin-in-the-Fields; this paper, Table 2.

Table 1. Summary of dataset used in Cox regression analyses, 1725-1824, excluding General Reception period (1756-60).

	Infants at risk at start of interval (aged one day old)	Deaths in each age interval		
		1-3 days	4-14 days	15-27 days
Period				
1725-29	107	5	24	13
1730-39	114	4	26	20
1740-49	348	22	87	46
1750-55	118	3	16	10
1761-69	197	3	29	13
1770-79	426	9	64	34
1780-89	436	10	40	33
1790-99	284	5	14	8
1800-09	215	2	9	3
1810-24	471	6	14	7
Total	2716	69	323	187
Male	1397	36	195	84
Female	1319	33	128	103
Maternal age				
<20	200	8	29	6
20-24	955	22	121	75
25-34	1252	34	136	91
35+	308	5	37	14
Legitimacy status (1752-1824)				
Legitimate	489	7	24	21
Illegitimate	1374	22	128	73
Legitimacy status unknown	234	7	29	7
Season of birth				
Winter	778	27	101	50
Spring	747	20	84	57
Summer	565	7	60	38
Autumn	626	15	78	42
Twins	65	16	17	8
Born in a labour ward	1920	31	165	92
Born 1783+	1271	20	65	38
Born in a labour ward 1783+	1245	16	62	35

Mother admitted in labour	930	31	110	67
Infants experiencing maternal death by end of interval		4	36	25

Table 2. Cox regression analyses of neonatal mortality, 1725-1824, excluding General Reception period (1756-60).[1]

	Hazard relative to base category[2]					
	1-3 days		4-14 days		15-27 days	
Independent variable (base category in brackets)	univariate	multivariate	univariate	multivariate	univariate	multivariate
Number at risk	2716		2641		2254	
Number of deaths in interval	69		323		187	
Maternal age (20-24)						
<20	1.76	**2.50***	1.17	1.31	**0.38***	**0.38***
25-34	1.18	1.11	0.86	0.80(*)	0.93	0.81
35+	0.70	0.68	0.94	0.82	0.59(*)	**0.45****
Mother dead by end of interval (no)						
yes	[3]	[3]	**7.71*****	**5.39***	**2.94*****	2.16(*)
In labour at admission (no)						
yes	1.57(*)	1.47	1.01	0.91	1.18	1.03
Multiple births (singleton)						
twin	**13.09*****	**14.22*****	**3.42*****	**3.12*****	**3.72*****	**3.93****
Infant sex (male)						
female	0.97	0.99	**0.68****	**0.71****	1.24	1.22
Ward type (mixed)						
labour ward	**0.33*****	0.77	**0.39*****	1.05	**0.30*****	0.81
Born 1783+ (relative to <1783)	**0.46****	**5.78***	**0.26*****	3.19(*)	**0.22*****	3.55(*)
Born 1783+ in labour ward		**0.10****		**0.30***		**0.16****

[1] Data were analysed using st commands in Stata 9.2. The proportionality assumption was tested by analysis of Schoenfeld residuals for multivariate models as a whole and for each variable.
[2] Statistical significance is indicated as P<0.1 (*); P<=0.05, *; P<0.01, **; P<0.001, ***
[3] The number of deaths was too small for analysis

Season of birth (winter)						
spring	0.77	0.90	0.86	0.93	1.18	1.29
summer	**0.35***	**0.40***	0.78	0.78	1.02	1.01
autumn	0.69	0.70	0.95	0.94	1.01	0.88
crowding	1.012	0.991	**1.014****	1.002	**1.021*****	**1.024****
Period (1810-24)						
1725-29	3.72*	1.41	**8.67*****	**9.01*****	**12.28*****	**7.52****
1730-39	2.78	2.05	**8.64*****	**8.18*****	**17.33*****	**6.83****
1740-49	5.07***	3.01	**10.02*****	**10.02*****	**14.52*****	**6.87****
1750-56	2.02	1.34	**5.00*****	**4.94****	**7.79*****	**5.56****
1761-69	1.20	0.66	**5.34*****	**5.74*****	**5.52*****	**4.83****
1770-79	1.66	1.26	**5.46*****	**5.77*****	**6.77*****	**3.52***
1780-89	1.82	1.74	**3.24*****	**3.19****	**5.89*****	**3.70****
1790-99	1.38	1.40	1.68	1.82	1.93	2.34
1800-09	0.73	0.92	1.42	1.61	0.94	1.28

Statistical significance is indicated as P<0.1 (*); P<=0.05, *; P<0.01, **; P<0.001, ***

Table 3. Cox regression analyses of neonatal mortality, 1752-1824, excluding General Reception period (1756-60).[4]

	Hazard relative to base category[5]					
	1-3 days		4-14 days		15-27 days	
Independent variable (base category in brackets)	univariate	multivariate	univariate	multivariate	univariate	multivariate
Number at risk	2097		2056		1830	
Number of deaths in interval	36		181		101	
Maternal age (20-24)						
<20	1.71	2.15	1.25	1.37	0.72	0.75
25-34	1.32	0.94	0.86	0.87	1.34	1.33
35+	0.94	0.74	0.66	0.68	0.95	0.95
Legitimacy (legitimate)[6]						
illegitimate	1.11	1.08	**1.93****	**1.89****	1.19	1.30
unknown	2.02	1.87	**2.53****	**2.88****	0.79	0.72
Mother dead by end of interval (no)						
yes	[7]	[7]	**8.39*****	**6.30*****	**5.83*****	**5.72*****
In labour at admission (no)						
yes	1.68	**2.23***	1.09	1.11	0.91	0.93
Multiple births (singleton)						
twin	**20.67*****	**26.75*****	**5.03*****	**4.68*****	**3.91****	**4.66****
Infant sex (male)						
female	0.94	1.03	**0.62****	**0.61****	1.06	1.01

[4] Data were analysed using st functions in Stata 9.2. The proportionality assumption was tested by analysis of Schoenfeld residuals for multivariate models as a whole and for each variable.
[5] Statistical significance is indicated as P<0.1 (*); P<=0.05, *; P<0.01, **; P<0.001, ***
[6] Variables for interactions of legitimacy status with maternal age, season of birth, and entering the workhouse in labour, were tested for inclusion in multivariate models, but neither type of interaction was significant or improved model fits.
[7] The number of deaths was too small for analysis

Ward type (mixed)						
labour ward	0.59	1.66	**0.40*** **	0.74	**0.47** **	0.88
Born 1783+ (relative to <1783)	0.81	7.11(*)	**0.35*** **	2.00	**0.33*** **	**4.42***
Born 1783+ in labour ward		**0.05** **		0.44		**0.13** **
Season of birth (winter)						
spring	0.86	1.10	0.99	1.04	**1.76***	**1.71***
summer	0.60	0.86	0.81	0.94	0.99	0.94
autumn	0.46	0.68	0.94	0.99	1.19	1.06
crowding	1.025(*)	1.004	1.007	0.999	1.007	1.015
Period (1810-24)						
1752-55	1.16	1.17	**5.99*** **	**3.87***	**3.86***	2.69
1761-69	1.20	0.51	**5.34*** **	**4.13** **	**5.52*** **	**4.57***
1770-79	1.66	0.83	**5.46*** **	**5.20*** **	**6.77*** **	**3.81***
1780-89	1.82	1.24	**3.24*** **	**3.02** **	**5.89*** **	**4.25** **
1790-99	1.38	1.28	1.68	1.72	1.93	2.40
1800-09	0.73	1.29	1.42	1.73	0.94	1.12