Mortality selection in the first three months of life and survival in the following thirty-three months in rural Veneto (North-East Italy) from 1816 to 1835

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Abstract

BACKGROUND

A number of studies have examined the influence of life conditions in infancy (and pregnancy) on mortality risks in adulthood or old age. For those individuals who survived difficult life conditions, some scholars have found a prevalence of *positive selection* (relatively low mortality within the population), while others have observed the prevalence of a so-called *scar-effect* (relatively high mortality within the population).

OBJECTIVE

Using micro-data characterized by broad internal mortality differences before the demographic transition (forty-three parishes within the region of Veneto, North-East Italy, 1816-35), we aim to understand whether children who survived high mortality risks during the first three months of life (early infant mortality) had a *higher or a lower* probability of surviving during the following 33 months (late infant mortality).

METHODS

Using a Cox regression, we model the risk of dying during the period of 3-35 months of age, considering mortality level survived at age 0-2 months of age as the main explanatory variable.

RESULTS

We show that *positive selection prevailed*. For cohorts who survived very severe early mortality selection ($q_{0\text{-}2}$ > 400‰, where the subscripts are months of age), the risk of dying was 20-30% lower compared to the cohorts where early mortality selection was relatively small ($q_{0\text{-}2}$ < 200‰).

CONCLUSIONS

This result points to a homeostatic mechanism: mortality variability among the q0-35 cohorts is half that of the mortality variability for both $q_{0\text{-}2}$ and $q_{0\text{-}35}$.

Introduction

The issue examined in this paper can broadly be described as follows:

Many period-specific influences during life may affect mortality at a later stage, although it is often unclear which direction the resulting influence will take. For example, epidemic experiences or conditions of famine early in life may so debilitate a cohort that it subsequently experiences higher death rates relative to earlier or later cohorts. Others, however, argue that high mortality experienced in early life selects out the frail members of the cohort, resulting in reduced subsequent mortality (Hobcraft and Gilks 1984, p. 264, quoted in Billari and Rosina 2000, p. 2015).

While the two effects may coexist within the same situation, we can only measure the final balance within a population (Preston *et al.* 1998; Quaranta 2013). A number of papers attribute the influence of life conditions in infancy (and pregnancy) on mortality risks during adulthood or old age; while some authors find a prevalence of insult accumulation, others observe positive selection.[1] If the events experienced in uterus and during the first years of life influence mortality risks many years later, the same dynamic could be present, and perhaps even stronger, between contiguous periods. We study the effect of mortality selection during the first three months of life (from here on *early infant mortality*) on mortality in the 33 months that followed (from here on *late infant mortality*). We aim to understand whether children who survived strong mortality risk during the first three months of life were 'positively selected' (i.e. they had a *higher* probability of surviving during the following 33 months) or, if rather they experienced a so-called scar-effect, i.e. a process of insult accumulation prevailed such that they had a *lower* probability of surviving during the following 33 months.[2]

We consider children born in Veneto (North-East Italy), using micro-data from the archives of forty-three parishes for the period 1816-35, before the decline in mortality which characterized the demographic transition. The old demographic regime in Veneto provides an excellent context for studying this issue in that, as we will see below, there were considerable differences in early infant mortality, both across different areas of the region and espescially across seasons. This intense variability makes it possible to identify, in detail, the possible influence of early infant mortality on mortality during the following 33 months.

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[1] See e.g. Caselli and Capocaccia 1989; Kannisto *et al.* 1997; Preston et al. 1998; Bengtsson and Lindström 2000, 2003; Doblhammer 2004; Shkolnikov 2012; Ekamper *et al.* 2013; Quaranta 2013. See also Bruckner *et al.* 2013, Helgertz and Bengtsson 2013, Shen and Zeng 2013 (papers presented at session 249 *Pathways to health: direct and indirect effects of early life conditions on later health,* at the IUSSP Conference of Busan, South Korea, on August 2013).

[2] In this paper we define *early infant mortality* as mortality risk during the first 3 months of life (age 0-2 months), and *late infant mortality* as mortality risk from the 4th to the 36th month of life (age 3-35 months). The idea is to focus on two age intervals that differ with regard to the causes of death: mortality after the 3rd month of life should only be slightly affected by birth shocks or endogenous weakness, and mainly by exogenous causes (Bourgeois-Pichat 1951). Data on causes of death written in the death registers of our data-base – even if rough, see footnote 9 – partially support the choice of using the end of the 3rd month as a breakpoint between early and late infant mortality: during the 4th month of life, two causes of death strongly related to birth ('spasm' and 'asthenia') drop to 39% of deaths compared to 62% for children who died during the 1st month, 64% in the 2nd month, and 59% in the 3rd month. We do not consider children who died over the age of 3 because – as we describe in the data section – the mechanism of linking birth and death records becomes more uncertain as age at death increases.

The idea of examining the connections between early and late infant mortality builds on our previous research. Dalla-Zuanna and Rossi (2010), using aggregate data on the mortality of children within the 19 regions of the Austro-Hungarian Empire for the cohort born in 1851 show that in the *Lander* where mortality was high in the first three months of life there was relatively low mortality in the successive periods. Up until the 36th month of life, the association between q_{0-2} and q_{3-35} (where the subscripts are months, as elsewhere in this article) was negative, albeit moderate (r = – 0.35), see figure 1. In the Habsburg Empire of the mid-1800s, there was a kind of compensation between early infant mortality and mortality in the following months, what we describe as the prevalence of *positive* selection. In this work we are going to similarly assess whether such an effect exists within a smaller territory, studied with a much greater degree of detail thanks to the availability of individual data.

Theoretical background and previous results

The issue of selection has already attracted the attention of scholars from various fields of study. When thinking about selection, it is impossible not to refer to Charles Darwin and his theory of evolution. In Darwin's theory, natural selection certainly plays a fundamental role. Yet a further reading of Darwin suggests that his idea of natural selection also included more than mortality. Mortality selection is indeed a specific case of natural selection; it is a directional positive selection that favours "the fittest" (Endler 1986), i.e. people with the strongest probability of surviving. The selectionist argument, according to Peters (1991), is a logical truth and not a scientific theory *per se.* It is a very general concept that has been employed by different disciplines, from economics to epistemology. Demographers might very well benefit from knowledge gained by developments in sciences like biology and biomedicine. For example, Carey (1997) aimed to demonstrate the broad relevance of actuarial studies on Mediterranean fruit flies (medflies) to issues pertaining to humans. In turn, a number of researchers have used demographic selection arguments, with contrasting results, to explain the levelling-off of medfly mortality (Carey *et al.* 1995).

In population studies, the notion of selection is often evoked to explain the demographic behaviour of migrant populations. For example, it has been suggested that low levels of mortality among migrants are the result of individuals who migrate being healthier and stronger compared to both those who did not emigrate and natives (the so called 'healthy migrant effect', see e.g. McDonald and Kennedy 2004; Kennedy *et al.* 2006). A similar selection effect has been used to explain the marital and reproductive behaviour of immigrant couples and women (Goldstein and Goldstein 1983; Chattopadhyay *et al.* 2006).

With regard to mortality analyses, however, things are quite different in that selection is not determined by an external event, as with migration, but by the same processes of elimination that apply to death. Demographers most often employ a selectionist approach to theories on ageing. As a population ages it simply becomes increasingly positively 'selected', as individuals with higher risk of death die sooner. The result is a population formed mostly by individuals with relatively low death rates (Carey and Liedo 1995a; Vaupel and Carey 1993; Vaupel, Manton and Stallard 1979). When focusing on the older age groups, this concept helps to explain deviation of the human mortality trajectory from the well-known Gompertz function (Manton and Stallard 1996). Due to positive selection, the increase in mortality rates at older ages is slower than the 8-10% per year observed in middle age.

Both the demographic and biological approaches share at least one common point when employing the notion of selection. If two identically heterogeneous populations have different levels of mortality, then changes in the mortality trajectory related to selection will occur at younger ages in the population with higher mortality, *ceteris paribus* (Carey 1997). Another example of positive selection has been observed for Swedish cohorts born during the 20th century: the risk of ischemic heart disease mortality during cold periods drops among children who were in uterus during a particularly cold period (Bruckner *et al.* 2013). Positive selection has also been observed with regard to significant crises in mortality: the few available case studies on mortality before and after the plague epidemics that swept through Europe between the 14th and the 18th centuries verify this result. Following these plagues, people who survived epidemic outbreaks would have enjoyed higher survival rates than those before the plagues, although said results are somewhat controversial (Biraben 1975-76; Del Panta 1980; Billari and Rosina 1998, 2000; Alfani 2010). It is, in fact, difficult to discern whether the plagues swept away the weakest or if, alternatively, the smaller surviving populations (which may have been as much as 30-50% less than before the plagues) relaxed Malthusian pressure, thanks to a higher ratio between resources and population. The lack of data, specifically on population during the centuries of plague in Europe, hinders further unraveling of the issue.

Other studies have shown the prevalence of the opposite effect: cohorts who survived serious mortality crises during the early years of life were also weaker later in life when compared to cohorts slightly younger or older. For example, a process of insult accumulation occurred in Italy for male cohorts born in 1880-99 who survived World War I: their mortality in adulthood and old age was slightly higher than that of their elder and younger 'brothers'; a consequence of diseases contracted during the war itself (Caselli and Capocaccia 1989; Caselli 1990). In southern Sweden during the 18th and 19th centuries, children who survived severe epidemics of smallpox or whooping cough, and severe nutritional stress, suffered higher levels of mortality as adults and in old age, particularly relative to airborne infectious diseases (Bengtsson and Lindström, 2000; 2003).

The same occurred with regard to Swedes born between 1912 and 1915 affected by the Spanish flu: exposure to the latter in the first years of life negatively affected both economic outcomes and health in old age. Health is also directly affected (not only indirectly via income and socio-economic position) (Helgertz and Bengtsson 2013, Quaranta 2013), and it has a long follow-up period, up to 70 years of age for cohorts born in Sweden during the 19th and the early 20th centuries. Quaranta (2013) finds positive selection for male birth cohorts suffering from high infant mortality, from age one up to about age 30, after which the scar-effect is greater than the selection effect. An increase of 12% in all causes of death between the ages of 18-63 was observed in Western Netherlands among people born in 1944-45, whose mothers were affected by the Great Famine during the first half of gestation compared with those whose mothers were not so affected. This difference is considerable, and is greater compared to individuals whose fathers were employed in manual vs. non-manual occupations (+8% for manual), and is independent of social class and education at age 18 (Ekamper *et al.* 2013). A similar dynamic also holds true for the cohorts most severely affected by the Great Famine of the 1930s or by World War II in Ukraine (Shkolnikov 2012). Other studies do not, however, show adult mortality differences between cohorts affected or not affected by famine during childhood (Kannisto *et al.* 1997).

The scar-effect has also been observed in China, among individuals born in the first half of the 20th century. The total negative effect of adverse childhood conditions on current health is more prominent among the most elderly (aged 80+ in 2008-09) compared to those who are slightly younger (aged 65-79, Shen and Zeng 2013).

Data

We use unpublished nominal data drawn from 19th century parish archives which are part of the IMAV project (Infant Mortality in Asburgical Veneto) based at the University of Padua's

Department of Statistical Sciences. The aim of the project is to collect historical data that will aid in disentangling the main dynamics of the very high infant mortality that characterized the Veneto region during the Austrian Empire (1816-66) (Derosas 2009; Dalla-Zuanna and Rosina 2011). During the 19th century, Veneto was divided into about 50 districts. In order to have a reliable statistical sample of each economic, social, and territorial context, the IMAV project is in the process of collecting data from at least one parish in each district of the Provinces of Venice, Padua, Treviso, Verona and Vicenza.

The data used in this paper come from the parochial archives of Colle Umberto, Bigolino, S. Martino, Selva, Asolo, Ormelle, Piavon, Monastier, Vedelago, S. Agnese, S. Lazzaro (Province of Treviso); S. Stino, S.Michele, Scorzè. Carpenedo, S.Pietro, S.Marco, Camponogara, Chioggia (Province of Venice); Onara, San Giorgio delle Pertiche, Eremitani, S. Sofia, Chiesanuova, Casalserugo, Valnogaredo and Faedo, Pontelongo, Pernumia, Urbana, Agna (Province of Padua); Valstagna, Valrovina, Thiene, Nove, S. Vito di Leguzzano, Lanzè e Settecà, Quargnenta, Arzignano, S. Pietro, Bosco e Nanto, Sarego (Province of Vicenza); Vestenanova and Caldiero (Province of Verona) – see figure 2. These forty-three parishes represent an extensive picture of the Veneto rural environment during the 19th century. In the period of 1816-66, approximately 152,000 children were born in these seven parishes, 62,000 of whom died at ages 0-5 years during the period 1816-70 (the role of parish priests as civil servants in filling out birth and death records continued during the years that followed the annexation of Veneto to the Kingdom of Italy in 1866 up until 1870).

From 1750-1840 the mortality of children in Veneto was extremely high, mainly due to mortality during the first month of life for children born during the winter[3]. During the eighty years that followed, mortality during the first year of life, and especially winter mortality during the first month, quickly declined (Dalla-Zuanna and Rosina 2011, see also figures 3 and 4). While scholars have examined the demographic history of Veneto between the last stages of the *ancient régime* and the demographic transition (Pozzi 1991; Derosas 2002; Rosina and Zannini 2004), the patterns of high mortality during the first month of life remain far from explained. That said, there are clear indications that the influence of cold external temperatures was decisive (Derosas 2009; Dalla-Zuanna and Rosina 2011).[4] The records employed here include birth and death registers filled out by the priests of each parish. These were then added to the 'traditional' registers of baptisms and burials as, during the Austrian Empire, priests were remunerated as civil servants, responsible for vital statistics.[5] Records from the birth registers include the following information:

- date of birth
- given name of the child
- given and family name of the mother and father

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[3] Levels of infant mortality equal to 350‰isuch as those recorded in Veneto in the century 1750-1850 are very high, even if not exceptional in Europe before the health transition. For example, mortality during the first year of life was 486□□(1862-70), 502 if not exceptional in Europe before the health transition. Augsburg, and 428ality during the first year of life was 486□□□□□in the village of Anhausen, belonging to the same district, according to the family reconstruction by Knodel (1968, table 3). However, the pattern of Bavarian parishes is not in line with the Veneto one, as mortality during the first month does not vary according to season (Knodel 1988, p. 62).

[4] According to regression models fitted by Dalla-Zuanna and Rosina (2011), a decrease of 1°C in the minimum external temperature during the winter corresponded to a 5% increase in the daily risk of death during the first month of life. The daily risk of death during the third and fourth days of life varied from 80‰ to 130‰ to 220‰ if the minimum external temperature varied respectively from +5°C to 0°C to –5°C.

[5] Church registers of baptisms from the mid-17th century on are widely available in the Catholic parishes of Veneto, while many burial registers can be found from the 18th century on, although in many parishes these registers date even further back (e.g. in the two parishes of Adria, see figure 2). Unlike the civil registers, the church records were not pre-printed, and as such are much more difficult to read. The data recorded in the ecclesiastical acts of baptism are quite similar to those recorded in the civil acts of birth. An important additional pieced of information contained in the civil acts is the date of the marriage, allowing us to identify children of the same parents without using the book of marriages, as would be necessary using only the church records. Moreover, the church records of baptisms do not- of course - report children who were not baptized (e.g. stillborns), as was the case instead for the civil registers. The information contained in the civil registers of death are also quite similar to those observed in the ecclesiastical burial records, although in the former cause of death is recorded in a much more systematic – although not complete – way.

- jobs of the mother and the father
- date of wedding
- date of the child's baptism.

Records from the death registers include:

- date of death
- given name of the child
- given and family name of the mother and father
- jobs of the deceased (or father for young children)
- place of birth
- age at death
- cause of death.

These registers were frequently checked by civil authorities (which was not the case for traditional ecclesiastic baptism and burial registers). They are very easy to use for demographic purposes as they are pre-printed and completed in a standardized way. We have linked birth certificates to death certificates for children born in the same parish who died at age 5 or younger, using as linkage keys: name and surname of the child, name of the father and name and surname of the mother. The linkage was facilitated by the availability of information on the children's age at death, as registered by priests; exact age was, however, ultimately calculated by matching the age at birth and death using Day Century Coding, or counting the number of days since January 1st, 1800 (Willekens 2013).

Pooling the forty-three parishes, more than 92% of children born in the same parish who died at age 5 or younger have been linked to their birth certificate (table 1).[6] The linkage performance is

[6] The no-linkage rate – which, as shown in Table 1, varies across the seven parishes – may depend on several factors: the accuracy of the parish priests in recording the events and the writing of the pastors themselves, but also the level of migratory exchanges of each parish. In fact, while our linkage procedure refers only to the deaths of babies born in the

even greater for children who died before their 3rd birthday. When it was not possible to find the corresponding birth certificate for a death certificate of children believed not to be born in the parish after 1816, we 'generated' a birth record. More specifically, we indicated the date of birth starting from the age at death indicated by the priest on the death certificate. Using this system, we face a source of underestimation of mortality. The generated birth records make-up 3.08% of the total number of births, with some differences among parishes (see table 1).[7]

Mortality could also be underestimated due to systematic under-reporting of those children who died shortly after birth, as observed in other Italian and European contexts in similar or slightly earlier periods (see e.g. Dalla-Zuanna et al. 2003; Dalla-Zuanna and Rossi 2010). However, in our parishes the deaths of these children were seemingly recorded with a good level of accuracy, as our data are consistent with that observed in situations where data quality is considered good. Within our sample (limited to 1816-35, see below), 4.1% of the children are classified as having died within the first day of life; among this group, at least half could be stillborn as 52% are nameless on the birth record (when it exists) and death record, while in 40% of cases the date of baptism is not reported on the birth record.

As a result, both the stillbirth rate and mortality rate within the first day of life in the parishes considered here could be around 2-3%, compatible with that suggested by Woods (2009) for the pre-transition health period. In addition, a 5% probability of death in the first day of life in the period 1750-1810 was recorded for the sample of parishes used by the Cambridge Group in the reconstruction of the British population; as in our sample, stillbirths are included among the dead in

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same parish, migration may have triggered more intense errors and potentially additional omissions (see the last column of Table 1 and the final part of this section).

7 This procedure is similar to that used by Schofield and Wrigley (1979, p. 80, note 14) in reconstructing mortality in England during the 16th and 17th centuries through linking baptism and burial records. To avoid underestimating early mortality, they create 'dummy births', i.e. children found in the burial registers who died in the first days of life 'which cannot be linked to preceding baptisms, but clearly belong to a given family'. Compared to the method used by Wrigley and Schofield, our approach may seem overly simplistic. However, it should be noted that the generated birth-records refer only to children who died in the first few years of life for whom it is indicated, such as place of birth, the same parish in which they died. Consequently, our procedure – while perhaps causing a slight increase in the number of births due to a birth-record potentially already being present in the file – allows us to avoid underestimating child mortality.

the first day of life (Wrigley et al. 1997; Davenport 2010). In his analytical reconstruction of the population history of three Bavarian village, Knodel (1970) found 2% stillbirths during 1800-49 while Oris, Derosas and Breschi (2004, p. 362) show that during the 18th and 19th centuries, the proportion of stillbirths was higher in protestant than in catholic contexts, suggesting that in the latter, 'false live births' (i.e. stillbirths baptized as live births in order to allow the baptism to take place) were more diffused. We cannot, of course, know for certain the "true" values for stillbirths and mortality in the first day of life in the Veneto region in the early 19th century. However, it seems difficult to imagine dramatic underreporting in our data.[8]

Finally our measures of mortality, which refer to the cohort[9] born within a parish, could be underestimated due to emigration, as some of the children born in the parishes considered here could have died (at age 0-2 years) in other parishes, following the emigration of their parents. If for families with very young children, emigrations were similar in number to immigrations, it is possible that our measures of mortality are underestimated, and that these underestimations are

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8 In the days following the first day of life, mortality in 1816-35 in the 43 parishes under observation was very high (second day= 15‰; third day= 19‰; fourth day=19‰; fifth day=16‰; sixth day=15‰; seventh day=16‰): the probability of dying between the 2nd and 7th day of life was 96‰, more than three times higher than that observed in the aforementioned sample of English parishes (28‰) – Dalla-Zuanna and Rosina 2011. Neonatal mortality was even much higher than that observed at the end of the 20th century in the poorest countries of the world, where the probability of dying in the first week of life (including the first day) was never higher than 45‰ (Hill and Choi 2006), not far from that observed in some Indian context around 1970, but only for children with a weight at birth of 1500-2000 grams (Visaria 1988, p. 104). However, levels similar to that of Veneto were found in other European pre-transitional contexts. For example, in the above cited family reconstruction of several Bavarian villages (note 3), Knodel (1988, p. 48) finds that neonatal mortality (during the first month) ranged between 67‰ and 190‰; Goubert (1968) finds the level of neonatal mortality to be nearly 150‰ in some 18th century French rural villages, 50% higher than that observed in the white population of Quebec during 1621-1729 (Lalou 1997, p. 205), For additional reviews and comparisons see also Oris, Derosas and Breschi 2004; Pozzi and Barona 2012. These high levels of mortality at ages 1-6 days might suggest an underestimation of mortality in the first day of life. However, since the 'discrepancy' between the first day and the following is observed only in the winter, and because – as illustrated in figure 4 – said 'discrepancy' is observed only for the period of 1750 to 1850, our data could very well portray the true situation, i.e. 'abnormal' levels of mortality during the first week of life for children born during the cold season, with the exception of the first day. Finally, Dalla-Zuanna and Rossi (2010) – comparing the mortality of children in the 19 regions of the Austro-Hungarian Empire for the newborns of 1851 – show that in the (now) Italian and Austrian regions the under-registrations of early deaths in birth and death registers (if present) were clearly much lower level than in Hungary and the Slavic *Lander*.

9 The word 'cohort' is commonly used in demography to identify people who experienced the same demographic event within the same time-span (e.g. children born in the year t, marriages celebrated in the year t). In this article, 'cohort' is used in a broader sense, to identify children with identical characteristics at birth (e.g. newborns in the parish of Agna in the winter of years 1816-20; newborns in the parish of San Giorgio delle Pertiche in July of year 1832).

greater where exchanges were more intense or lower where exchanges were less intense. This issue should not, however, greatly affect our research goals in that said underestimation should be similar, in relative terms, when and where early infant mortality was higher or lower.

Preliminary results and methodological choices

Figure 5 shows that the death probabilities q_{0-2}, q_{3-35} and q_{0-35} in the pool of forty-three parishes are relatively constant until 1840 and then decline in the years that follow. As our aim is to study selection before the decline in mortality, we include only the 57,586 children born during 1816-35 in our analysis.[10]

The crucial point is to find the 'key covariate', or the variable that describes the mortality level during the first three months of life, that can in turn be used to 'explain' the mortality risk of children who survived. Previous studies on the impact of temperature and climatic conditions on health reveal that winter mortality in Veneto was clearly higher than summer mortality, mainly during the early stages of life (Breschi *et al.* 2000; Dalla-Zuanna and Rosina 2011). In our sample as well, children born in the cold seasons were exposed to greater risk of death during the first month of life (table 2 and figure 6). Season of birth could thus be considered a proxy variable for early infant mortality risk.

Figure 7 shows the probabilities of death within 3-months periods for the ages 3-35 months, pooling the forty-three parishes, according to season of birth (summer vs. winter). The shape of the

[10] In what follows we provide some additional information on data quality for the 57,586 children born in the seven parishes during 1816-35. The M/F sex-ratio at birth is 1.07, i.e. a value fully consistent with the sex-ratio observed broadly for humankind. For 6.3% of the children was not it possible to discern the job of the father (47.7% farmer, 23.3% craftsman or belonging to the working class, 7.9% merchant, 1.7% servant, 12.4% employee, civil servant or land owner). Cause of death was reported in 90% of the death records: this proportion grows notably with age. Moreover, causes are often confused with symptoms, as was common in death records dating to the 19th century.

two graphs is similar, dropping from month 3 to month 35 and peaking in the summer and autumn (mainly due to gastro-intestinal diseases). The general level of mortality during 3-35 months of age is, however, higher for children born in the summer, who survived a lower neonatal death risk compared to children born in the winter, who instead survived a higher neonatal death risk.

While informative, the use of seasons is complicated by a scarcity of precise information on several aspects described in the literature as determinant in the definition of neonatal mortality in Veneto. A second option is thus the use of a more specific variable that combines season of birth with year of birth and parish of birth. These last two elements have in fact previously been shown to be relevant in the definition of mortality risk in Veneto (Dalla-Zuanna and Rosina 2011). We therefore decided to assign to each individual who survived the first three months the early infant mortality of his/her specific cohort. This designation was carried out in two different ways. First, we calculated 688 different levels of early infant mortality, provided by the combination of 4 seasons at birth, 4 groups of five-year intervals at birth, and 43 parishes of birth. Rates of mortality in the first three months of life range from 822‰ (cohort of children born during the winter in the years 1816-20 in the parish of Bigolino) to 54‰ (cohort of children born during the summer in the years 1831-35 in the parish of Piavon). The scattergram between early and late infant mortality for these 688 cohorts is shown in figure 8. Finally, the 688 cohorts are pooled according to 4 increasing levels of early infant mortality, and figure 9 shows a clear bivariate inverse association between early and late infant mortality.

Using five-year intervals, parish and season may not be a precise enough measure to identify the specific environment a child experienced during his/her first three months of life. Early infant mortality could, for any number of reasons, vary from year to year or month to month, especially due to climate micro-oscillation. However, the number of children born in each year/season/parish is not large enough to calculate a stable measure of early infant mortality for smaller cohorts. To overcome this problem, we estimated the 10,320 early infant mortality probabilities (12 months at birth, 20 years at birth, 43 parishes of birth) using the following logit regression model:

$$q_{0\text{-}2} = \frac{\exp(\beta_0 + \beta_1 * feb + \ldots + \beta_{11} * dec + \beta_{12} * 1817 + \ldots + \beta_{30} * 1835 + \beta_{31} * SGdP + \ldots + \beta_{36} * Monast)}{1 + \exp(\beta_0 + \beta_1 * feb + \ldots + \beta_{11} * dec + \beta_{12} * 1817 + \ldots + \beta_{30} * 1835 + \beta_{31} * SGdP + \ldots + \beta_{36} * Monast)}$$

Where *feb* and *dec* are months, *1817* and *1835* are years, *SGdP* and *Monast* are the two parishes of San Giorgio delle Pertiche and Monastier; the month of January, the year 1816 and the parish of Agna are the baseline.

The results range from 739‰ (cohort of children born in January of 1817 in the parish of Agna) to 42‰ (cohort of children born in July of 1822 in the parish of Piavon) and potentially provide a more detailed and complete picture compared to using only a 'rough' measure of early infant mortality for a five-year interval.

We assigned the 'key covariates' to children who survived the first three months of life, together with several other variables from our dataset that may 'explain', at least partially, late infant mortality differences. In accordance with the literature – and given the preliminary results in table 2 – we do not expect to observe large differences between the sexes in terms of late infant mortality. We similarly do not expect to see considerable differences in late infant mortality in the five-year intervals from 1816-20 to 1831-35, as the downward trend in late infant mortality had yet to begin (see Figure 5). We expect, however, that late infant mortality changes according to parish of birth. Moreover, we expect that late infant mortality is higher during the summer, as suggested in Figure 6.

Our aim is to verify whether children who survived a context of high early infant mortality had lower or higher mortality in the following 33 months. As children who died during the months 3-35 are censored, one way to assess this question is a semi-parametric Cox regression, which provides the monthly risk of death as a response variable, controlling for the elimination process (see e.g. Bruckner *et al.* 2013; Ekamper *et al.* 2013). We model the risk of death between the 4th and the 36th month of life for individuals still surviving at the end of their 3rd month, using the above described covariates as explanatory variables. Our explanatory variables do not vary over time, with the exception of month of life, which has instead been taken into consideration by transforming our database into a person-period format.[11]

Results

The covariates included in the first five models are simply indices of early infant mortality (see Table 3): season at birth (Model 1), calculated early infant mortality (Model 2), early infant mortality estimated by logit regression model (Model 3), season at birth and calculated early infant mortality (Model 4), and season at birth and estimated early infant mortality (Model 5). In Models 4 and 5 – when early infant mortality is included – the association between season at birth and late infant mortality disappears. In addition, as season at birth and early infant mortality are strongly interrelated, the latter prevails in these two models. The 'goodness of fit' for models 2 and 3 is better than the 'goodness of fit' for model 1 (where season of birth is the only covariate). In light of these results, in the following models the season at birth variable is not included and we perform two parallel analyses using calculated early infant mortality and estimated early infant mortality as separate measures of selection during the first three months of life.

[11] Each individual now has a number of rows which correspond to the number of months lived. The last row corresponds to the month in which the subject died or is censored. We have associated each row with the relative season. For example, an individual born in May (season: spring) of 1816 who lived for 6 months has six rows in this new database format. The second row, in particular, indicates that the individual was alive in June (season: summer) of the same year. Notably, the last row indicates that the subject died in October (season: autumn) of 1816. In this way, it is possible to account for a possible effect of the transition from one season to another on the risk of death between the 4th and the 36th month of life.

In order to determine whether selection during months 0-2 provides additional explanation of mortality at ages 3-35 months, we measure whether the statistical performance of a 'basic' model (including only parish, time period and sex) improves when early infant mortality is included as an explanatory variable.

In the basic model, the risk of death between the 4th and the 36th month of life is strongly related to parish, whereas sex and period do not influence the risk (Table 4, Model 6). When early infant mortality is added, the performance of the model improves: including the calculated early infant mortality (Model 7) sees the 'goodness of fit' (log-likelihood) rises by 14 (Chi^2=28, d.o.f.=3, p<0.001); including the estimated early infant mortality (Model 8) sees the 'goodness of fit' (log-likelihood) rises by 19 (Chi^2=38, d.o.f.=3, p<0.001). Summing up, the model improves when estimated early infant mortality is used. After including early infant mortality in the model, the rank of parishes does not change, showing that interaction between the two variables is weak.

Model 9 introduces the transition between seasons as a time-varying covariate: when using winter as the baseline, the risk of dying during months 3-35 of life is significantly higher when there is a transition to a warmer season (4.8% higher in the transition to summer compared to 1.2% in the transition to autumn), confirming the results of Figures 6, 7 and 9. This result is likely the outcome of the greater impact of gastro-enteric diseases during summer and autumn.[12]

[12] Cause of death is not always reported and is often confused with symptoms (see also footnote 8). However, by carefully examining death records at age 3-35 months, a cause of death likely identifiable as gastrointestinal disease is reported for 3,249 deaths (14.1% of total), with big seasonal differences (626 in winter, 977 in spring, 956 in summer, and 690 in autumn).

Conclusions

The key result of this paper is that mortality selection during months 0-2 may have played a significant role in determining differences in mortality during months 3-35 among cohorts born in forty-three Veneto parishes, in the period of 1816-35, i.e. before the start of the mortality decline which formed part of the demographic transition. For children that survived a severe early infant mortality selection (q_{0-2}>400‰, born mainly during winter), the hazard ratio of surviving the following 33 months was about 20% higher than that of children with relatively small early mortality selection (q_{0-2}<200‰, born mainly during summer). This result suggests a sort of homeostatic mechanism, as mortality differences among the cohorts are lower for q_{0-35} than for both q_{0-2} and q_{3-35}: in considering the 688 cohorts obtained by crossing 4 seasons at birth, 4 five-year groupings at birth, and 43 parishes of birth, we observe that the variation coefficient (σ/μ) is 0.53 for q_{0-2}, 0.54 for q_{3-35}, but only 0.31 for q_{0-35}.

These results are limited to the context of our study (Veneto in the early decades of the 19th century), characterized by very strong mortality during the first week/month of life (excluding the first day), mainly for children born during the cold season. As we mentioned at the beginning of this article, while a scar-effect could coexist with positive selection, one predominates in different contexts and/or at different stages of life (even within the same cohort, as shown by Quaranta (2013) for Sweden). More generally, our results indicate the possibility that differences between cohorts in mortality during a given interval of age could also be due to differences in selection for death, for the same cohorts, during the age interval which immediately preceded.

This work provides several novel elements for the interpretation of differences in late infant mortality before the demographic transition. Many questions, however, remain unanswered; some of which could be addressed through our database. First, it would be interesting to find a more refined model for considering the selection process. Given that the predominating causes of death during the first few days of life were clearly quite different from those more common in the weeks that followed (Bourgeois-Pichat 1951), and the fact that the database contains the exact day of birth and exact day of death, it could be possible to consider narrower time spans and to measure, for example, whether the intensity of selection during the first week had an effect on the risk of dying during the subsequent weeks or months. Second, in order to disentangle territorial and environmental differences in late infant mortality, future research should focus on the characteristics of the environment in which each child tried to survive after overcoming the 'sieve' of the first weeks or months of life. Third, the selection procedure could be tested across different social strata, using the job of the father as recorded on the birth and death records. Finally, it may be useful to more carefully consider the causes of death reported in the registers, especially for deaths occurring after the third month of life, so as to understand whether the higher mortality of children who were 'less selected' is due to any specific causes of death.

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Table 1. Number of birth and death records under age 5 in the forty-three parishes, and some indices of linkage performance

	total births (1816-66) (a)	created births (1816-66) (b)	deaths before the 5th birthday (1816-71) (c)	No linkage rate (%) (b/c)
TV - Colle Umberto	2,424	21	770	2.73
TV - Bigolino	2,016	30	866	3.46
TV - S.Martino	1,455	19	404	4.70
TV - Selva	2,891	57	1,182	4.82
TV - Asolo	1,811	83	728	11.40
TV - Ormelle	1,550	70	508	13.78
TV - Piavon	1,985	53	538	9.85
TV - Monastier	4,510	149	1,612	9.24
TV - Vedelago	1,662	39	844	4.62
TV - S.Agnese (city)	3,212	186	1,321	14.08
TV - S.Lazzaro (city)	1,292	29	460	6.30
VE - S.Stino	4,090	172	1,469	11.71
VE - S.Michele	1,985	39	861	4.53
VE - Scorze’	2,511	32	906	3.53
VE - Carpenedo	4,581	115	1,754	6.56
VE - S.Pietro (city)	16,444	399	7,022	5.68
VE - S.Marco (city)	5,571	479	1,992	24.05
VE - Camponogara	2,535	61	995	6.13
VE - Chioggia	4,091	202	1,400	14.43
PD - Onara	2,278	21	910	2.31
PD - S.Giorgio	2,707	145	1,130	12.83
PD - Eremitani (city)	3,965	280	2,062	13.58
PD - S.Sofia (city)	4,690	11	1,769	0.62
PD - Chiesanuova	3,201	63	1,289	4.89
PD - Casalserugo	2,354	15	1,096	1.37
PD - Valnog./Faedo	1,532	24	737	3.26
PD - Pontelongo	3,705	131	1,780	7.36
PD - Pernumia	4,609	136	2,070	6.57
PD - Urbana	2,202	17	973	1.75

PD - Agna	4,171	61	2,000	3.05
VI - Valstagna	5,508	96	1,904	5.04
VI - Valrovina	1,868	36	770	4.68
VI - Thiene	12,301	130	5,626	2.31
VI - Nove	3,758	159	1,771	8.98
VI - S.Vito	2,303	74	1,019	7.26
VI - Lanze' e Setteca'	1,531	108	726	14.88
VI - Quargnenta	1,521	12	557	2.15
VI - Arzignano	8,566	443	3,082	14.37
VI - S.Pietro (city)	2,602	185	1,164	15.89
VI - Bosco e Nanto	2,388	119	946	12.58
VI - Sarego	2,697	104	1,153	9.02
VR - Vestenanova	1,957	41	723	5.67
VR - Caldiero	3,180	39	1,058	3.69
TOTAL	**152,210**	**4685**	**61,947**	**7.56**

Table 2. Data on early and late infant mortality, according to select covariates. Children born in forty-three parishes in the region of Veneto during 1816-35

	Months 0-2		Months 3-35		Prob. of death	
	Exposed (a)	Dead (b)	Exposed (c=a-b)	Dead (d)	q0-2 (b/a)	q3-35 (d/c)
Season at birth						
Winter	14,623	6,367	8,256	1,461	435	177
Spring	16,183	3,214	12,969	2,433	199	188
Summer	14,216	2,199	12,017	2,412	155	201
Autumn	12,564	4,264	8,300	1,502	339	181
Early infant mortality (calculated)						
Low (<200‰)	23,368	3,332	20,036	3,866	143	193
Medium (200-300‰)	13,711	3,454	10,257	1,977	252	193
High (300–400‰)	8,925	3,035	5,890	1,076	340	183
Very high (>400‰)	11,582	6,223	5,359	889	537	166
Early infant mortality (estimated)						
Low (<200‰)	22,426	3,197	19,229	3,820	143	199
Medium (200-300‰)	11,840	2,632	9,208	1,666	222	181
High (300–400‰)	10,890	3,550	7,340	1,379	326	188
Very high (>400‰)	12,430	6,665	5,765	943	536	164
Sex						
Male	29,845	8,623	21,222	3,985	289	188
Female	27,741	7,421	20,320	3,823	268	188
Period						
1816-20	13,421	4,051	9,370	1,681	302	179
1821-25	15,343	4,092	11,251	1,899	267	169
1826-30	14,516	3,965	10,551	2,096	273	199
1831-35	14,306	3,936	10,370	2,132	275	206
Parish						
TV - Colle Umberto	931	186	745	84	200	113
TV - Bigolino	785	253	532	104	322	195
TV - S.Martino	653	127	526	62	194	118
TV - Selva	1,045	331	714	98	317	137

TV - Asolo	159	56	103	19	352	184
TV - Ormelle	582	169	413	45	290	109
TV - Piavon	659	88	571	75	134	131
TV - Monastier	1,641	366	1,275	222	223	174
TV - Vedelago	627	244	383	73	389	191
TV - S.Agnese (city)	1,182	309	873	217	261	249
TV - S.Lazzaro (city)	441	121	320	64	274	200
VE - S.Stino	1,444	263	1,181	158	182	134
VE - S.Michele	543	140	403	94	258	233
VE - Scorze'	915	193	722	131	211	181
VE - Carpenedo	1,582	312	1,270	298	197	235
VE - S.Pietro (city)	5,984	1,316	4,668	1,087	220	233
VE - S.Marco (city)	2,024	421	1,603	289	208	180
VE - Camponogara	988	291	697	133	295	191
VE - Chioggia	1,639	235	1,404	243	143	173
PD - Onara	856	284	572	120	332	210
PD - S.Giorgio	1,133	302	831	244	267	294
PD - Eremitani (city)	1,462	441	1,021	314	302	308
PD - S.Sofia (city)	2,012	462	1,550	267	230	172
PD - Chiesanuova	1,182	296	886	218	250	246
PD - Casalserugo	851	288	563	112	338	199
PD - Valnog./Faedo	661	265	396	76	401	192
PD - Pontelongo	1,412	465	947	234	329	247
PD - Pernumia	1,901	794	1,107	151	418	136
PD - Urbana	804	317	487	70	394	144
PD - Agna	1,583	687	896	148	434	165
VI - Valstagna	2,208	461	1,747	265	209	152
VI - Valrovina	640	165	475	86	258	181
VI - Thiene	5,257	1,951	3,306	558	371	169
VI - Nove	1,639	542	1,097	220	331	201
VI - S.Vito	963	381	582	73	396	125
VI - Lanze' e Setteca'	605	229	376	81	379	215
VI - Quargnenta	551	154	397	60	279	151
VI - Arzignano	3,268	905	2,363	297	277	126
VI - S.Pietro (city)	934	212	722	213	227	295

VI - Bosco e Nanto	903	288	615	99	319	161
VI - Sarego	1,024	349	675	123	341	182
VR - Vestenanova	766	160	606	115	209	190
VR - Caldiero	1,132	210	922	168	186	182
TOTAL	**57,586**	**16,044**	**41,542**	**7,808**	**279**	**188**

Table 3. The risk of dying between the 4th and the 36th month of life by season at birth and early infant mortality, calculated or estimated. Cox model for children born in forty-three parishes of the region of Veneto during 1816-35

	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
	HR	p-val	HR	p-val	HR	p-val	HR	p-val	HR	p-val
Season of birth										
Winter	1	-					1	-	1	-
Spring	1.070	0.04					1.023	0.58	0.990	0.81
Summer	1.151	0.00					1.104	0.03	1.049	0.27
Autumn	1.030	0.43					1.008	0.84	0.994	0.87
Early infant mortality (calculated)										
Low (<200)			1	-			1	-		
Medium (200-300)			1.000	0.99			1.035	0.27		
High (300-400)			0.940	0.07			0.989	0.79		
Very High (>400)			0.847	0.00			0.897	0.03		
Early infant mortality (estimated)										
Low (<200)					1	-			1	-
Medium (200-300)					0.902	0.00			0.911	0.00
High (300-400)					0.938	0.04			0.957	0.26
Very High (>400)					0.807	0.00			0.825	0.00
LL	-82240		-82239		-82230		-82234		-82228	
LR	21.6		23.61		40.33		32.32		44.71	
Prob>Chi^2	0.0001		0		0		0		0	

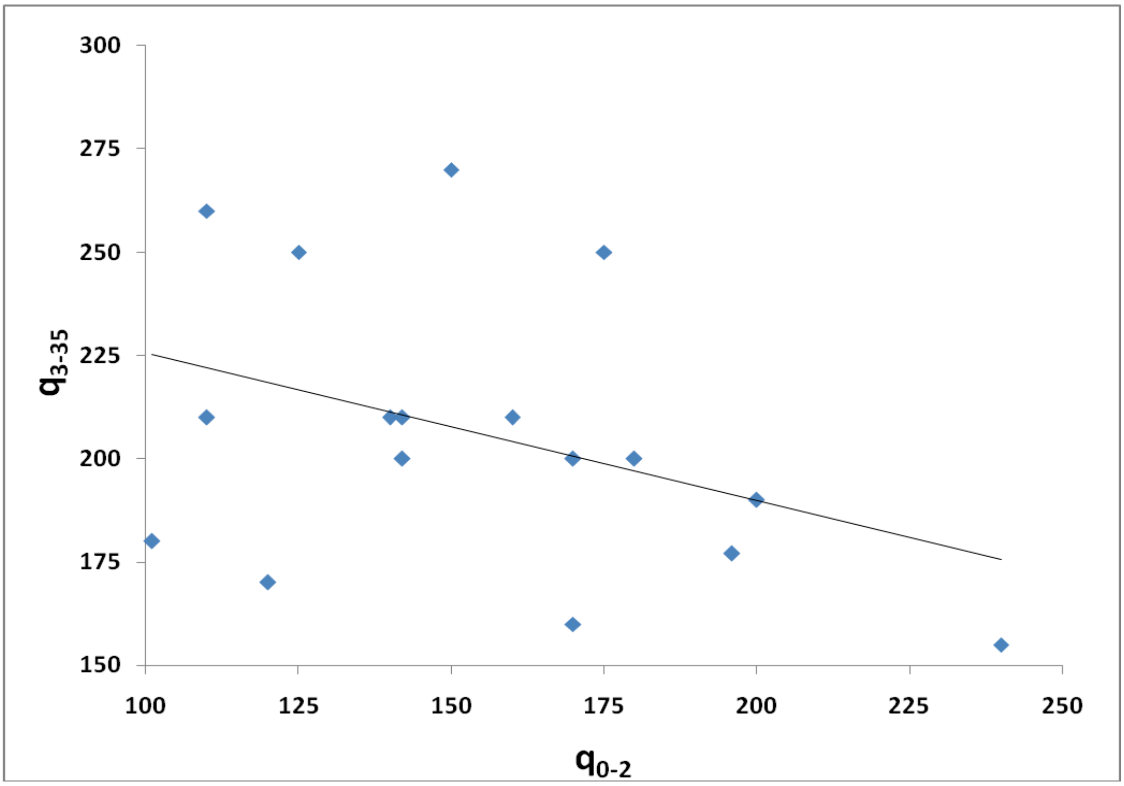
*HR: Hazard Ratio

Table 4. Covariates of the risk of dying between the 4th and the 36th month of life for children who survived the third month of life. Two complete models with early infant mortality calculated or estimated (7 and 8); one model with a time-varying covariate (9). Cox model for children born in forty-three parishes of the region of Veneto during 1816-35.

	MODEL 6		MODEL 7		MODEL 8		MODEL 9	
	HR	p-val	HR	p-val	HR	p-val	HR	p-val
Early infant mortality (calculated)								
Low (<200)			1	-				
Medium (200-300)			0.961	0.17				
High (300-400)			0.879	0.00				
Very High (>400)			0.837	0.00				
Early infant mortality (estimated)								
Low (<200)					1	-	1	-
Medium (200-300)					0.929	0.02	0.925	0.01
High (300-400)					0.923	0.01	0.919	0.01
Very High (>400)					0.791	0.00	0.788	0.00
Sex								
Male	1	-	1	-	1	-	1	-
Female	0.998	0.93	0.998	0.94	0.998	0.92	0.998	0.92
Period								
1816-20	1	-	1	-	1	-	1	-
1821-25	0.920	0.01	0.907	0.00	0.906	0.00	0.906	0.00
1826-30	1.098	0.00	1.084	0.01	1.085	0.01	1.085	0.01
1831-35	1.145	0.00	1.133	0.00	1.132	0.00	1.132	0.00
Parish								
PD - Agna	1	-	1	-	1	-	1	-
…								
TV - Colle Umberto	0.667	0.00	0.619	0.00	0.604	0.00	0.602	0.00
VE - S.Stino	0.799	0.05	0.732	0.01	0.724	0.01	0.721	0.01
VI - Valstagna	0.908	0.35	0.848	0.11	0.823	0.06	0.820	0.06

VR - Vestenanova	1.158	0.24	1.063	0.63	1.058	0.65	1.058	0.65
…								
Season transition (time varying)								
Winter							1	-
Spring							1.012	0.00
Summer							1.048	0.00
Autumn							1.012	0.00
LL	-81922		-81908		-81903		-81542	
LR	657.34		685.18		695.1		1475.69	
prob>Chi^2	0		0		0		0	

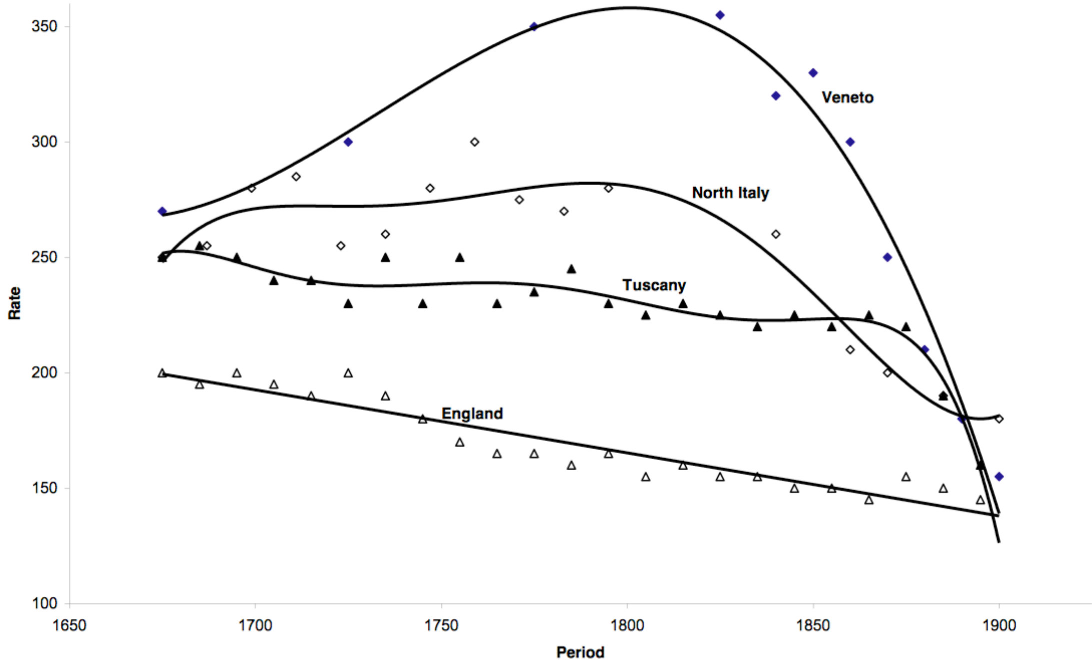
Figure 1. Probability of dying (‰) during months 0-2 and 3-35 in the nineteen Lander of the Austro-Hungarian Empire for the cohort born in 1851



Source: Dalla-Zuanna and Rossi 2010.

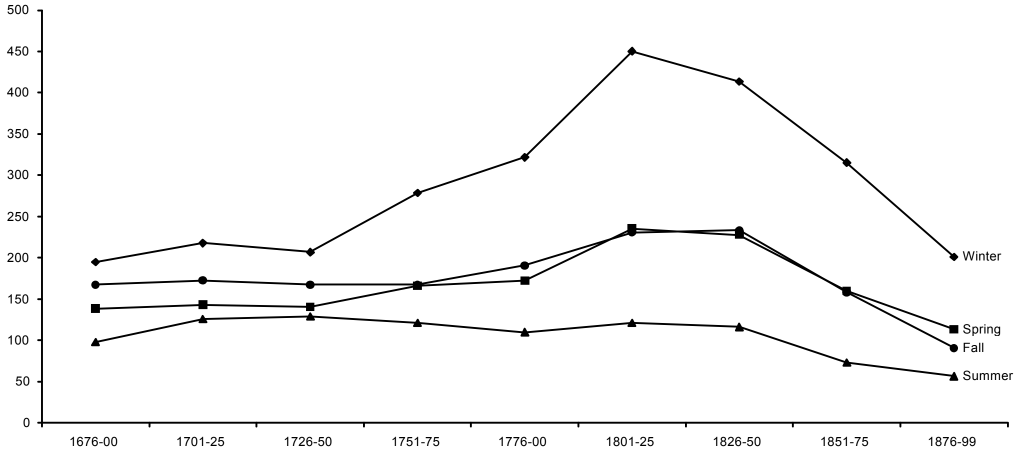
Figure 2. Location of the forty-three Veneto parishes considered in this study

Figure 3. Secular trends in mortality rates during the first year of life (‰) in some areas of Italy and in England, 1675-1900



Source: Dalla-Zuanna and Rosina 2011.

Figure 4. Probability of death (‰) during the first month of life by season of birth in the parish of Adria (in the province of Rovigo) in 1650-1900



Source: Dalla-Zuanna and Rosina 2011.

Figure 5. Annual probability of death at ages 0-2, 3-35, and 0-35 months (‰). Children born in forty-three parishes in the region of Veneto in 1816-68, and those dead in 1816-70

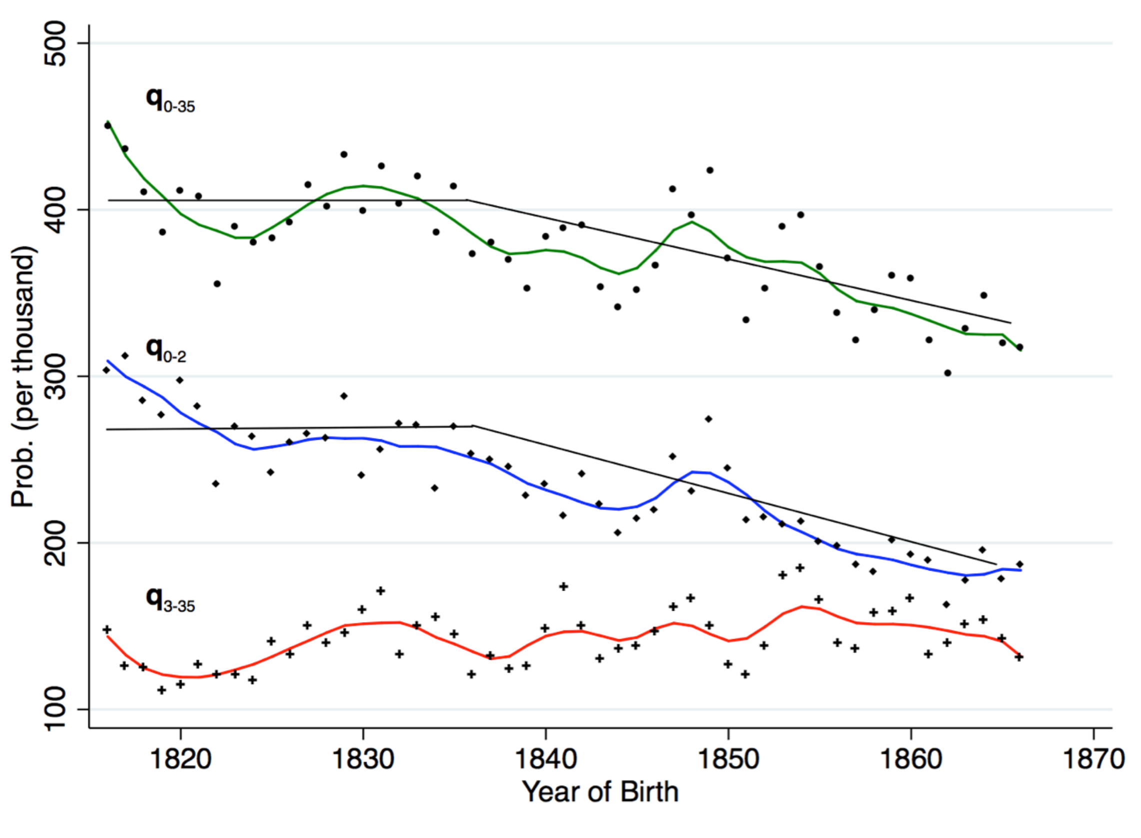


Figure 6. Early and late infant mortality (‰) by season of birth. Children born in forty-three parishes in the region of Veneto during 1816-35

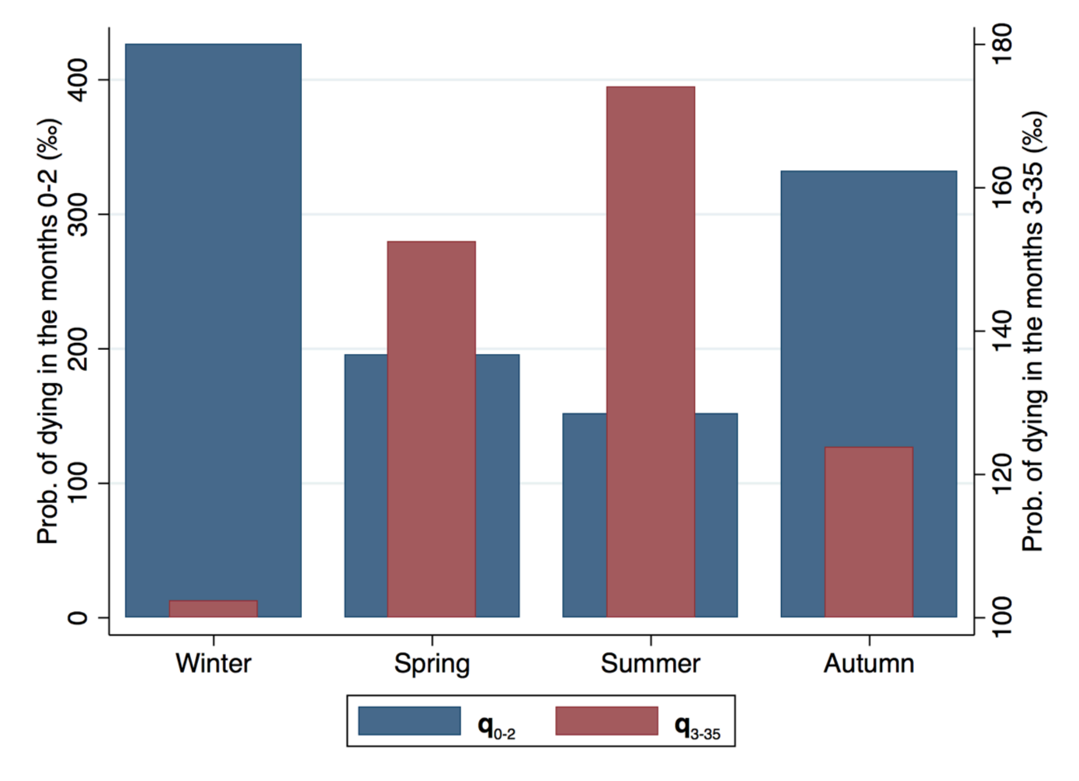


Figure 7. The probability of death within successive 3-month age groups for those aged 3-35 months. Children who survived the first three months of life, born during winter (Dec, Jan, Feb) and summer (Jun, Jul, Aug) in forty-three parishes in the region Veneto during 1816-35

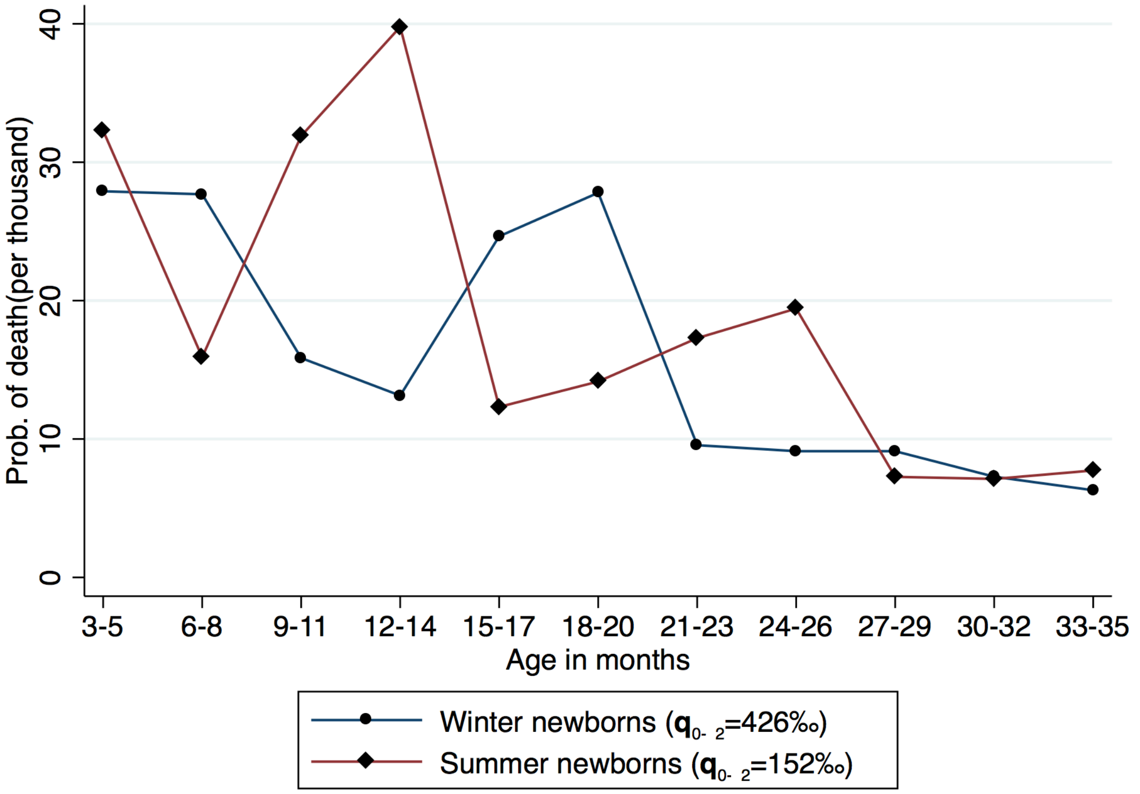


Figure 8. Early and late infant mortality for 688 cohorts provided by the combination of 4 seasons at birth, 4 groups of five-year cohorts at birth, and 43 parishes of birth. Children born in seven rural parishes of the region of Veneto during 1816-35

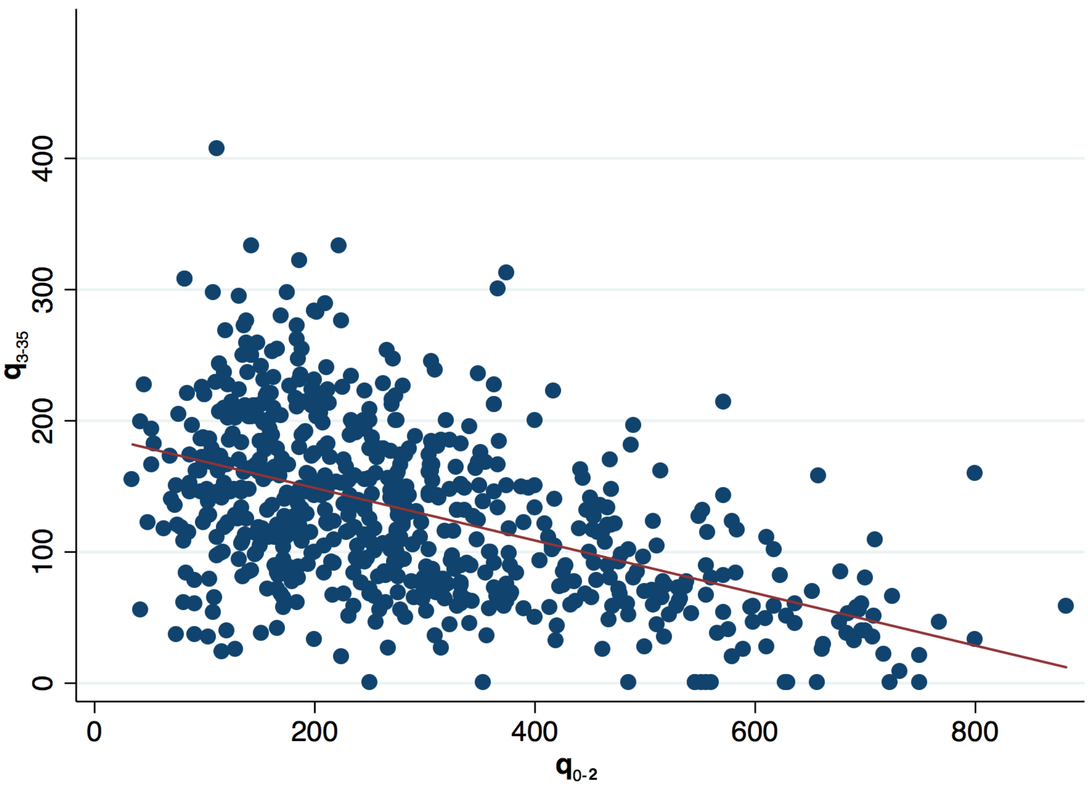


Figure 9. Early and late infant mortality (‰). 112 cohorts (7 parishes x 4 time periods x 4 seasons) pooled according to the level of early infant mortality. Children born in forty-three parishes of the region of Veneto during 1816-35