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Research Article

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 (seven 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 ($q_{0-2} > 400‰$, where the subscripts are months of age), mortality

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hazard of death during the following 33 months was 20%–30% lower compared to the cohorts where early mortality selection was relatively small ($q_{0-2} < 200‰$).

CONCLUSIONS

This result points to a homeostatic mechanism: mortality variability among the cohorts is, for $q_{0-35,}$ half that of the mortality variability for both q_{0-2} and q_{3-35}.

1. 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, Sill, and Drevenstedt 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.[4] If the events experienced in utero 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

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[4] See e.g., Caselli and Capocaccia 1989; Kannisto, Christensen, and Vaupel 1997; Preston, Sill, and Drevenstedt 1998; Bengtsson and Lindström 2000, 2003; Doblhammer 2004; Shkolnikov 2012; Ekamper et al. 2013; Quaranta 2013. See also Bruckner, Catalano, and Smith 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).
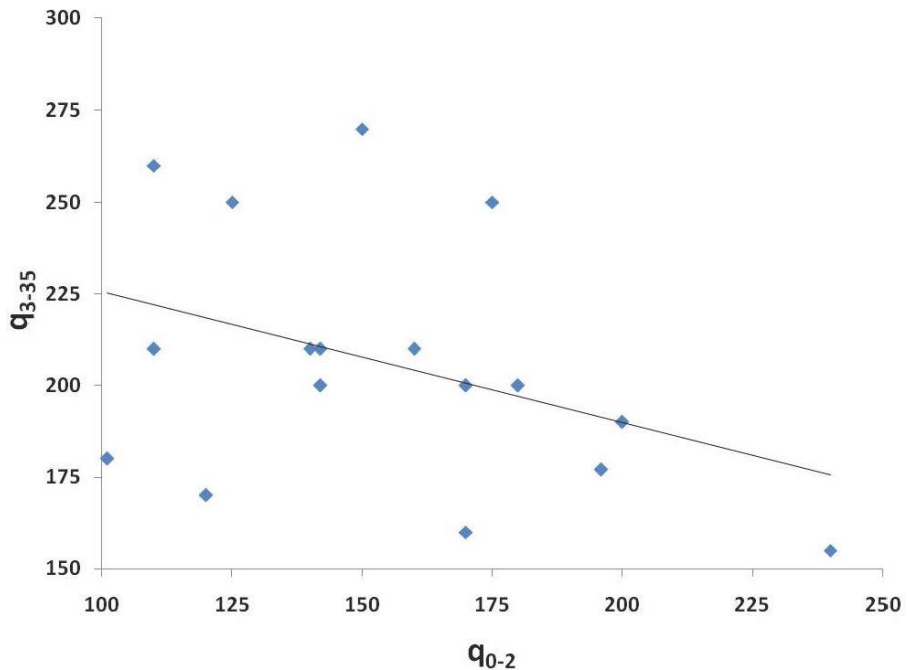
months) or if rather they experienced a so-called scar-effect, i.e., a process of insult accumulation prevailed such that they had a lower probability of surviving during the following 33 months.[5]

We consider children born in Veneto (North-East Italy), using micro-data from the archives of seven parishes for the period 1816–1835, 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 especially 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.

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 *Länder* 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.

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[5] 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 database (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.

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

Source: Dalla-Zuanna and Rossi 2010.

2. 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, Liedo, and Vaupel1995).

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, McDonald, and Biddle 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, White, and Debpuur 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 utero during a particularly cold period (Bruckner, Catalano, and Smith 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 these 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 unravelling 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 compared to cohorts slightly younger or older. For example, a process of insult accumulation occurred in Italy for male cohorts born in 1880–1899 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 the Western Netherlands among people born in 1944–1945 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, Christensen, and Vaupel 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 2008–2009) compared to those who are slightly younger (aged 65–79, Shen and Zeng 2013).

3. Data

We use unpublished nominal data drawn from 19th century parish archives which form 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 (1816–1866) (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 dataset will be completed in 2014. The data used in this paper come from the parochial archives of Agna, San Giorgio delle Pertiche, Chiesanuova and Urbana (Province of Padua), Carpenedo (Province of Venice), and Selva del Montello and Monastier (Province of Treviso) – see Figure 2. These seven parishes represent an extensive picture of the Veneto rural environment during the 19th century. In the period of 1816–1866, approximately 24,000 children were born in these seven parishes, 10,000 of whom died at ages 0–5 years during the period 1816–1870 (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[6]. 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 ancien 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

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[6] Levels of infant mortality equal to 350‰, such as those recorded in the Veneto region in the century of 1750 to 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‰ (1871–75), and 444‰ (1879–88) in the Bavarian district of Augsburg, and 428‰, 471‰, and 400‰ during the same three periods 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 pattern, as mortality during the first month does not vary according to season (Knodel 1988, p. 62).

2009; Dalla-Zuanna and Rosina 2011).[7] 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.[8] 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
- 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.

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[7] 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.

[8] 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 similar to those recorded in the civil acts of birth. An important additional piece of information contained in the civil acts is the date of 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 in the civil registers. The information contained in the civil registers of death are also 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.

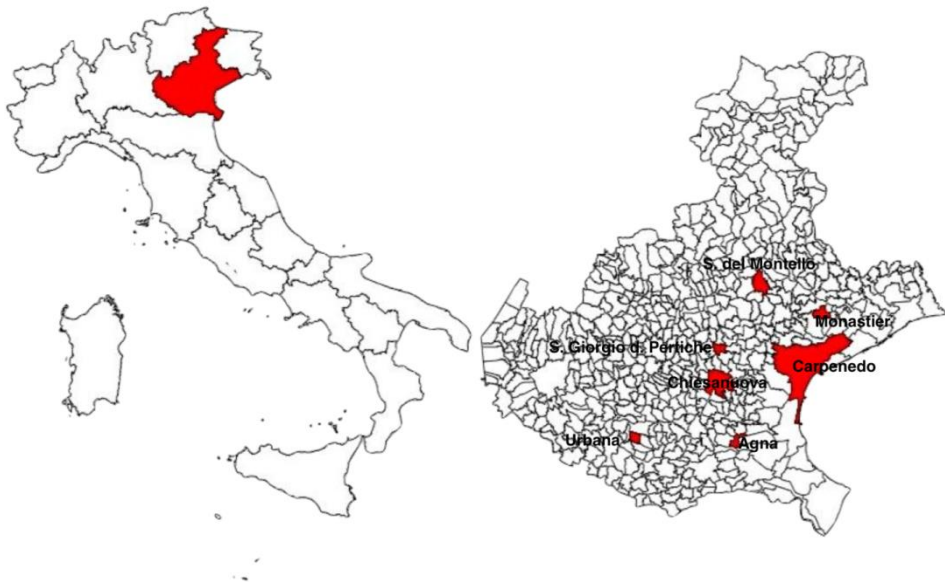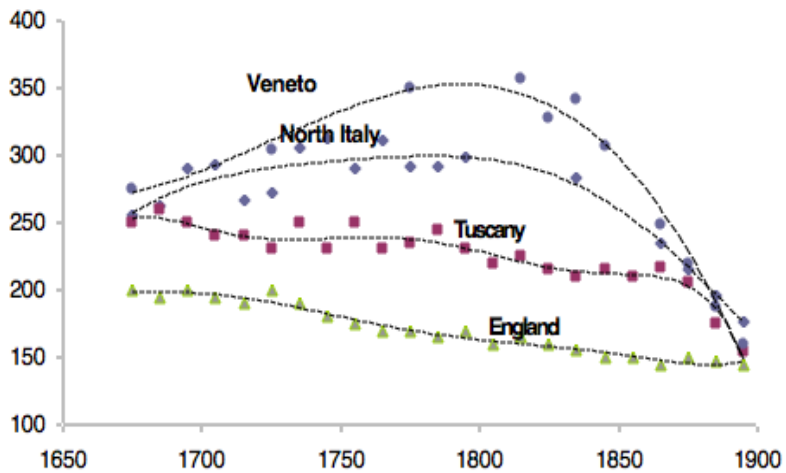**Figure 2:** **Location of the seven Veneto parishes considered in this study**

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.

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 seven parishes, more than 97% of children born in the same parish who died at age 5 or younger were linked to their birth certificate (Table 1).[9] The linkage performance is even greater for children who died before their third birthday. When it was not possible to find the corresponding birth certificates for death certificates of children believed not to have been 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 2.44% of the total number of births, with some differences among parishes (see Table 1).[10]

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[9] 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 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).

[10] 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 we 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.

Table 1: **Number of birth and death records under age 5 in the seven parishes, and some indices of linkage performance**

	Births (1816–66)	Deaths before 5th birthday (1816–70)	No-linkage rate % (1816–70)	'Generated' births % (1816–35)	Deaths at age 0–2 years born elsewhere % (1816–35)
Agna (Padua)	2,532	1,296	1.13	1.10	3.94
San Giorgio delle Pertiche (Padua)	2,863	1,296	0.85	5.35	6.10
Chiesanuova (Padua)	3,087	1,292	4.43	1.97	11.22
Urbana (Padua)	2,425	1,020	1.25	0.77	13.73
Carpenedo (Venice)	5,006	2,030	6.51	2.51	3.55
Selva del Montello (Treviso)	2,981	1,215	2.77	1.97	0.41
Monastier (Treviso)	4,828	1,777	3.38	3.30	1.86
Total	23,722	9,926	2.90	2.44	4.02

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, D'Angelo, and Rosina 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 1816–1835, see below), 5% 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 the first day of life (Wrigley et al. 1997; Davenport 2010). In his analytical reconstruction of the population history of three Bavarian villages, Knodel (1970) found 2% stillbirths during 1800–1849 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
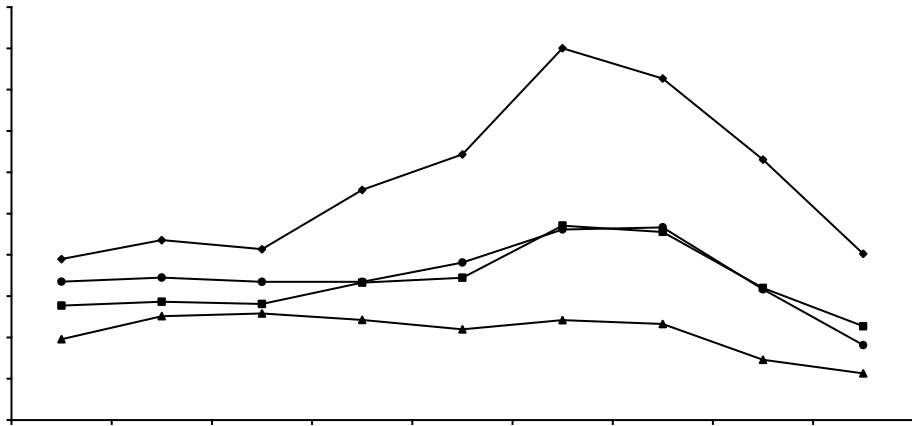
the Veneto region in the early 19th century. However, it seems difficult to imagine dramatic underreporting in our data.[11]

Finally our measures of mortality, which refer to the cohort[12] 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. To better understand the extent of this underestimation we calculated the proportion of deaths at age 0–2 years, born in a parish other than the one studied (see the last column of Table 1). On average, this proportion for the seven parishes is around 4%. 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 greater where exchanges were more intense (as in Urbana and Chiesanuova) or lower where exchanges were less intense (as in Selva del Montello or Monastier). This issue should not, however, greatly affect our research goals in that the said underestimation should be similar, in relative terms, when and where early infant mortality was higher or lower.

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[11] In the days following the first day of life, mortality in 1816–1835 in the 7 parishes under observation was very high (second day= 21‰, third day= 21‰; fourth day=23‰; fifth day=20‰; sixth day=19‰; seventh day=16‰): the probability of dying between the 2nd and 7th day of life was 114‰, four 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 contexts 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 – the 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-registration of early deaths in birth and death registers (if present) was clearly at a much lower level than in Hungary and the Slavic *Länder*.

[12] 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).

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**
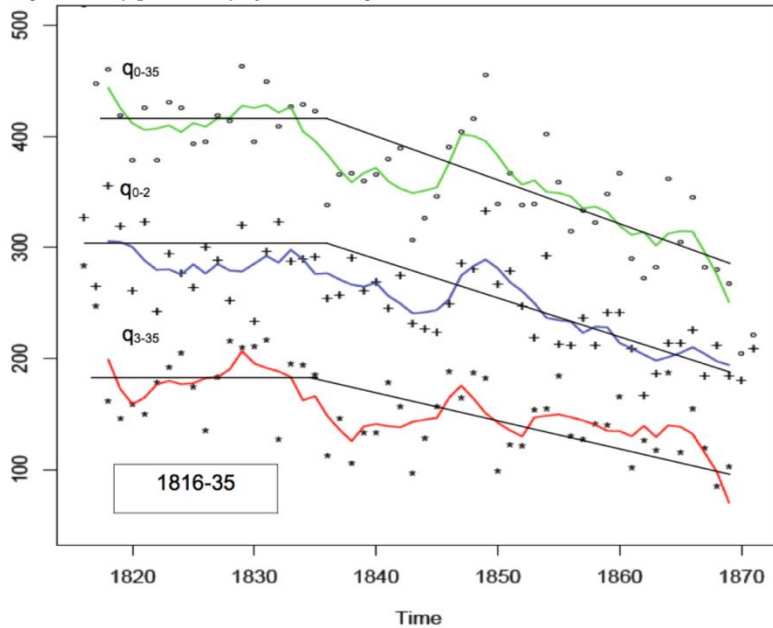
4. Preliminary results and methodological choices

Figure 5 shows that the death probabilities $q_{0–2}$, $q_{3–35}$, and $q_{0–35}$ in the pool of seven 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 8,809 children born during 1816–1835 in our analysis.[13]

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[13] In what follows we provide some additional information on data quality for the 8,809 children born in the seven parishes during 1816–1835. Sex is reported for all children but two, and 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 only 1.5% of the children was it not possible to discern the job of the father (85.4% farmer, 6.5% craftsman or belonging to the working class, 2.1% merchant, 3.3% servant, 1.2% employee, civil servant, or land owner). The low number of children belonging to last category (the 'wealthiest' group) made it impossible to use this variable for differential purposes. Cause of death was reported in 76% of the death records: this proportion grows notably with age (69% for deaths at age 0–2 months, 87% for deaths at age 3–35 months). Moreover, causes are often confused with symptoms, as was common in death records dating from the 19th century.

Figure 5: **Annual probability of death at ages 0–2, 3–35, and 0–35 months (‰). Children born in seven rural parishes in the region of Veneto in 1816–68, and those dead in 1816–70**

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, Derosas, and Manfredini 2000; Dalla-Zuanna and Rosina 2011). In our sample also, 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.

Table 2: **Data on early and late infant mortality, according to select covariates. Children born in seven rural parishes in the region of Veneto during 1816–35**

	Months 0–2		Months 3–35		Probability of death (per thousand)	
	Birth a	Dead b	Exposed c=a–b	Dead d	q_{0-2} b/a	q_{3-35} d/c
Season at birth						
Winter	1,968	861	1,107	190	438	172
Spring	2,854	740	2,114	397	259	185
Summer	2,137	393	1,744	360	184	206
Autumn	1,850	556	1,294	222	301	172
Early infant mortality (calculated)						
Low (<200‰)	2,849	443	2,406	502	155	209
Medium (200–300‰)	3,001	757	2,244	416	252	185
High (300–400‰)	1,626	586	1,040	162	360	156
Very high (>400‰)	1,333	765	568	89	573	157
Early infant mortality (estimated)						
Low (<200‰)	3,000	466	2,534	515	155	203
Medium (200–300‰)	2,003	461	1,542	297	230	193
High (300–400‰)	1,947	593	1,354	238	305	176
Very high (>400‰)	1,859	1,031	828	119	555	144
Sex						
Female	4,381	1,252	3,129	587	286	188
Male	4,428	1,299	3,129	582	294	186
Period						
1816–20	1,902	581	1,321	256	305	194
1821–25	2,437	679	1,758	319	279	181
1826–30	2,284	640	1,644	311	280	189
1831–35	2,186	651	1,535	283	298	184
Parish						
San Giorgio delle Pertiche (PD)	1,049	277	772	187	265	242
Chiesanuova (PD)	1,159	295	864	197	254	228
Agna (PD)	1,585	689	896	148	435	165
Urbana (PD)	800	316	484	67	395	138
Carpenedo (VE)	1,559	307	1,252	280	197	224
Selva del Montello (TV)	1,028	321	707	92	312	130
Monastier (TV)	1,629	346	1,283	198	212	154
Total	8,809	2,551	6,258	1,169	290	187

Figure 6: **Early and late infant mortality (‰) by season of birth. Children born in seven rural parishes in the region of Veneto during 1816–35**
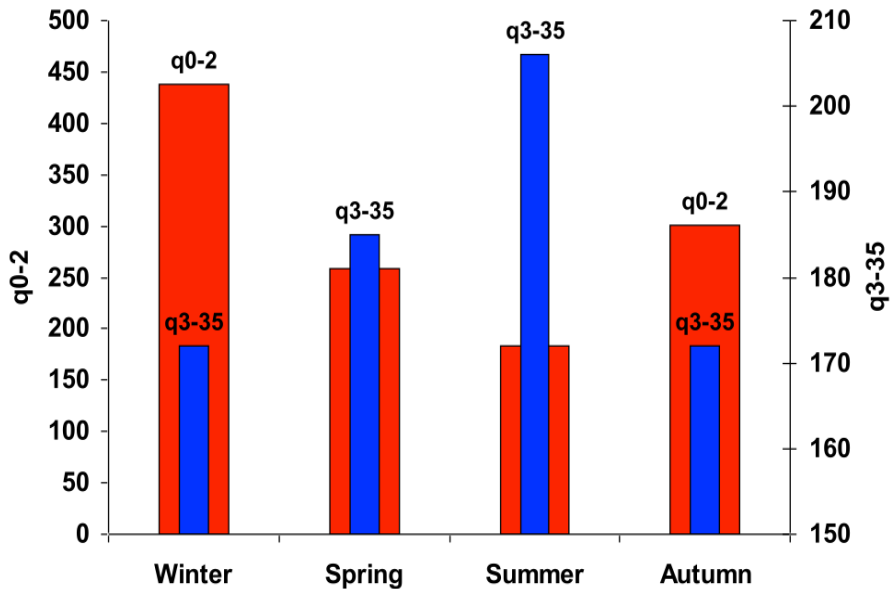

Figure 7 shows the probabilities of death within 3-month periods for the ages 3–35 months, pooling the seven parishes, according to season of birth (summer vs. winter). The shape of the two graphs is similar, dropping from month 3 to month 35 and peaking in the summer and autumn (mainly due to gastro-intestinal 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.

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 seven rural parishes in the region Veneto during 1816–35**

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 112 different levels of early infant mortality, provided by the combination of 4 seasons at birth, 4 groups of five-year intervals at birth, and 7 parishes of birth. Rates of mortality in the first three months of life range from 736‰ (cohort of children born during the winter in the years 1826–1830 in the parish of Urbana) to 104‰ (cohort of children born during the summer in the years 1826–1830 in the parish of Selva del Montello). The scattergram between early and late infant mortality for these 112 cohorts is shown in Figure 8. Finally, the 112 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.

Figure 8: **Early and late infant mortality for 112 cohorts provided by the combination of 4 seasons at birth, 4 groups of five-year cohorts at birth, and 7 parishes of birth. Children born in seven rural parishes of the region of Veneto during 1816–35**
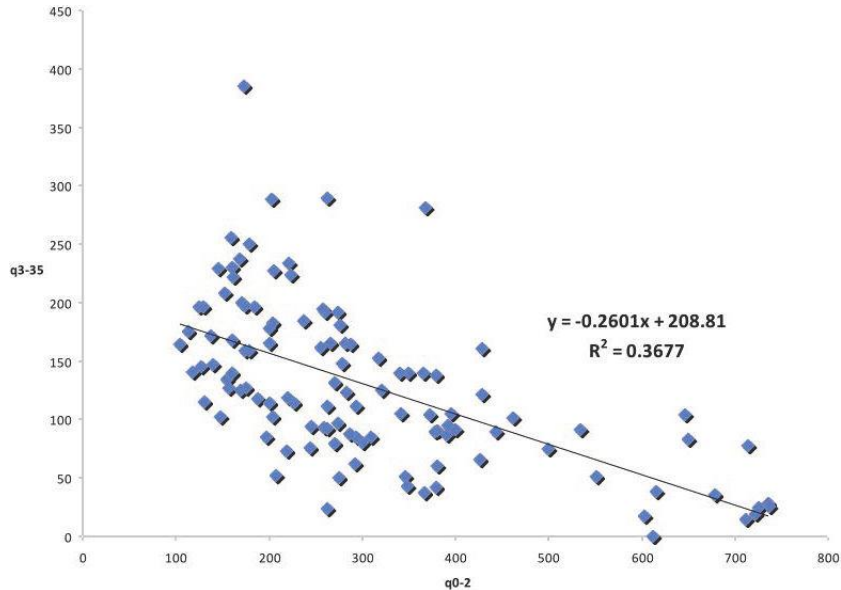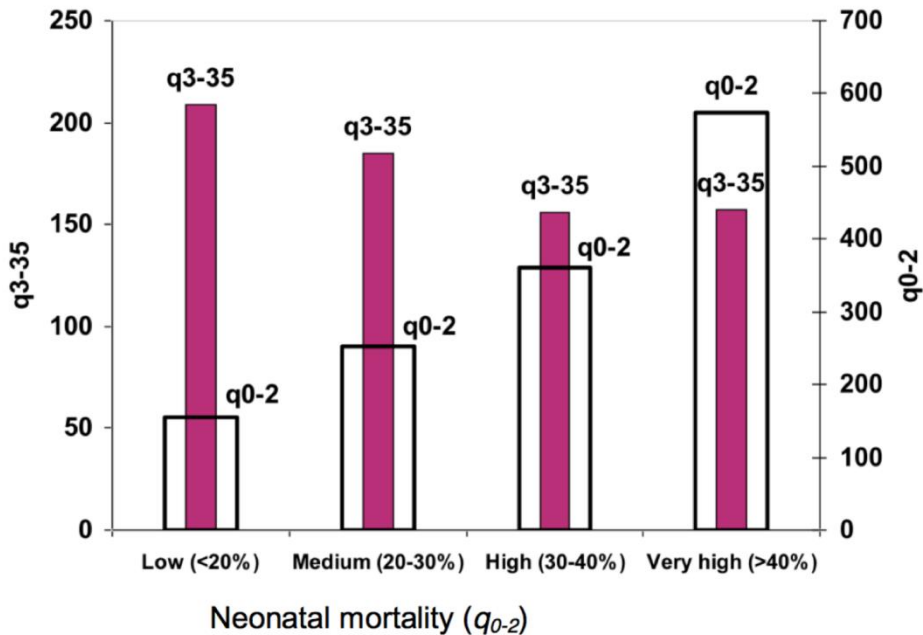

Using five-year intervals, parish and season may not be a precise enough measure to identify the specific environment a child experienced during his/her first three months of life. Early infant mortality could, for any number of reasons, vary from year to year or month to month, especially due to climate 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 1,680 early infant mortality probabilities (12 months at birth, 20 years at birth, 7 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; and the month of January, the year 1816, and the parish of Agna are the baseline.

Figure 9: **Early and late infant mortality (‰). 112 cohorts (7 parishes × 4 time periods × 4 seasons) pooled according to the level of early infant mortality. Children born in seven rural parishes of the region of Veneto during 1816–35**

The results range from 734‰ (cohort of children born in December of 1818 in the parish of Agna) to 64‰ (cohort of children born in May of 1830 in the parish of Carpenedo) 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 1816–1820 to 1831–1835, as the downward trend in late infant mortality had yet to begin (see Figure 5). We expect, however, late infant mortality to vary according to parish of birth. Moreover, we expect late infant mortality to be 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, Catalano, and Smith 2013; Ekamper et al. 2013). We model the risk of death between the 4th and the 36th months 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.[14]

5. 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

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[14] 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 months of life.

mortality and estimated early infant mortality as separate measures of selection during the first three months 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.

Table 3: **The risk of dying between the 4th and the 36th months of life by season at birth and early infant mortality, calculated or estimated. Cox model for children born in seven rural parishes of the region of Veneto during 1816–35**

	Model 1		Model 2		Model 3		Model 4		Model 5	
	HR*	p-value	HR	p-value	HR	p-value	HR	p-value	HR	p-value
Season at birth										
Winter	1	—					1	—	1	—
Spring	1.11	0.244					0.97	0.765	0.95	0.612
Summer	1.23	0.023					1.02	0.887	1.01	0.939
Autumn	0.99	0.922					0.93	0.460	0.88	0.226
Early infant mortality level (calculated)										
Low (<200‰)			1	—			1	—		
Medium (200–300‰)			0.87	0.037			0.88	0.078		
High (300–400‰)			0.72	0.000			0.74	0.004		
Very high (>400‰)			0.72	0.005			0.73	0.014		
Early infant mortality level (estimated)										
Low (<200‰)					1	—			1	—
Medium (200–300‰)					0.93	0.353			0.95	0.496
High (300–400‰)					0.84	0.030			0.85	0.062
Very high (>400‰)					0.68	0.000			0.69	0.001
LL	-10,098		-10,093		-10,095		-10,093		-10,093	
LR	8.41		18.24		16.85		19.39		19.70	
Prob>Chi^2	0.038		0.000		0.001		0.003		0.003	

*HR: Hazard Ratio.

In the basic model the risk of death between the 4th and the 36th months 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) rise by 8 (Chi^2=16, d.o.f.=3, p=0.001); including the estimated early infant mortality (Model 8) sees the 'goodness of fit' (log-likelihood) rise by 5 (Chi^2=10, d.o.f.=3, p=0.019). To summarise, the model is improved when calculated 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.

Table 4: **Covariates of the risk of dying between the 4th and the 36th months 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 seven rural parishes of the region of Veneto during 1816–35**

	Model 6		Model 7		Model 8		Model 9	
	HR	p-value	HR	p-value	HR	p-value	HR	p-value
Early infant mortality level (calculated)								
Low (<200‰)			1	—			1	—
Medium (200–300‰)			0.88	0.074			0.85	0.025
High (300–400‰)			0.69	0.000			0.68	0.000
Very high (>400‰)			0.80	0.112			0.79	0.087
Early infant mortality level (estimated)								
Low (<200‰)					1	—		
Medium (200–300‰)					1.00	0.950		
High (300–400‰)					0.88	0.114		
Very high (>400‰)					0.74	0.008		
Sex								
Female	1	—	1	—	1	—	1	—
Male	0.98	0.765	0.98	0.754	0.98	0.739	0.99	0.815
Period								
1816–20	1	—	1	—	1	—	1	—
1821–25	0.92	0.304	0.89	0.162	0.90	0.231	0.89	0.154
1826–30	0.96	0.589	0.94	0.435	0.95	0.506	0.93	0.427
1831–35	0.93	0.388	0.91	0.271	0.93	0.408	0.89	0.197
Parish								
Agna (PD)	1	—	1	—	1	—	1	—
S. Giorgio delle Pertiche (PD)	1.55	0.000	1.43	0.002	1.43	0.002	1.45	0.001
Chiesanuova (PD)	1.44	0.001	1.31	0.022	1.32	0.015	1.31	0.023
Urbana (PD)	0.83	0.218	0.81	0.144	0.80	0.136	0.83	0.195
Carpenedo (VE)	1.43	0.000	1.20	0.130	1.26	0.038	1.20	0.116
Selva del Montello (TV)	0.78	0.055	0.70	0.009	0.72	0.015	0.70	0.011
Monastier (TV)	0.94	0.551	0.80	0.071	0.84	0.130	0.81	0.076
Transition between seasons (time-varying)								
Winter							1	—
Spring							1.01	0.117
Summer							1.07	0.000
Autumn							1.03	0.000
LL	-10,066		-10,058		-10,061		-9,932	
LR	73.67		88.09		83.23		348.38	
Prob>Chi^2	0.000		0.000		0.000		0.000	

*HR: Hazard Ratio.

   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 (7.5% higher in the transition to summer compared to 3.3% 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.[15]

6. 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 seven rural Veneto parishes in the period 1816–1835, 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 20%−30% 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 112 cohorts obtained by crossing 4 seasons at birth, 4 five-year groupings at birth, and 7 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-

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[15] 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 237 deaths (20.3% of total), with tremendous seasonal differences (11 in winter, 17 in spring, 107 in summer, and 102 in autumn, which includes the relatively warm month of September).

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. These three points will be reconsidered once the IMAV (Infant Mortality in Asburgic Veneto) sample of 50 parishes is complete, and thus a much broader group of rural and urban settings in the Provinces of Vicenza, Padua, Treviso, Venice, and Verona become available. 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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