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An Analysis of Extremely High Nineteenth-Century Winter Neonatal Mortality in a Local Context of Northeastern Italy

Une analyse des niveaux extrêmement élevés de mortalité néonatale hivernale au 19e siècle dans une région du Nord-Est de l'Italie

Gianpiero Dalla-Zuanna · Alessandro Rosina

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Abstract Beginning in the mid-seventeenth century, infant mortality in Veneto (a region in northeastern Italy) began to increase, starting at 250‰ and rising to 350‰ by the mid-nineteenth century—one of the highest levels ever recorded in modern Europe. This dramatic change—in a period of worsening economic conditions—was due to variations in winter neonatal mortality, which was 3–4 times higher in Veneto than in other areas with similar winter temperatures (such as England). We combine micro-data on neonatal mortality with daily data on temperatures for a specific context during the period of 1816–1868 characterized by very high neonatal mortality. We find that the risk of death was particularly intense during the first week of life and strongly correlated with external minimum temperature. Through a comparison of these results with other findings in the literature, we suggest that the increase in winter neonatal mortality in Veneto could have principally been caused by the deteriorating physical condition of mothers, lessening the 'quality' of infants who consequently were quite susceptible to cold temperatures.

Keywords Infant mortality · Event-history analysis · Italy

Résumé À partir du milieu du 17e siècle, la mortalité infantile à Veneto (région au Nord-Est de l'Italie) a augmenté, passant de 250 ‰ à 350 ‰ au milieu du 19e siècle, l'un des niveaux les plus élevés jamais enregistrés dans l'Europe moderne. Cette évolution dramatique – dans une période de dégradation du contexte économique – était dûe aux fluctuations de la mortalité néonatale pendant l'hiver, mortalité qui était à Veneto 3 à 4 fois supérieure à celle d'autres régions ayant des

G. Dalla-Zuanna (✉)
Department of Statistical Sciences, University of Padua, Via Cesare Battisti 241, 35100 Padua, Italy
e-mail: gpdz@stat.unipd.it

A. Rosina
Catholic University of Milan, Milan, Italy

températures hivernales similaires (telles que l'Angleterre). Dans cette analyse, nous avons combiné des microdonnées sur la mortalité néonatale avec les températures quotidiennes relevées dans un contexte régional spécifique au cours de la période 1816–1868, caractérisée par une mortalité néonatale très élevée. Il apparaît que le risque de décès a été particulièrement élevé pendant la première semaine de vie et fortement corrélé avec la température extérieure minimale. A partir d'une comparaison de ces résultats avec d'autres retrouvés dans la littérature, nous émettons l'hypothèse que l'augmentation de la mortalité néonatale en hiver à Veneto était principalement causée par une dégradation de la condition physique des mères, diminuant la « qualité » des enfants et les rendant par conséquent plus sensibles aux basses températures.

Mots-clés Mortalité infantile · Analyse des biographies · Italie

1 Introduction

Over the last few decades, numerous studies have sought to explain historical differences in the risk of dying during the earliest stages of life (see e.g. Vallin 1991; Lee 1991; Preston and Haines 1991). Nevertheless, two important patterns remain less than fully explained. First, although infant mortality (the risk of dying during the first year of life) during the *ancien régime* was everywhere higher than 100‰, considerable differences existed between populations living in adjacent regions and countries (Livi Bacci 1997, point 2). For example, in 1850–1854, child mortality during the first month of life (neonatal mortality) and during the months 1–11 differed greatly among the regions of the Austrian Empire, that included Veneto and Lombardy, which together make up a large portion of Northern Italy (Dalla-Zuanna and Rossi 2010). In addition, secular trends may have significantly varied between neighbouring populations (Livi Bacci 1997, point 6). Although these issues are not easily disentangled, they are crucial to understanding the historical determinants of infant mortality.

In this article, we focus on the risk of dying during the earliest stages of life during the eighteenth and nineteenth centuries in Veneto, the region home to Venice situated in northeastern Italy. A complete comparative map of infant mortality for the regions of Europe from 1650–1900 is not available. However, it is possible to make comparisons by combining the results from a number of different studies. On the secular trends of infant mortality in several northern Italian regions, refer to the article of Del Panta (1997). For Friuli-Venezia Giulia, see Breschi (1999). For a comparison of secular trends in Lower Austria, the Austrian Alpine regions, and other regions in the Alps, see Viazzo (1997). Some data for Germany—which partially depict the secular trend of Veneto—were collected by Flinn (1981, Appendix). For some comparative data on the regions of the Austrian Empire around 1850, see Dalla-Zuanna and Rossi (2010).

The history of population change in Veneto during the final centuries of the demographic *ancien régime* provides an informative case for understanding the fundamental role that changing levels of infant mortality played in influencing both population trends and demographic dynamics (Rossi and Rosina, 1998; Dalla-Zuanna et al., 2004). Population stagnation in Veneto during the eighteenth century (the final decades of the Republic of Venice) and the early nineteenth century can be directly associated with increased infant mortality (Rosina 1995). Furthermore, the results of our analysis are potentially of interest, and applicable, well beyond the geographical region under study. Veneto shares this particular historical pattern of infant mortality (1650–1850) with other regions in Europe. This is especially true with regard to several bordering Italian regions (Emilia-Romagna, Lombardy, and Friuli-Venezia Giulia), but also to a number of areas in Germany and in the former Austrian Empire. While some mountainous zones experienced distinct demographic trends (Breschi 1999), infant mortality in several large and crowded regions of Europe (mainly in the plains and low hill terrain) increased during the eighteenth century. The fact that a similar secular pattern of infant mortality occurred across a number of regions suggests that there may exist a common explanation for this change, especially as other areas of Europe experienced quite different demographic levels and trends.

After a review of the literature on the economic and social situation in Veneto during this century (Sect. 2), our first aim is to describe the remarkable pattern of infant mortality in Veneto during the 100 years of 1750–1850: Sect. 3 clearly shows that the extra-mortality is mainly due to the exceptional neonatal risk of death of winter months. As a consequence, the second aim of this article is to analyse the statistical association between the external temperature and the risk of dying in the winter during the first 30 days of life, using a person–period data set that combines the daily risk of dying in a parish during 1818–1867 with the daily data of external temperature (Sects. 4 and 5). In the final section, we discuss several possible interpretations of our results, indicating possible directions for future research.

2 The Worsening of Living Conditions in Veneto during 1750–1850

Studies of Italy's economic history suggest that during the 1700s, the general living conditions of the working class significantly deteriorated. Combined observations of population estimates, real wages, and *per capita* income from 1700 to 1859 reveal that while the population doubled (from 13 to 26 million inhabitants), real hourly wages were halved, and per capita income decreased by 20% (Malanima 2006). One possible interpretation is that the significant increase in population which followed the end of the great epidemics (the last significant plague occurred in 1630 in northern Italy and 1667 in southern Italy) produced excessive population pressure on an area already characterized (at the end of the 17th century) by high levels of urbanization. Indeed, at the time, Italy, along with the Netherlands, had the highest population density in all of Europe. In addition, Malanima (2003, p. 288) points out:

> Italy completely missed the First Industrial Revolution, the age of coal, iron and mixed farming. It was impossible to adapt the English model to the available natural resources. The lack of coal, the scarcity of iron and the dry soils of the peninsula, with the only exception of part of the Po Valley, was thus an obstacle too difficult to overcome considering the technological level of the time. The relative backwardness of the peninsula grew during the 19th century. From the late Middle Ages to the end of the 19th century, Italy followed the downward curve from a condition of progress to a state of backwardness.

Within the larger context of declining living conditions, it is essential to understand the specific social and economic history of Veneto, here examined in light of its current borders, thus excluding the provinces of Pordenone and Udine, which now belong to the region of Friuli-Venezia Giulia. At the beginning of the nineteenth century, approximately two million inhabitants lived in Veneto; 100 years later, this number had risen to three million (Rosina and Zannini 2004).

In 1630, the last great plague dealt a devastating blow to the Republic of Venice, wiping out 40% of the population. Over the following century, the number of inhabitants grew rapidly, replacing the human void left by the epidemic and growing to 2.2 million by the mid-eighteenth century, or 40% greater than the size of the population immediately preceding the plague of 1630. As in other places, substantial population growth in Veneto was sustained by an increased productivity guaranteed by corn crops (rather than wheat) and by the spread of ‘industrial crops’ such as the mulberry tree. Inhabitants simultaneously struggled, however, with a dramatic decrease in the real value of wages and the consequent need to increase per capita working hours. Along with the increase in population, entire forests were cut down (even in the high hill areas) to make room for the now near-omnipresent cultivation of maize and mulberry trees. Although (to the best of our knowledge) thorough research has not been done on this topic, we presume that relentless deforestation led to an increasing scarcity of wood, needed to heat homes in the winter in the absence or prohibitively high price of coal (Lazzarini 2002. pp. 57–62; Zannini and Gazzi 2003). In addition to these problems, during the seventeenth and into the first half of the eighteenth century, Venice began a slow but steady decline, gradually loosing its secular ability to attract wealth as European commerce began to move out of the Mediterranean and across the Atlantic Ocean.

It is possible to gain a more precise understanding of the relative economic situation in Italy and Veneto compared to the larger European context. The earliest comparison of income across European nations concerns the year 1870 (Maddison 2003, Appendix 2). In this year, *per capita* income in Italy was 50% that of the UK, 58% that of the Netherlands, 59% that of Belgium, 85% that of France and 86% that of Germany. The relative position of Veneto was even worse. In 1891 (the first year for which data are available), *per capita* income in the three regions of northeast Italy (Veneto, Trentino Alto Adige and Friuli) was 15% lower than the average level for Italy as a whole (Malanima and Daniele 2007). From an economic standpoint, this area was by far the most backward in central-northern Italy, and one of worst off in Western Europe.

In order to consider some consequences of this unhappy economic situation, let us consider the relationship between population and resources in Veneto during 1750–1850. During this period, the nutritional health of several populations in Europe greatly deteriorated (for a review see Livi Bacci 1990, Chap. 5). Several studies show that northern Italy similarly experienced an extensive decline in the quality of nutrition. In the region of Lombardy, for example, draftees born in 1750 had an average height of 168.5 cm, compared to 164.5 cm for those born during the first half of the nineteenth century (A'Hearn 2003). Although (as far as we know) data on height of this quality for the eighteenth—nineteenth centuries are not available for other Italian regions, a number of clues suggest that this dramatic negative trend was also experienced in Veneto. Several studies show—more directly—that northern Italy experienced an extensive decline in the quality of nutrition. Along with the decreasing income, another important factor influencing nutritional health was the progressive (and for the poorest, almost total) substitution of wheat with corn. This modification began during the last decades of the sixteenth century, and was completed by the beginning of the nineteenth century (Fornasin 1999; Livi Bacci 1990). A serving of *polenta* (corn meal mush) of equal weight to a portion of bread has significantly lower calorie content. In addition, maize does not have any vitamin PP (PP stands for Pellagra Prevention); thus, a diet based solely on polenta facilitates the spread of pellagra, a vitamin-deficient disease. Pellagra affects metabolism and was a leading cause of death in many areas of northern Italy, including a number of districts in Veneto. In 1881, the first year, the causes of death were recorded on a national scale, and pellagra was high on the list for northeast Italy (Livi Bacci 1986). As late as 1881, Sormanni wrote:

> Of weak parents… poorly nourished, are born wispy and sickly offspring. We have witnessed the predominance of this frailness in Lombardy and Veneto, home also to the greatest endemic infections: malaria, scrofula, and pellagra…

3 Winter Neonatal Mortality: A Description

Infant mortality in Veneto steadily increased from 1650 to 1800, starting at 250‰ in the mid-seventeenth century (the ending point of a 300-year period of severe and recurring plagues) and eventually reaching a high of 350‰ by the end of the eighteenth and during the earliest decades of the nineteenth century. The levels of infant mortality in Veneto during the period of 1750–1850 are among the highest ever recorded for a large area over a significant amount of time. Indeed, among the regions of the Austrian Empire in 1854, the greatest risk of dying during the first month of life is observed in Veneto (Table 1). Following this period, however, infant mortality in Veneto steadily began to decline. By the early 1900s, infant mortality had dropped to 150‰ (Fig. 1).

First, we begin with a brief description of our main data source. At the turn of the seventeenth century, spurred by decrees from the council of Trent and Paolo V's

Table 1 Probability of infant death (×1,000) circa 1854 in the provinces of the Austrian Empire

Regions (in German)	No. of births	Stillbirths and month 0	Months 1–11	Year 0
Österreich unter der Enns	63,387	178	228	365
Österreich ob der Enns	21,411	154	218	339
Salzburg	4,264	175	218	355
Steiermark	31,088	140	152	270
Karnthen	9,648	144	116	243
Krain	13,724	94	141	221
Görz, Gradisca, Istrien etc.	18,631	154	169	297
Tirol und Vorarlberg	25,702	134	108	228
Böhmen	184,905	127	155	262
Mahren	74,837	109	151	244
Schlesien	17,213	129	165	272
Krakau	5,266	105	156	244
Galizien	165,846	116	210	302
Bukowina	18,096	93	140	220
Lombardien	103,920	165	136	279
Venedig	*79,965*	*215*	*112*	*304*
Ungern	323,137	140	176	292
Serbische Wojwodschaft und Temeser Banat	77,044	128	130	241
Kroatien-Slawonien	28,372	126	221	319
Siebenburgen	71,686	99	111	200
Militargranze	42,151	136	192	302
Kronländern	1,380,293	138	165	280

Source: Our calculation on original data from the Tafeln zur Statistik der Osterreichischen Monarchie (1854). See also Dalla-Zuanna and Rossi 2010

1614 edict, priests in the Catholic areas began to regularly record baptisms and deaths in the ecclesiastic parish registers. Over the years and through the studies of many scholars, data for numerous parishes in Veneto have been gathered in a non-nominative manner (for a review, see Rosina and Zannini 2004). The quality of this data is generally good, better that that observed in other areas of Italy where often neither births nor the deaths of children who died immediately after birth were registered (D'Angelo et al., 2003; Rossi, 1970, 1977). For each burial, the parish priest usually indicated the age at death (in days, weeks or months for early deaths). It is thus easy to calculate the probabilities of dying during the first week (early neonatal mortality), the first month (neonatal mortality), and the first year of life (infant mortality). In this article—to the best of our knowledge—we report data for the parishes in Veneto where infant mortality was calculated using these criteria of classification.

In a number of places in Veneto, infant mortality increased during the eighteenth century (Del Panta 1997; Rosina 2000; Rosina and Zannini 2004). Most of this increase was due to negative variation in winter neonatal survival, whereas the level

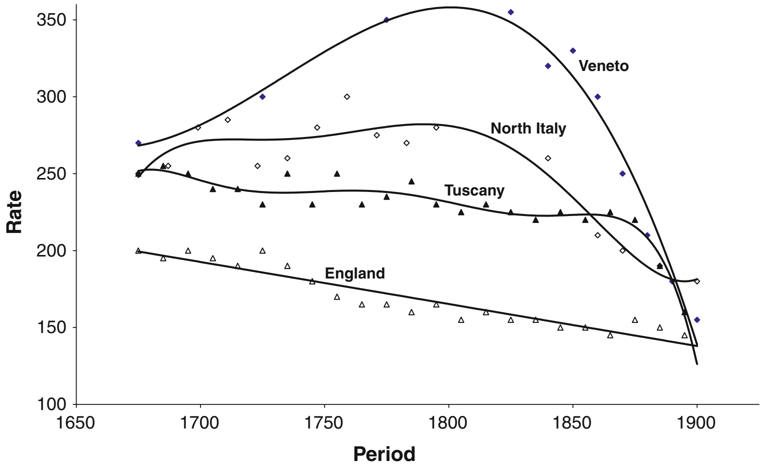

Fig. 1 Secular trends in infant mortality rates (‰) in selected areas of Italy and in England. 1675–1900. *Sources*: For Veneto 1675–1775: Rosina and Zannini 2004, p. 36 (mean level of: 5 parishes, 1651–1700; 9 parishes, 1701–1750; 16 parishes, 1751–1800). For Veneto 1800–1900: Del Panta 1997, p. 15. For England: Woods 1997, p. 76. For Tuscany and North Italy: Del Panta 1997, pp. 15–18. In order to emphasize the secular trends, data are interpolated with polynomials

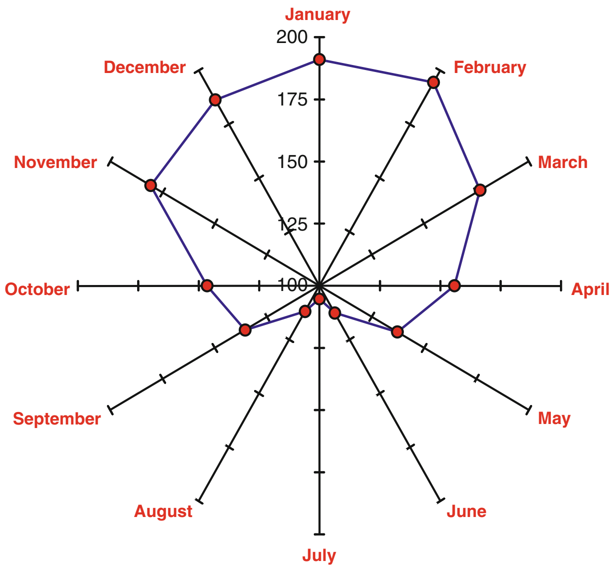

Fig. 2 Mortality during the first month of life in Veneto (Index number: Italy = 100). 1872–1879. *Source*: Rosina and Zannini 2004

of neonatal mortality during the summer months remained the same as that observed for the other Italian regions (Fig. 2; see also Breschi and Livi Bacci 1986, 1997). We show the secular trends in the probability of dying during the first month of life by season of birth for four villages spread across the region. For each parish

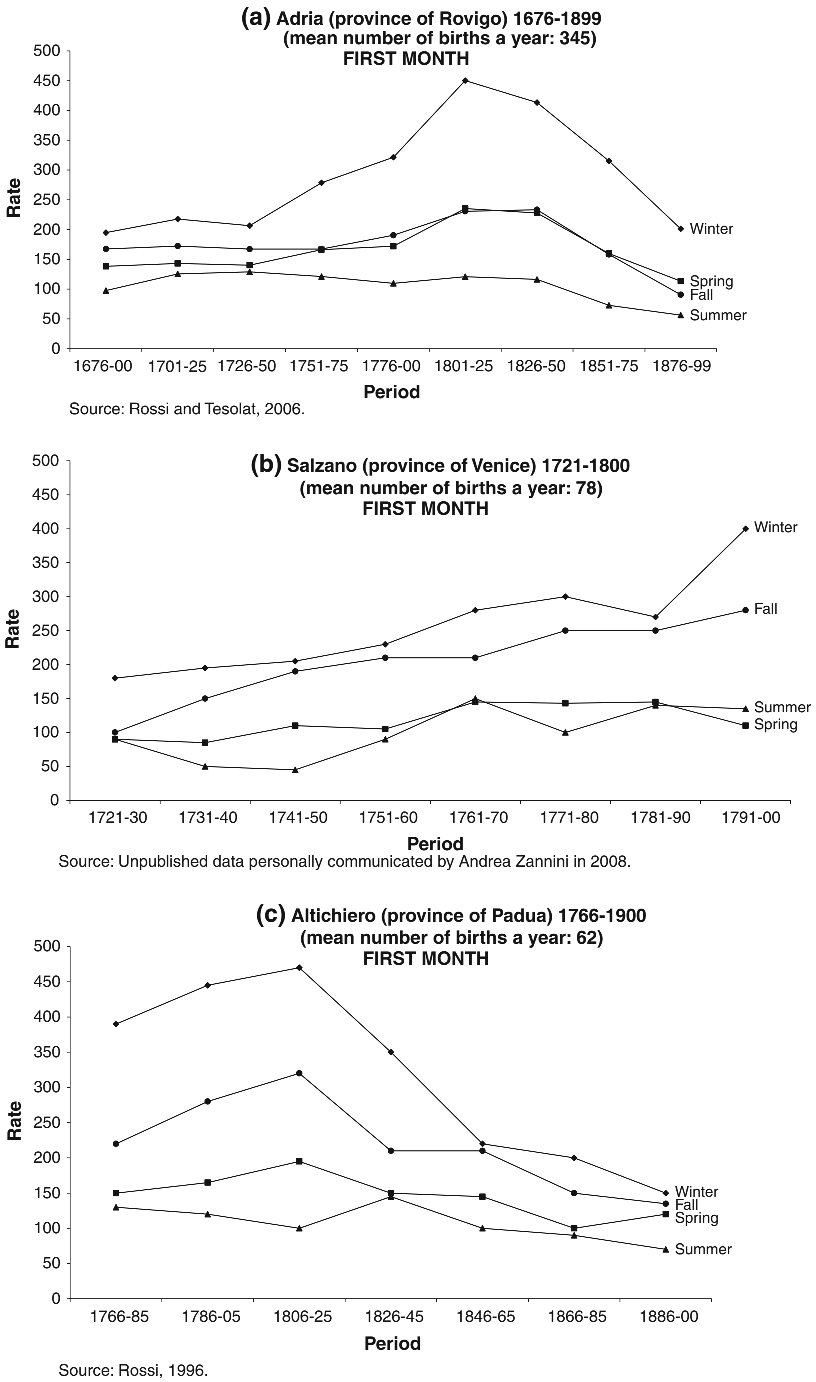

Fig. 3 Probability of dying (×1,000) by season of birth in selected parishes of Veneto (1650–1900). Specific ages during the first year of life

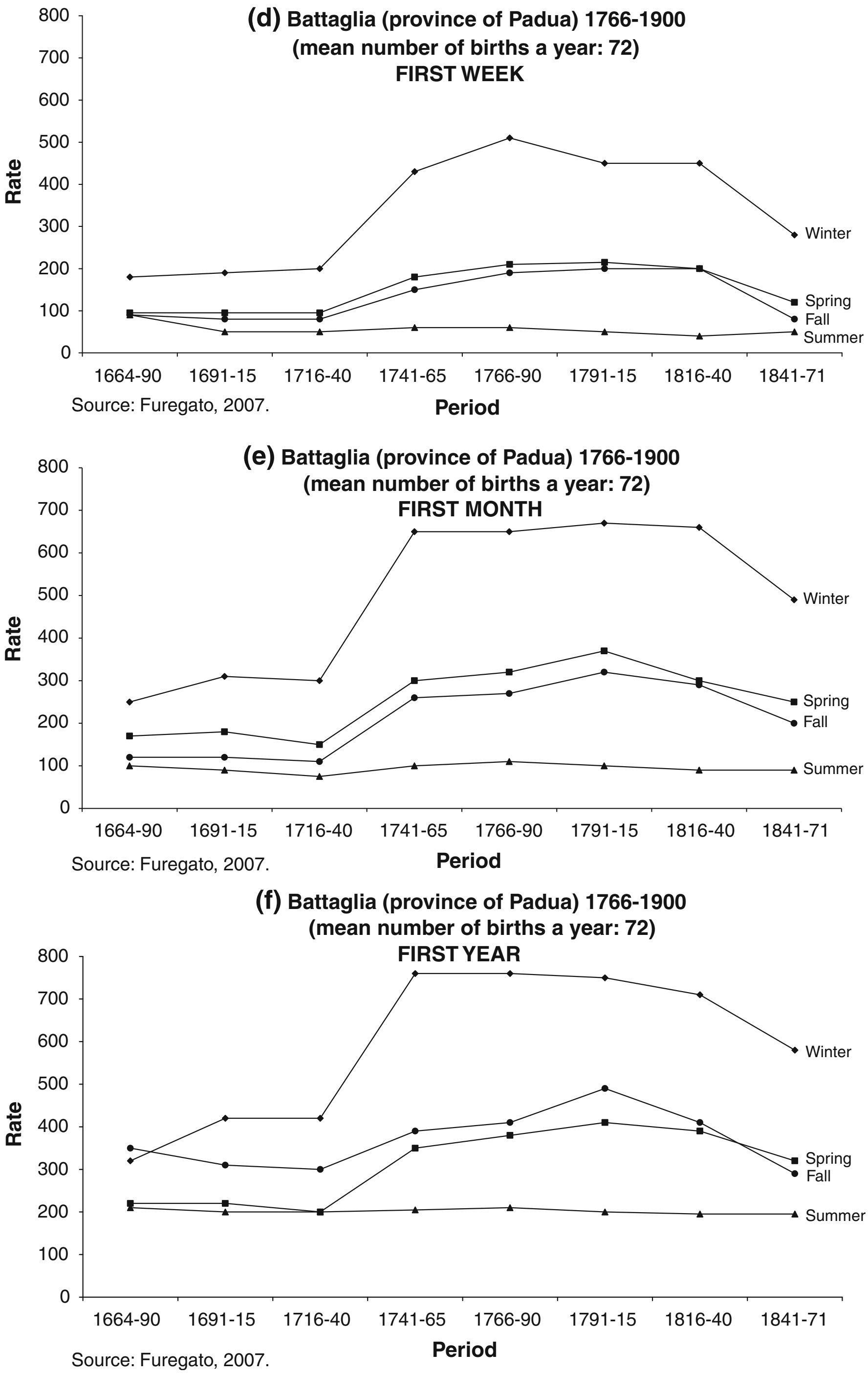

Fig. 3 continued

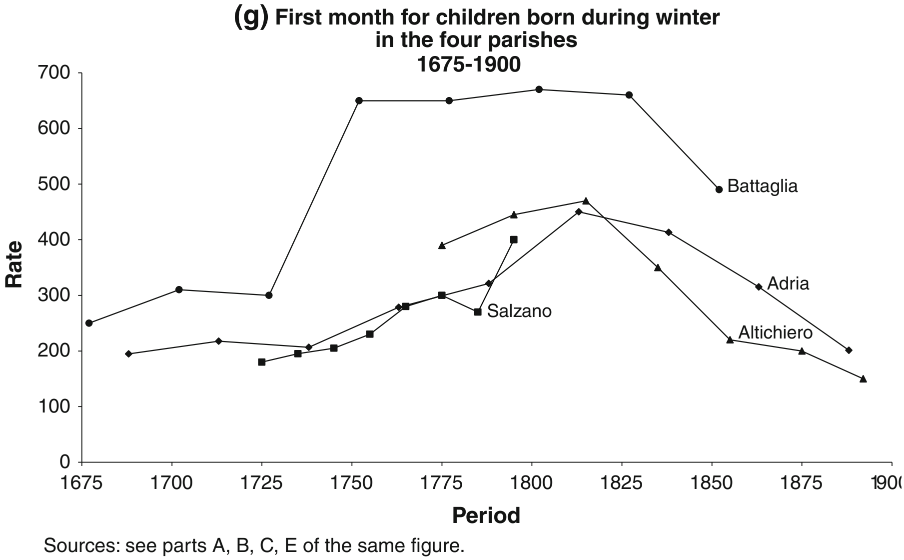

Fig. 3 continued

presented in Fig. 3, changes in neonatal mortality for children born during the cold season played a determinant role in the overall secular trend of infant mortality.

Take, for example, the case of Adria, a town of 9,000 inhabitants located on the left bank of the Po River, near the Adriatic Sea. The data available from 1676–1899 for this town are of quite good quality (Rossi 1970, 1977; Rossi and Tesolat 2006). The secular trend of infant mortality in Adria is as follows: 1651–1700: 207‰; 1701–1750: 254‰; 1751–1800: 279‰; 1801–1850: 329‰; and 1851–1899: 220‰ (Rossi 1970, p. 133). During the eighteenth century, neonatal mortality doubled for children born during the winter, reaching as high as 400‰ in the early 1800s. This very high level persisted throughout the first half of the nineteenth century. In the subsequent period (1850–1900), winter infant mortality dramatically declined. In contrast, throughout the period 1676–1850, neonatal mortality and mortality in the first 2–11 months of life for children born in the summer did not change. In the parish of Battaglia (located 15 km from Padua), the increase in winter neonatal mortality during the period of 1750–1850 was not due to any exceptional events, although this trend is somewhat complicated by large annual oscillations typical of small communities during the *ancien régime* (Furegato, 2007). Moreover, data from Battaglia show that the growth in winter mortality was mainly due to events occurring during the first week of life (Fig. 3).

In order to focus on events occurring during the first month of an infant's life, we considered two parishes where neonatal mortality did not start to decline until 1850 (Agna) and 1860 (Casalserugo). In Table 2, infant mortality in these two parishes during the first half of the nineteenth century is compared with two different contexts in the eighteenth century: Alì (a hill parish in northern Sicily, where temperatures were about the same as those in the Veneto plains in July, and about

Table 2 Probability of dying (‰) by age in Casalserugo (Padua, Veneto), Agna (Padua, Veneto), Alì (Messina, Sicily) and England. Children aged 0–4 born during the eighteenth and nineteenth centuries

Age	Casalserugo born in 1818–1867	Agna born in 1816–1847	Alì (Sicily) born during the Eighteenth century	England born during the Eighteenth century
Day 0	23	26	30*	29
1–6	154	189	25	28
7–29	164	179	43	35
Month 1–5	75	68	52	56
6–11	39	31	33	41
Year 1	78	66	41	51
2–4	58	73	67	64
First				
Day	23	26	30*	29
Week	173	210	54	56
Month	309	351	95	89
Year	386	414	170	175
Years 1–4	131	144	104	111
Years 0–4	467	512	258	268

* Estimated (as the number of children who died during the first day was underreported)

Sources: The probabilities for Casalserugo, Agna, and Alì are calculated using nominative linkages. For Alì, see D'Angelo et al. (2003). For England, see Wrigley and Schofield (1981), p. 226)

Table 3 Probability of dying (‰) in the first month of life by season in Casalserugo and Agna during the first half of the nineteenth century. Stillbirths are not included

	Winter	Spring	Summer	Fall
Casalserugo (1818–1867)	584	294	107	265
Agna (1816–1847)	618	353	154	332

Sources: Data from nominative linkages

10°C higher in January) and England (where temperatures were about the same as in the Veneto plains in January, and around 6°C lower in July). There are certainly differences between the Veneto parishes and the other two contexts presented in Table 2; see, for example, the probability of death in months 1–11 and years 1–4. On the other hand, these dissimilarities seem minimal when one looks at the differences in the probability of dying during the first month, and above all, during the first week (with the exception of the first day). The probability of dying in days 1–6 was six/seven times higher in Agna and in Casalserugo than in Alì and in England. The relevance of winter neonatal mortality is also clearly depicted by the results presented in Table 3, which show significant seasonal differences in neonatal mortality in Agna and Casalserugo.

4 Data

By means of the previously described macro (aggregated)-data, it was possible to study the secular trend in infant mortality by season and age at death for several Veneto parishes. In order to enhance our analysis of the association between temperature and the risk of dying during first month of life, we used available micro (individual)-data, focusing on the first half of the nineteenth century (i.e. when infant mortality in Veneto was extremely high (see again Fig. 1)).

The micro-data used for this study come from a village in Veneto (Casalserugo, situated 10 km from Padua and quite close to the village of Battaglia, which similarly had very high levels of winter neonatal mortality during the first half of the nineteenth century, cf. Table 3 and Fig. 3). The results of this study are part of an extensive research project on infant mortality in the Veneto at the dawn of demographic transition. Thus far, data for the period of 1815–1870 have been collected for 20 parishes—both urban and rural—in the provinces of Padua, Vicenza, Treviso, Venice and Verona. Although a comprehensive analysis has not yet been published, we could already observe that infant mortality in the southern part of the province of Padua—where Casalserugo is situated—was higher than the regional average and began to decline later and more slowly. Indeed, the region in which this parish is located had one of the highest neonatal mortality rates in all of Western Europe during this time period. Focusing the analysis within this context thus enables us to highlight the micro-connection between temperature and neonatal risk of dying in an 'extreme' situation.

We used two kinds of micro-data. The first consists of *civil registers of births and deaths* which each parish priest (or rabbi, in the Jewish communities) was required to compile during the period of Austrian rule (1815–1866 in Veneto), in addition to their ecclesiastic registers of baptisms and burials. The civil registers were often checked by state authorities, as testified by their frequent stamps and notes on the register pages. They are generally easier to read than the ecclesiastic registers as they were pre-printed and their overall quality is quite good. As reported above, in this study, we use the civil registers from the parish of Casalserugo. In order to analytically study infant mortality, we have linked the events of birth and death recorded in the civil registers to the same individual by using data reported at each event as 'linkage-keys': family name, given name, the name of the father, and the family name and given name of the mother. Since the (often approximate) age at death was reported in the death registers, it was also possible to calculate the linkage performance: 99% of the deaths of children who died within the first 5 years of life can be linked to their births. In Casalserugo, the number of births reported in the civil register overlaps with the number of baptisms in the ecclesiastic registers.

In another parish where the same nominative linkage procedure was applied and performed about as well (Agna, 40 km far from Padua), the number of births in the civil registers is higher than the number of baptisms, as children who died before being baptized were still reported in the civil register. Since almost all of the non-baptized newborns of Agna died on the day of birth, we consider them to be stillbirths. The tables reported in the *Tafeln zur Statistik der Osterreichischen Monarchie* from 1827–1965 provide additional data on infant mortality (Rossi and

Fanolla 2007; Dalla-Zuanna and Rossi 2010; see also Table 1). For several years, data on stillbirths were given separately. For example, in 1854 this source reports a proportion of 1.3% stillbirths in Veneto and 1.5% in the Empire as a whole. It is possible that the criterion adopted in Agna (inclusion in the Civil Register of children who died before baptism) was the general rule, whereas the standard employed in Casalserugo (inclusion in the Civil Register only of children who had been baptized) was an exception. As far as we know, however, a complete analysis of these data has yet to be carried out. Casalserugo did not have a hospice for foundlings. However, some children may have been taken to the foundling hospice in Padua shortly after birth and baptism, and then handed over for nursing in other parishes. Evidence of this practice exists in the form of descriptions such as 'a nurse' and 'the foundling hospital' which replace the place of birth on the acts of child death in some Veneto parishes. Although a few of these cases are also found in Casalserugo, we did not include them in our calculations of death probabilities, as only linked children, for whom both birth and death acts are known, are considered. This approach could result in some underestimation of infant mortality because not only could a certain number of children born and baptized in Casalserugo have died elsewhere, but also the (relatively few) foundlings who did die in Casalserugo were not taken into account. Given the nature of the data at our disposal, it is impossible to say anything more on this topic. It is likely, however, that very few children were abandoned in Casalserugo as the number of illegitimate infants born in Casalserugo throughout the period under observation is negligible (less than 1%). In addition, neonatal and infant mortality was so high as to suggest that—especially during the winter—poor people did not abandon babies to avoid having to care for them.

These data can thus be considered as reliable. In addition to the high proportion of infant deaths linked to births, it is important to highlight the accuracy of the birth acts, where basic data were always provided with great precision. Moreover, a comparative study shows that the general quality of the data on infant mortality for the Italian regions of the Austrian Empire (Lombardy and Veneto) around 1850 was quite good, comparable with that of the German-speaking *Länder*, and certainly greater than that observed in the eastern and southern areas of the Empire (Dalla-Zuanna and Rossi 2010).

The second micro-data set used concerns *daily temperature (minimum, maximum and mean) and atmospheric pressure*, recently published for several European towns during the periods of 1700–2000: Milan (Italy): 1763–1998; Cádiz (Spain): 1786–1996; Stockholm (Sweden): 1722–1998; Belgium (multi-site): 1767–1998; Uppsala (Sweden): 1756–1998; St. Petersburg (Russia): 1743–1996. Data for Padua have been reliably comparable since 1774 (Camuffo 2002).

The two data sets just presented were merged and organized into a person–period data set. The period (unit of observation) is every specific day from birth to the end of the first month of life. Casalserugo is located only 10 km from Padua and thus temperatures in the two places should be very similar. Consequently, for each day, the minimum temperature has been added into the data set as the main explanatory variable. For a child who was still alive at the end of the first month, the observation is right-censored. For a list of the available daily variables, see Table 4. The discrete-time approach is particularly suitable in the presence of ties. As shown in

Table 4 Person-days and neonatal deaths by variables in the data set for Casalserugo (1818–1867)

	Exposures		Occurrences	
	N	%	N	%
Year of birth				
1818–1819	2,014	3.6	24	3.3
1820–1829	11,430	20.5	142	19.4
1830–1839	11,028	19.8	138	18.9
1840–1849	10,770	19.3	158	21.6
1850–1859	11,030	19.8	158	21.6
1860–1867	9,474	17.0	111	15.2
Total	55,746	100.0	731	100.0
Month of birth				
1	2,885	5.2	105	14.4
2	3,111	5.6	106	14.5
3	5,434	9.8	133	18.2
4	6,077	10.9	72	9.8
5	7,676	13.8	33	4.5
6	3,996	7.2	19	2.6
7	4,905	8.8	26	3.6
8	6,173	11.1	13	1.8
9	5,437	9.8	18	2.5
10	4,305	7.7	56	7.7
11	3,415	6.1	67	9.2
12	2,332	4.2	83	11.4
Total	55,746	100.0	731	100.0
Age at baptism (days)				
0	11,753	21.1	257	35.2
1	24,648	44.2	330	45.1
2	9,350	16.8	91	12.4
3	4,039	7.2	22	3.0
4+	5,956	10.7	31	4.2
Total	55,746	100.0	731	100.0
Duration of marriage (years)				
0	2,650	4.8	54	7.4
1–4	17,868	32.1	247	33.8
5–9	15,436	27.7	188	25.7
10–14	10,065	18.1	122	16.7
15–19	6,886	12.4	83	11.4
20+	2,841	5.1	37	5.1
Total	55,746	100.0	731	100.0
Occupation of the mother				
Agriculture	44,100	79.1	577	78.9
Other	11,646	20.9	154	21.1
Total	55,746	100.0	731	100.0

Table 4 continued

	Exposures		Occurrences	
	N	%	N	%
Occupation of the father				
Agriculture	45,818	82.2	584	79.9
Other	9,928	17.8	147	20.1
Total	55,746	100.0	731	100.0

Table 4, which contains all the variables available in our data set, the number of events in each time-unit (especially in the first days of life) is very high. Merging the two data sets was possible only for Casalserugo, as Agna is located far from Padua, and daily data on temperature were not available.[1]

5 Results

A detailed analysis of the association between temperature and the risk of neonatal death was carried out using our micro-data set. First, we looked for further confirmation of newborn excess mortality during the winter. Second, we produced detailed estimates of the probability of death within the first 30 days of life for those births which occurred in the months of December, January and February. Lastly, we examined the analytical relationship between temperature and mortality during the winter.

In our first model, we estimated the effects of the season without considering specific climatic data. We used a logistic regression where the response variable was death (or not) in the first month of life in Casalserugo (Table 5). The risk of dying during the first month of life is very high (310‰). This is especially true in the winter (584‰) compared to the summer (107‰) and confirms the descriptive patterns displayed in Table 3—the starting point of our analysis.

In a second model, we applied a discrete-time hazard regression to the detailed data of Casalserugo, concentrating on December, January and February. These are the months with the highest neonatal mortality of the year.[2] In total, 503 children born in the winter (8,328 person-days) and 294 events (deaths before the end of the first month of life) are included in the data set. We allowed for a correlation among children within the same family by using the GEE (Generalized Estimating Equations) approach (Diggle et al. 1994). This tool aids in controlling for unobserved characteristics shared by children of the same mother. The main explanatory variable is the minimum temperature of the day, included in the models as a time-dependent covariate. The other explanatory variables were mainly included as control factors. In order to account for the bell-shaped baseline risk of death in the first month, we considered either age as a continuous variable by including a quadratic term on the

[1] Data (available upon request) were processed using SAS.

[2] In order to test the consistency of our results, we employed another model in which we included the month of March and obtained very similar results (unpublished and available on request).

Table 5 Neonatal mortality by season in Casalserugo (1818–1867)

Season of birth	Probability of dying (×1,000)	Odds ratio	95% Confidence limits	
Summer (J–J–A)	107	1	Reference	
Autumn (S–O–N)	265	3.2	2.2	4.4
Winter (D–J–F)	584	11.6	8.3	16.3
Spring (M–A–M)	294	3.5	2.6	4.8

Note: The odds ratios are the result of a logistic model, where the response variable is death (or not) in the first month of life. Other covariates in the model include: sex, year of birth, social class of the parents, distance marriage-birth, distance birth-baptism (see Table 4). The total number of births is 2,392

Table 6 Discrete-time hazard regression of daily mortality in the first month

	Model A age as a continuous variable				Model B age as a categorical variable			
	Param.	s.e.	*P*-Value	Odds ratio	Param.	s.e.	*P*-Value	Odds ratio
Intercept	−3.75	0.278	<0.001	0.02	−3.16	0.071	<0.001	0.04
Ln age	2.09	0.305	<0.001	8.08				
(ln age)^2	−0.74	0.082	<0.001	0.48				
Age								
0–1					−0.15	0.160	0.340	0.86
2–3					1.01	0.115	<0.001	2.75
4–6					0.64	0.111	<0.001	1.90
7–13					0.02	0.152	0.923	1.02
14+ (ref.)					0	–	–	1
December (ref.)	0	–	–	1	0	–	–	1
January	0.03	0.141	0.842	1.03	−0.03	0.086	0.690	0.97
February	0.05	0.146	0.741	1.05	0.04	0.088	0.636	1.04
MIN temperature C°	−0.05	0.015	0.001	0.95	−0.05	0.019	0.016	0.95
MIN * Age								
0–1					0.01	0.044	0.964	1.01
2–3					−0.04	0.031	0.265	0.96
4–6					−0.03	0.030	0.369	0.97
7–13					0.06	0.038	0.112	1.06
14+ (ref.)					0	–	–	1

Children born in December, January, and February in Casalserugo (1818–1867)

Note: 503 children born in the winter (8,328 person-days) and 294 events (deaths before the end of the first month of life) are included in the data set. Other covariates in the model include: sex, year of birth, social class of the parents, distance marriage-birth, distance birth-baptism (see Table 4). Intra-family correlation: 0.0132

logit scale (Model A), or age as a categorical variable in suitable classes (Model B). In order to better explain the effect of temperature on neonatal mortality, we fitted several lagged models to the same data set. However, the minimum temperatures during the preceding days were not statistically significant if the temperature of the current day was included in the model as a covariate (Table 6).

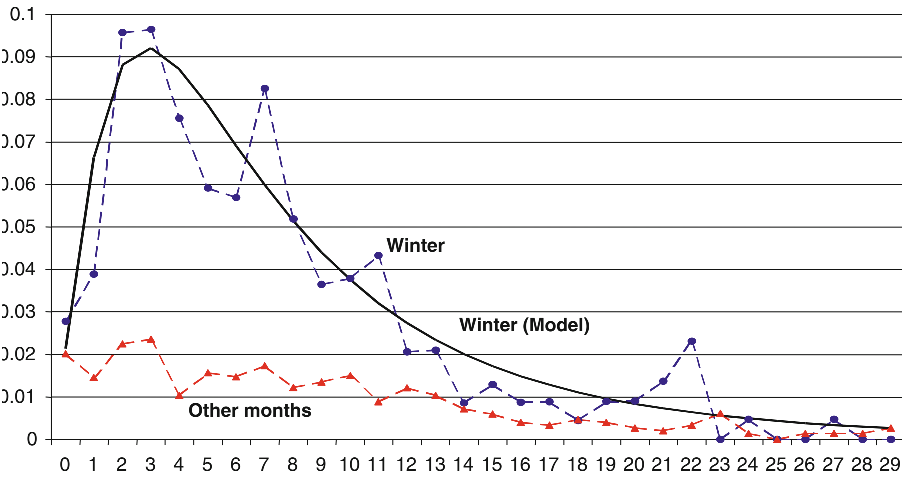

Fig. 4 Daily probability of dying during the first month of life by season in Casalserugo (1818–1857): observed and predicted values from model A (see Table 6)

The pattern of the risk of death by age (in days) is shown in Fig. 4. The probability of dying in the wintertime dramatically increases, reaching a peak in the second and third day of life and then subsequently decreasing. In other words, the most critical period is during the first week, omitting the first day. The same model, when applied to children born in the less cold months, shows that the probability of dying monotonically decreases.

The effect of temperature on the survival of winter newborns is substantial and strongly significant. A decrease of 1°C corresponds to a 5% increase in the daily risk of death during the first month of life (Table 6). According to both models A and B, the daily risk of death during the third and fourth days of life varies from 80 to 130 to 220‰, if the minimum temperature varies respectively from +5 to 0 to −5°C. It is interesting to note that with the inclusion of the minimum temperature in the model, the effect of the month of birth (December, January or February) is no longer statistically significant (the regression models including month and excluding temperatures are available on request). This is a notable result, as some authors have suggested that the survival chances of children are related to the health conditions of their mothers during several susceptible periods of their pregnancies (particularly the second trimester), and that these conditions may vary seasonally (i.e. due to energy stress induced by the harvest cycle; see Scott and Duncan, 2002, Chap. 13). This may also hold true in Casalserugo, but for those unlucky children born during the wintertime, the cause of death seems to be overwhelmingly a matter of external temperature. While the interaction between temperature and age is not significant, the effect of temperature is nevertheless stronger during days 2–6. Furthermore, the probability of death is significantly higher during days 2–6 than during the second week of life (analytical results not shown). If this result is considered together with the shape of the daily-risk function (see Fig. 4), then we again have confirmation that the most critical period during the winter was the first week of life, omitting the first day.

In conclusion, our analysis provides empirical evidence that for the unlucky children born during winter, the risk of dying during the first month of life was extremely responsive to external temperature, particularly during the first week, and above all during the days 2–6. These results further confirm the findings of Ekamper et al. (2009) about the extreme vulnerability of children when temperatures reached low values.

6 Discussion

This article has had two aims: to describe the remarkable intensity of winter infant mortality in Veneto during the century of 1750–1850, and, more specifically, to analyse the effect of external temperature on the risk of dying during the first 30 days of life and to examine whether this effect varies by age. We showed that the significant increase in infant mortality in Veneto during the eighteenth century, and its subsequent rapid decline in the second half of the nineteenth century was caused mainly by considerable variation in neonatal mortality in the wintertime. The worst time period in this regard was from 1750–1850, when the probability of dying in the first month of life during the colder months (December, January and February, the so called 'meteorological winter') reached levels as high as 400‰ births. These levels are significantly higher than those observed in other areas of Italy and Europe (i.e. Tuscany and England) where winter temperatures were similar to those in Veneto, but winter neonatal mortality was much lower. With specific regard to the first month of life, the risk of dying in the winter months was not homogenous: the period of the highest risk was clearly during the first week.

Although we carefully analysed the statistical association between temperature and the risk of dying during the first 30 days of life in Veneto during the first half of the nineteenth century, the available data do not allow us to reliably delve further into the causal mechanisms. Nevertheless, our results, combined with other findings in the literature, provide support for several possible explanations, show others to be less plausible, and suggest directions for future research.

6.1 Causes of death

Information regarding the cause of death, reported in the burial records of Veneto parishes from the eighteenth and nineteenth centuries, is vague and does not fit contemporary disease classification schemes. Our results do, however, allow us to reflect on several plausible illnesses that may have been responsible for low survival rates during the eighteenth century. In particular, the observed seasonality of neonatal deaths was probably not due to endogenous causes linked to pregnancy, birth or congenital anomalies, as these tend to appear in relatively the same measure throughout the year. We may also exclude some other illnesses and contagious diseases that do not specifically affect newborns and are not immediately fatal. Diseases such as diarrhea do, however, have a seasonal pattern, but peak in the summertime for weaned children (Kale et al. 2004). Respiratory illnesses (pneumonia, bronchitis, pleurisy and bronchopneumonia), on the other hand, are more common in the winter. An empirical means of examining whether disease is a causal factor of very high winter neonatal mortality is to analyze the evolution of the daily risk of death following birth. Indeed, the newborn is at a higher risk of dying of respiratory diseases precisely during the second and third weeks of life, as shown by the earliest available infant mortality data of good quality, detailed by cause and age at death (Istat 1934, pp. 128–131).

6.2 Temperature shock for low-weight newborns

The winter increases in infant deaths in Veneto during the eighteenth century were mainly due to events which occurred during the first week of life. This suggests that high winter neonatal mortality in Veneto during 1750–1850 was caused by factors which amplified the effects of cold temperatures: (1) the increasing inability of newborns to survive low temperatures at birth, and/or (2) the growing incapability of parents to protect their children from the cold. In Veneto, during the eighteenth and nineteenth centuries, several issues may have augmented these risks. More specifically, it should be underlined that low-weight newborns are less able to react and adapt to the temperature shock which typically characterizes the hours following delivery, especially when external temperatures are low (see WHO 1997; Costello 2000; Kambarami and Chidede 2003; Darmstadt et al. 2006; Knobel and Holditch-Davis 2007). Evidence of general malnourishment suggests that underfed mothers may have given birth to low-weight infants. According to contemporary data collected in developing countries, the risk of a mother delivering an underweight newborn (<2,500 g) increases for each centimetre below average height, for each kilogram underweight, and for each centimetre below satisfactory mid-upper arm circumference (Lechtig et al. 1978; WHO 1995; Ramakrishnan 2004; Ashdown-Lambert 2005).

6.3 Economic decline and worsening nutrition in Northern Italy and Veneto during the eighteenth century

Thus far, we have no direct proof of a growing proportion of malnourished mothers in Veneto. However, there are a number of indications which suggest that during this period the living conditions of the working classes deteriorated throughout the Padana lowland, particularly in the eastern area (see Sect. 2). Consequently, the notion that increasingly high winter neonatal mortality in Veneto over the course of the eighteenth century and into the nineteenth century can be explained by the deteriorating physical condition of mothers and by the inability of parents to protect their children from the cold is consistent with knowledge of the region's economic and social history.

6.4 The lack of preventive Malthusian checks

Population growth which followed the end of the plague epidemics was not accompanied by significant changes in productive capacity or by any preventive checks on uncontrolled population growth. The average age at first marriage of women in the mid-eighteenth century was low from a Western perspective (20–21 years old), practically identical to the marrying age a century earlier (Rosina and Zannini 2004). In other areas of Italy such as in Tuscany, however, population growth after the epidemics was slower due to a rise in the average age at marriage (Breschi and Rettaroli 1995). In other words, the preventive Malthusian brakes did not work in Veneto during the seventeenth and eighteenth centuries.

6.5 Post-neonatal control?

The proposed explanatory chain (general worsening of living conditions → malnourished mothers → low-weight newborns more susceptible to neonatal hypothermia → lower likelihood of survival in the first days of life during the winter) seems to be the most plausible in the light of available data. An alternative explanation might be an increasing prevalence during the seventeenth- and eighteenth-century winters of, 'infanticide by neglect' (Knodel and van de Walle 1979, p. 230). It is not easy to imagine extensive rational strategies of 'post-neonatal control' such as abandonment or infanticide (Mason 1997) which, for some unknown reason, became much more common during the winter. However, it is possible that child neglect—not unlike that seen during other seasons or previous centuries—had much worse consequences during colder periods, especially in a setting characterized by a lack of material resources. Early baptism—even if no more frequent than in the previous centuries—may also have been especially dangerous for frail and low-weight children of weak mothers. On the other hand, such parental behavior would probably fall into a category of 'too much (spiritual) attention' rather than 'infanticide by neglect'.

We conclude with some reflections concerning possible lines of future research. First, more extensive studies using the extremely clear, simple, and complete preprinted registers of birth, deaths, and marriages for the provinces that were in the past part of the Austrian Empire would allow for rich comparative analysis. By means of these historical records, further study might address not only the topic of infant mortality, but also other important population trends of the nineteenth century, such as the demographic transition, its timing, geography and causes.

Second, the association between daily temperature and mortality could be more fully explored in other territorial contexts, thanks to the availability of lengthy series of the tested and verified published data on temperatures in other cities (see the bottom of Table 4; see also Camuffo 2002, with CD attached).

Third, in order to gain a greater in-depth understanding of the hypothesized causal factors of high winter neonatal mortality during the period 1750–1850, more data are necessary. Analysis of the links between neonatal mortality and external temperatures could be extended by considering other indicators that also oscillate across months or years. For example, the prices of essential materials such as firewood and grain typically tended to fluctuate in urban contexts, where these goods were not self-produced and had to be bought. Other direct measures of seasonal variation in working-class nutritional status could be obtained by collecting data on the weight and/or the body mass index of draftees. Data on mothers from some developing countries suggests that these aspects are quite closely related to the harvest cycle. As weak mothers produce fragile children—who in turn are more susceptible to death caused by the cold—the seasonal pattern of nutrition may interact with the seasonality of temperatures, influencing neonatal mortality. Some encouraging results of Derosas (2009) on Venice during the nineteenth century suggest that this path of research deserves to be pursued further.

Finally, additional data on the private and public care of infants would help clarify and shed new light on why northern Italy, notwithstanding persistent malnutrition, started so early on the road towards the health transition. There are many signs, however, beginning in the mid-nineteenth century, of a growing awareness of the importance of caring for an infant in its earliest moments of life, both at the familial level and at the socio-political institutional level (Derosas 2003). These data are mainly qualitative, however, and research would best be pursued by exploring the rich archives of the nineteenth century.

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