Neonatal mortality, Cold Weather and Socio-Economic Status in two Northern Italian Rural Parishes from 1820 to 1900

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(Provisional draft, please do not quote)

**Abstract**

**Background**

Cold-related diseases, such as hypothermia and severe infectious disease, represent one the most frequent causes of neonatal death in a number of developing countries, while a new scholarly interest regards the effects of cold external temperature on neonatal mortality at the onset of demographic transition.

**Objective**

Firstly, we aim to study the effects of season and cold temperature on neonatal mortality at the onset of demographic transition focusing on two Italian parishes in the rural areas around Bologna between 1820 and 1900. Secondly, we aim to assess whether this effect might vary according to socio-economic status (SES) to investigate the most vulnerable social groups.

**Methods**

By means of logistic regression and discrete-time event history analysis, we estimate the effects of season and temperature using micro-data from parish registers together with daily records of the external temperature. Interaction between the season and the temperature are also considered with respect to socio-economic status.

**Results**

We show that the risk of dying during the first month of life varied according to external temperature’s variation and to socioeconomic status, demonstrating that neonates born to landless rural labourers suffered a higher neonatal mortality risk during winter and when the temperature was low during childbirth. Interactions between temperature and SES were found significantly only in the more recent interval from 1860-1900.

**Conclusions**

The risk of dying during first month of life increases as external temperatures reduce with a clear influence of the day of birth’s temperature suggesting that low temperatures on the day of birth exert a fundamental scarring effect on children survival. We also found significant differences in neonatal mortality by SES, demonstrating more pronounced season and temperature effects on rural proletarians’ families. The result shows that during the second half of the century, a period of intense socio-economic transformations, rural proletarians experienced a clear worsening of their living conditions.

INTRODUCTION

Cold-related diseases, such as hypothermia and severe infectious disease, represent one the most frequent causes of neonatal death in a number of developing countries (Lunze et al. 2013). So, focusing on a historical population we investigate the role of local climatic conditions on neonatal mortality, normally measured by air temperature. Some recent studies have linked temperature and neonatal mortality in Veneto, a Northern Italy region, during the final centuries of the demographic *ancien régime*. The effect of cold weather on neonatal mortality was demonstrated in Casalserugo for the period 1700-1830 (Dalla Zuanna and Rosina 2011) and Venice for the interval 1816-1868 (Derosas 2009). Both studies also showed the importance of living standards and nutritional trends.

Following this new scholarly interest, firstly we propose to assess the effects of cold external temperature on neonatal mortality in a latter period at the onset of demographic transition, during a more intense phase of socio-economic transformations. To pursue this aim, we focused on two rural parishes bordering Bologna in Northern Italy from 1820-1900, embracing the critical period after the National Unification (1861), when a severe economic crisis hit the rural population.

As a second aim, we assess whether the effect of cold weather on neonatal mortality in these parishes might vary according to socio-economic status (SES) to investigate and shed light on the most vulnerable social group in such a critical period of socio-economic transformations. Evident socio-economic disparities among individuals, high neonatal mortality and illiterate rates made these two parishes similar to some contemporary communities in developing countries. By demonstrating that even in a pre-industrial society some socio-economic group were more capable to protect their own newborns than others did, we could provide useful suggestions to address policy intervention in contemporary resources-limited environments.

By means of multivariate statistical models, we estimated the effects of season and temperature using micro-data from parish registers and daily records of external temperature. In fact, for these two parishes, we are fortunate to have reliable daily climate data (Menne et al. 2012a; Menne et al. 2012b) and detailed demographic information from parish registers (Rettaroli and Scalone 2012) We can also rely on precise information on the living standards of the rural population (Jacini 1885; Tanari 1881)[[1]](#footnote-1). Interactions among cold climatic conditions (low temperature and winter season) and SES were considered to assess the neonatal mortality risk in the poorest families during colder winters.

In the following section, we briefly introduce the theoretical framework for neonatal mortality analysis. Then, in the next two sections, sources of data are presented and the socioeconomic, climatic and demographic characteristics of the study area are described. The fifth section is devoted to methods while in the last two sections the results from both aggregate and micro-level analysis are shown and discussed.

THEORETICAL FRAMEWORK

In this section, we introduce the theoretical framework that underlined the construction of our empirical model. First, we listed the general neonatal mortality determinants that will be included in the analysis as main control variables. As second point, the evidences proving the effect of cold weather on neonatal death are presented, explaining the role of hypothermia and related infectious diseases. Then we formulate the rationale to hypothesize differential effects of cold weather by socio-economic status (SES) and to include an interaction term between external temperatures and SES in the model. A final overview of the period under study will be also given, since changes in the effect of cold weather among different social groups are also expected.

*Neonatal mortality determinants*

According to the World Health Organization (2006), in the early days after childbirth, causes of death are mostly related to endogenous factors, such as obstetrical causes, malformations, and prematurity, whereas exogenous factors, such as infections, take over after the first week of life. All these causes of death are related to several biodemographic factors at both neonate and mother levels.

Previous studies on neonatal mortality (e.g. Drevenstedt et al. 2008; Ward 2004; Pinnelli and Mancini 1997) firstly showed that being male increases the risk of early death, while newborns of a multiple delivery have higher levels of perinatal and neonatal mortality (e.g. Reid 2001; Wrigley et al. 1997), because they are supposed to have a low birth-weight and are more likely to be premature (Ward 1993).

The role played by mother’s age in neonatal mortality has been widely discussed in the literature, finding higher mortality for infants born to very young and very old mothers. Previous studies have conjectured that the higher risks for very young mothers could be because of mother-fetus competition for nutrients or difficulties in maternal physical growth (Kramer and Lancaster 2010), whereas infants born to older mothers could be affected by higher likelihood of maternal morbidities or congenital abnormalities (Pozzi 2002; Carolan and Frankowska 2011). According to the maternal-depletion hypothesis (Winkvist et al. 1992), short inter-birth intervals generally impoverish the mother’s physiological state, increasing neonatal mortality risks (DaVanzo et al. 2008), whereas a longer length of time between childbirths could allow mothers to recover from the pregnancy-breastfeeding cycle (DaVanzo et al. 2008; Scalone 2014). The death of a previous child could also decrease the neonatal death risk, since it interrupts breastfeeding, reducing maternal depletion.

Considering the exogenous socio-economic factors in the area under study, we expect significant socio-economic differences in neonatal mortality since poor landless rural labourers’ children would have the greater risk of neonatal death than the other groups (Breschi, Derosas and Manfredini 2000; Reid 2001; Derosas 2009; Dalla Zuanna and Rosina 2011). Short-term economic crises could also impact on neonatal and infant survivorship, as previous studies already assess the effect of prices’ increases on infant and child mortality, finding a negative effect on the survivorship between 2 and 12 years. The grain price was assumed as a proxy of the living standard and nutritional levels in that period, finding not an immediate effect on neonatal mortality but with one year of delay after childbirth (Breschi, Derosas, and Manfredini 2004).

*Effects of cold weather on neonatal mortality*

Infant and neonatal mortality in Italy, at least until the beginning of the nineteenth century, was strongly affected by climatic conditions (Breschi and Livi Bacci 1994; Breschi and Livi Bacci 1986; Breschi, Derosas and Manfredini 2000). Studies on infant mortality in northern and central Italy showed a U-profile of the neonatal mortality by month of birth (Breschi, Derosas and Manfredini 2000; Breschi and Livi Bacci 1994) and an evident relationship with lowest winter temperatures (Derosas 2009; Dalla Zuanna and Rosina 2011; Ferrari and Livi Bacci 1985). Therefore, we mainly expect that winter-born children had the greatest risk of neonatal mortality, whereas those born in summer experienced the lowest levels.

Focusing on Casalserugo from 1700-1830 and Venice from 1816-1868, Dalla Zuanna and Rosina (2011) and Derosas (2009) respectively showed that higher winter neonatal mortality was mainly due to lower outdoor temperatures. Both these two seminal studies concluded that hypothermia probably played the main role in the winter excess of neonatal mortality and colder weather conditions had a direct effect on neonatal death.

According to the main medical literature, hypothermia is defined as a newborn body temperature ranging from 35.5 to 36.5 Celtius degrees, it is generally considered as a direct cause of death only in a small proportion of newborn mortality, since it is mainly associated with common causes of neonatal deaths such severe infections, prematurity, and asphyxia (Lunze et al. 2013). Particularly in premature and low birth weight newborns below 2,500 grams (World Health Organization 2006), thermoregulatory mechanisms are easily overwhelmed, leading to metabolic deterioration and direct death from hypothermia or indirect mortality from associated causes such as severe infections (Lunze and Hamer 2012).

*Differential effect of cold climate on neonatal mortality by socio-economic status*

To argue that cold weather could have a differential effect on neonatal mortality by socio-economic status, the disparities in nutritional levels among the different social groups have to be primary taken into account. Poor mothers could suffer a chronic state of malnutrition and an insufficient vitamin intake during pregnancy and consequently could cause an immature development of fetus (Pozzi 2000). In these terms, low socio-economic status neonates experienced a low weight at birth more frequently than neonates of other socio-economic groups did (e.g. Ward 1993) and therefore could be much more exposed to the pernicious effects of cold weather and low temperatures (Derosas 2009).

Considering the Bologna area, differential effects of low external temperature among the main two socio-economic groups, sharecroppers and landless rural labourers, could be due to differences in quantity and quality of the nutritional intake. On the one hand, sharecroppers were normally able to assume an adequate caloric intake during the entire year, since they could rely on their own food supplies preserved by drying and salting (Comizio Agrario di Bologna 1881; Tanari 1881). On the other hand, the nutrition of landless rural labourers was generally at an adequate level only during the work season, whereas it became insufficient in amount and variety during the unemployment periods. As a consequence, we can assume that because of their chronic malnutrition, landless rural labourers’ neonates more frequently had low weight at birth and thus were more exposed than the sharecroppers’ ones to the effects of severe cold days.

Since in resource-limited communities the hypothermia prevalence was found strongly correlated with environmental temperatures (e.g. Bang et al. 2005, Darmstadt et al. 2006, Agarwal et al. 2007), differential effects of cold weather by socio-economic status could also due to differences in household quality. Since in those contexts, childbirths are given more frequently at home, an infant’s low body temperature is also associated with the parental ability to heat the birth place (Sreeramareddy et al. 2006). In the nineteenth century, poorer housing conditions were widely reported for landless rural labourers who, in many Italian areas, could not afford to have a fireplace or a proper chimney at home or window frames (Jacini 1885). In these terms, dwelling standards were related to socioeconomic status since it is likely that the poorest groups experienced more precarious housing conditions[[2]](#footnote-2).

Previous studies showed that infant’s low body temperature is also associated with having a young and inexperienced mother (e.g. Zabelle et. al. 1990). More substantial family resources and better infant care has been seen where other women were co-resident. Considering our study area, in larger and multiple sharecroppers' households, other co-resident relatives could support young mothers in taking care of their neonates (Breschi, Derosas and Manfredini 2004; Breschi, Manfredini and Pozzi 2004), avoiding harmful practices in childrearing, such as a premature exposure to cold weather conditions. On the contrary, in simpler and nuclear landless rural labourers’ families, mothers were the only persons involved and they could not rely on any other help in protecting their children from adverse climatic and environmental conditions.

*The labourers living conditions in the second part of the Nineteenth century*

Given the length of our demographic and climate series arriving at the beginning of the twentieth century, a supplementary focus on the socio-economic and demographic transformations of that period is necessary. It is possible to assume that, during the nineteenth century, housing improvements, relevant progresses in obstetrical techniques and childrearing knowledge contributed to reducing infant mortality levels in this rural area (Scalone et al. 2013).

However, the improvements of living conditions did not concern the whole population, since the poorest strata of the rural population and the landless labourers experienced a progressive worsening in their living standards due to the economic and political transformations occurred during the period in question. After the national unification in 1861, cereals imported from the United States and France caused a market crisis that affected the agricultural sector. From 1869, a new tax on grinding wheat and cereals (*tassa sul macinato*) generally impoverished the rural populations, particularly affecting the landless rural labourers. The situation further worsened when the Italian Government increased the duties (1887-1888) on imported goods and the French authorities raised the custom duties on Italian agricultural products, further hurting the agricultural sector, thereby affecting the living standards of the rural population (Cazzola 1996). In the same period, the traditional sharecropping economy steadily declined as large-scale, capitalist agriculture took place in the Bologna area, since new modern agricultural machines were introduced, cutting off the number of working days for the landless labourers and increasing temporary and permanent unemployment (Cazzola 1996, Kertzer and Hogan 1986). Given the worsened living conditions of the rural landless labourers, we also expected that, in the second part of the nineteenth century, low temperatures could severely impact on the labourers’ group.

SOURCES AND DATA

*Demographic Sources*

To investigate the relationship between temperature and the risk of dying during the first month of life, we analysed the demographic data and climate sources that were available. We used parish registers and the Status Animarum of San Donnino and San Nicolò, covering about 11,000 individuals between 1820 and 1900, in which we counted 2,786 births and observed 292 deaths in the first month of life (Rettaroli e Scalone 2012). Together, the parish registers and the annual collection of the Status Animarum provide complete information about the stock and flow of the populations of San Nicolò and San Donnino during the nineteenth century. The parish registers offered complete nominative information about the births, deaths and marriages that occurred in the territories of the parishes, whereas the Status Animarum was a type of census drawn up by the parish priest each year during the Easter period. It reported information by household, listing the name, sex, age, marital status, paternity and maternity of members of each family (Rettaroli and Scalone 2012).

Some concerns may be related to the stillbirth registrations. Since the Catholic Church was spiritually concerned to save the neonates’ souls, the priests tended to properly register the early deaths, in some cases also including the babies dying during the childbirth. From this point of view, the used source could include in the early neonatal deaths a number of late foetal losses.

By using the Status Animarum, information on the occupations of the heads of households can be taken into account (Rettaroli and Scalone 2012). The classification scheme for the occupations distinguished among three main socio-economic groups in that area considering the father’s occupation at birth. On the one hand, the rural group is distinguished between “landless rural labourers” and “farmers and sharecroppers”. On the other hand, we have a non-rural group including artisans, petite bourgeoisie and non-farm workers. Individuals with unknown socio-economic status were classified in this third group. Since in the Status Animarum, individuals are listed by family group, it is also possible to consider specific household structures. Mortality estimates based on this kind of family reconstitution can be biased due to unobserved migration because death dates tend to be missing when individuals moved and died in other places. However, this bias generally has a limited impact on neonatal mortality measures, since it was not common for a new mother and her neonate to migrate within a month of delivery.

*Temperature Registers*

Another source used for this research is climate registers from the Astronomic Observatory of the University of Bologna; these provided minimum, mean and maximum temperatures for each day during the entire studied period. Since the Astronomic Observatory of the University was located less than five kilometers from San Donnino and San Nicolò, it represents the ideal climate source to be associated to the demographic used data. These daily temperatures are now available in the dataset of the Global Historical Climatology Network (Menne et al. 2012a; Meme et al. 2012b).

Table 1 shows minimum, maximum, mean and standard deviations and some selected percentiles of the minimum temperatures by month, distinguishing between the two sub-periods 1820-1859 and 1860-1900. In this study, we only considered the minimum temperatures. The data confirmed that the winter months were the coldest, since December, January and February are associated to minimum values evidently below 0° C in both the two sub-periods. In these coldest months, even the *average* values are frequently below zero. It is worth noting that negative minimum values were also registered in March and November. Even if the averages from 1820 to 1859 are slightly lower than those of the second sub-period, the minimum values are reached in the second period. Nevertheless, these monthly series appear quite stable since they have almost the same standard deviations in both the first and the second sub-periods.

Table 1 here

*Price Series*

During the nineteenth century, Bologna was an important market where agricultural products of the surrounding area like corn, wheat, other cereals, vegetables, hemp, rice and grapes were traded. Nevertheless, for the Bologna market, no historical source reports a unique and complete series of cereal, wheat or corn prices, since various registers covered different sub-periods of our studied period. Because of this, we first reconstructed a series of wheat prices that spans from 1820 to 1860, by collecting and harmonizing prices from different sources (Dal Pane 1969; Fronzoni 2004; Opera pia de' poveri vergognosi in Bologna1888). These prices are taken from the Bologna market and referred to the calendar years, while for the remaining period from 1861 to 1900 the official prices at the national level are taken into account. We preliminary compared the reconstructed series to those of other towns in the Emilia area (Ferrara and Parma), finding quite similar and coherent trends. The prices progressively increased from the second half of the 1840s to the middle of the 1870s and then slightly decreased until the end of the century. Ideally, it would be preferable to have a monthly prices series in order to exactly measure the impact of the maternal nutritional stress on the foetal and neonatal period. Unfortunately, the available data are limited to the calendar years and consequently the price information refers to the average price level of two consecutive harvest years. In these terms, this covariate has to be interpreted as a more general proxy to control for the market conditions and the nutritional levels in the medium term that included the years of birth and the immediate previous one.

*The “Person-Day” Dataset*

The information contained in the various sources was linked on a nominative basis to reconstitute the neonatal individual biographies in the first month of life. The procedure of nominative reconstitution produced longitudinal “person-day” dataset suitable to carry out a discrete event history analysis. This dataset has a rectangular shape where each row contains information referred to each day of a neonate life from the first to thirtieth day from birth (unless the newborn died before the thirtieth day of life), supplemented with a number of constructed variable regarding the main bio-demographic and socio-economic characteristics. The biodemographic variables are related to sex of the newborn (a dummy whether he/she is a female or male), multiple births (a dummy whether twin or a singleton), age of the mother (a four-category variable), time from last birth and survival status of previous child (a four-category variable combining dummy variables on intervals shorter or longer than 19 months and the life status of last child). A time-varying variable takes into account the age of the newborn, distinguishing the following neonatal sub-periods: 0-1 days, 2-3, 4-6, 7-13 and equal to or more than 14 days. Other two covariates referred to the SES and specific household characteristics (the number of women aged 60 and above in the household). Other exogenous variables are also taken into account: controlling for parish of residence, year of birth, season or month of birth and wheat price that referred to one year lagged before the birth.

The dataset also includes the main covariates in our analysis that are season of birth and the daily temperatures, and their interaction with socio-economic status. Each record reports two kind of temperature registrations: time-constant temperatures were referred to the day of birth and did not vary on the following person-day records, where time-varying temperatures changed on each day-record according to the correspondent daily temperature.

STUDY AREA

*Geography, Climate and Population*

Our study focuses on San Donnino and San Nicolò di Villola, two parishes located in the flat rural area of the Po valley bordering Bologna on the north-east direction. The two parishes were located outside the ancient walls of Bologna, in the bordering rural belt around the town. The separation of the rural hinterland was not only symbolic, but also administrative and material. For centuries, the doors of the town were locked during the night, and people and goods travelling from the countryside to the downtown were under the strict control of the custom officers. Nevertheless, strong and important economic relationships existed between the town and its bordering rural zone.

The climatic conditions of the Bologna plain included prolonged rainy and dry periods with frequently sudden and violent weather events. Snow, frost, hail and fog were common in cold seasons, while during the summer the hot weather favoured the development of insects and molds that sometimes spoiled part of the crop. Furthermore, seasons rarely changed gradually, so agricultural work was always uncertain (Tanari 1881).

In 1820 both parishes together counted 881 inhabitants, more than 1,000 in 1840 and 1,158 in 1900; during the same period, the number of families increased from 134 to 182. San Donnino had always had a larger population than San Nicolò; the difference grew from 93 inhabitants in 1820 to 250 in 1900. The population and number of families in San Nicolò remained constant during the period in question. The population of San Donnino grew from 487 to 704, an increase of 44.6%. Taking the two parishes together, the size of the average family remained stable during the entire period, varying from 6.6 in 1820 to 6.4 in 1900 (Rettaroli and Scalone 2012).

*Socioeconomic Characteristics*

Before industrialization, the plains close to Bologna were populated mostly by two social groups tied to the agricultural sector—those bound by sharecropping contracts and those engaged in wage labor (Bellettini 1971; Kertzer and Hogan 1989). The sharecropping contract, frequently just an oral agreement, consisted in splitting the harvest between the owner and the sharecropper (Breschi et al. 2014; Scalone et al. 2017). In 1860, at the middle of the studied period, in the two considered parishes, on a total of 158 households, 71 and 47 were respectively headed by a sharecropper or a rural landless worker (Rettaroli and Scalone 2012). Considering still the middle of the studied period, landless labourers mainly lived in nuclear families with an average of 4.3 members, whereas the sharecroppers in larger multiple households with a mean of 8.8 members (Rettaroli and Scalone 2012). While sharecroppers experienced relatively stable economic conditions, relying on their sharecropping contracts (Bellettini 1971), landless rural labourers could only count on seasonal and often temporary income, without any contractual protection (Tanari 1881).

Although education was compulsory and there were enough schools, school attendance was low because teachers were unable to understand the effective needs of the rural population and, also, parents needed children to help in the agricultural work. Even during winter, children were often not able to attend school, frequently located far from their house, because of the snow, rain and frequently the lack of decent clothes or shoes. In 1881 the percentage of the population of Bologna's rural area that was illiterate was still very high, equaling 63.3 %.

*Neonatal Mortality in the Bologna Area*

Perinatal mortality rates, as well as infant mortality levels, were lower in the province of Bologna in relation to those registered across the whole region of Emilia-Romagna. Studies have found that these differences were due to better geographic-environmental conditions (Angeli, Del Panta and Samoggia 1995) and to improvements in obstetrical assistance and infant care, which were already advanced in the nineteenth century[[3]](#footnote-3), thus leading to reductions in stillbirths and perinatal risk. This benefit might also have been extended to rural families (Ward 2004).

Between 1820 and 1900, the average neonatal mortality rate (deaths in the first month of life per 1000 births) in San Donnino and San Nicoló was equal to 105 ‰.

Looking at some preliminary estimates based on these data, neonatal mortality rates were highest in winter and lowest in summer. As shown in Figure 1, we can see that neonatal mortality had a reverse relation with temperatures from 1820 to 1900.

Figure 1 here

Even if there are no precise information regarding the area under study, it is possible to look at the 1888 statistics on perinatal causes ofdeaths in Emilia (table 2). We noted that more than half of deaths were due to “infantile atrophy”, about 9% to “diseases of the intestines”, about 85 to “respiratory deseases, and almost 6% to “sclerema[[4]](#footnote-4)” (skin lesions and inflammations).

Table 2 here

According to the definition of that time, “atrophy” (that literally mean ‘lack of nourishment’) consisted of underweight or immature body development, and was due to congenital causes or poor maternal nourishment (Manfredini and Pozzi 2004). Both “infantile atrophy” and “sclerema” seem to be connected to the existence of weak, underweight or premature neonates. Albeit we must be careful of the low-quality classification of death, we can observe that a relevant proportion of the neonatal deaths could be related to the neonates’ low weight or weakness.

METHODS

Following the approach proposed by Dalla Zuanna and Rosina (2011), we investigated the association between season, temperature and the risk of neonatal death by SES, combining logistic regression analysis with discrete-event history modelling. By means of logistic regressions, we firstly assessed the neonatal mortality risk in winter and estimated the interaction between seasons and SES from 1820 to 1900. Secondly, we assessed the effects of daily temperature and its interaction with SES focusing on the coldest period of the year (winter, together with the months of November and March) using a discrete event-history approach. In this case, we estimated and compared the models on two sub-intervals from 1820-1859 and 1860-1900, as we consider the National Unification of 1861 as a turning point of the main socio-economic transformation in Italy.

*Logistic Regression Analysis*

In our first model, we estimated the effects of the season and its interaction with SES, using the sample of *n* = 2,786 neonates and 292 neonatal deaths that occurred between 1820 and 1900 and grouped among *m* = 947 mothers. A logistic regression was used adopting a dummy variable “death (or not) in the first 30 days of life” as a response variable:

 (1)

where *π* denotes the probability that a neonates *i* from a mother *j* dies within the 30 days following delivery, as *α* represents a set of constants, *β* is a vector of parameters for the covariates, and *X* is the vector of the time-constant covariates that refers to the day of birth.

A cluster random effect - grouping children with the same mother *j* - was included to take into account unexplained interfamily variation and consequently improve the estimates of the parameters (Larsen et al. 2000). To consider the unexplained mortality component due to unobserved familial and maternal characteristics, we created a latent variable, grouping the observed neonates by their own mothers (Scalone et al. 2017). Therefore, we assumed that the *m* cluster random variables were mutually independent and had identical Gaussian distributions with a mean of zero and *u* variance. Traditional measures to investigate variance components in random-effects logistic models were computed: the standard deviation *u* of the cluster random effects and the intra-class correlation coefficient (ICC, often indicated by *ρ*), given by the ratio of variance between second-level units to total variance. ICC represented the percentage of the total individual variation in the propensity for neonatal dying attributable to variation among mothers. It quantifies the variation within groups and can also be interpreted as a measure of the residual correlation in the propensity for dying between two new-borns randomly selected from the same mother (Larsen et al. 2000; Larsen and Merlo 2005)[[5]](#footnote-5).

As modelling strategy, a set of logistic regression model was estimated (table 3). Firstly, a base model is shown including only the socioeconomic status and the season of birth. Then a full model includes controls for other bio-demographic and exogenous factors such as numbers of family members and older women, time trends, wheat prices and parish of residence. In a final model, the interactions between socio-economic status and season are also taken into account.

*Discrete-Time Event History Analysis*

Once having tested the risk of neonatal mortality in the cold winter season, we considered the impact of the external daily temperatures. Our reconstituted micro-individual data permitted multivariate statistical analysis, using event-history techniques to estimate the odds of dying within a month of birth. The characteristics of the person-day dataset suggested that the use of discrete-time models with a person-day record as the unit of analysis would be suitable (Allison 1982; Dalla Zuanna and Rosina 2011). We concentrated on the births occurred in November, December, January, February and March during the period from 1820 to 1900, because they generally registered the highest neonatal mortality as well as the lowest temperatures. In total, 1.206 children, born from November to March (32,355 person-days), and 175 events (deaths before the end of the first month of life) were taken into account.

We used the person-day dataset and also extended the previous equation (1) including a t subscript that refers to the current tth day within 30 days after childbirth:

 (2)

where *β* represents a parameter vector and *X* refers to the time-invariant controls (biodemographic variables, household covariates, parish, year of birth, wheat price and minimum daily temperature registered in the birth day), *Z* and *γ* stands respectively for the time-varying covariates (age of neonates and minimum current daily temperature) and the correspondent vector of coefficients.

As in the previous model specification, a cluster random effect at mother level was also included. For all models, Stata 12 was used for the statistical analyses (Stata Statistical Software: Release12. College Station).

Preliminary focusing on the period from 1820-1900, a Base Discrete-Event History Model includes only SES categories and temperatures, whereas a Full Model also takes into account the other bio-demographic, household and exogenous controls (table 4). A final set of models (table 5) further considers the interaction between SES and temperatures for the 1820-1900 period, and distinguishing the two subintervals from 1820-1859 and from 1860-1900.

*Expected Outcomes*

In the first logistic regression analysis, higher neonatal mortality risks are expected in the cold winter season and for rural landless labourers, while a significant interaction between season and SES is also expected, as already explained in the Theoretical Framework section.

Considering the control variable, higher neonatal mortality risks are expected for male, twins, younger and older mothers, and shorter birth interval with the last child alive. Positive linear effects are expected for the number of individuals and the number of women 60 years old and over in household, respectively proxies of the family wealth and caregiving attention. To control for the effects of short-term economic fluctuations, wheat prices were also taken into account and an increase in wheat prices is expected to impact negatively on the neonatal survivorship. Controlling for the parish of birth, lower risks of neonatal death are expected for newborns in San Donnino that was closer to the town of Bologna. The models include a birth year variable to control the beneficial effects in neonatal survivorship due to progress in obstetrical care and so expecting a negative linear effect.

In the second discrete-event history model, the effect of the temperatures, as time-constant and time-varying variables referring, are expected to be negative linear.

As random effects at the mother level are also included in both the logistic and the event-history model, passing from the base model to the full model including the biodemographic factors and the exogenous variables, we expected that the residual variation due to the unexplained component at the family level decreases and consequently the intra class correlation progressively reduces.

RESULTS

In a preliminary logistic regression, the dependent variable is the probability of dying within 30 days after childbirth taking into account all the births from 1820 to 1900. The results of this analysis are presented in Table 3.

Looking at the base model in table 3, the group of “Artisans, bourgeoisie and others” experienced 29 % lower neonatal mortality than the reference category of the sharecroppers and farmers. The effect of season of birth is statistically significant. The risk of neonatal deaths in winter and springtime is respectively 2.5 and 1.8 times higher than in the summer, whereas the effect in autumn with 1.5 higher risk is weakly significant. In these terms, the effects of season appear stronger than the ones related to the socio-economic differences. This tendency is still confirmed in the full model (table 3) that shows stronger and even more significant seasonal effects.

Considering the bio-demographic covariates in the full model, female neonates experienced a lower risk of dying, with a weak statistical significance (just less than 10 %). Twins registered a much higher risk of neonatal mortality fully significant. It must be noted that more than 30 twins out of 62 died in the first month of life, showing how much dangerous a multiple birth was.

We do not find a statistically significant role of the family context, though the results are consistent with our expectations. The numbers of household members and women over 60 years of age are inversely associated with neonatal mortality risk registering a weak significance within a level of 10 %.

A unit increment in wheat price significantly increased the risk of neonatal death by 4.4 %, with one year of delay.

As expected, the year of birth registers a significant declining linear effect.

Looking at the SES\*season interaction model, the “artisans and others” had a significant lower neonatal death risk than the other two rural groups during winter, whereas the landless labourers experienced higher risk in winter, but without a full statistical significance (around 10 %).

The models in table 3 also included clustered random effects at mother level. As expected, we find a progressively lower level of intra-class correlation when full control variables and interactions are considered.

Table 3 here

The event history models in Table 4 include only the births that occurred in November, December, January, February and March, during the studied period, since in those months the higher neonatal mortality rates and the lowest external temperatures were generally registered. The first base model at table 4 takes only into account the SES, the minimum temperature on the day of childbirth as time-constant and the temperatures referred to the other following 29 days afterwards as time-varying. Lower temperatures on the day of childbirth increased the risk of neonatal death significantly, whereas no significant effect was found for the daily temperature[[6]](#footnote-6). This result is stable and persists in the full model (table 4), with a 9 % reduction in neonatal mortality risk for a unit increment in the temperatures at birth.

It is confirmed that multiple births appear extremely dangerous, whereas neonates of mother younger than 25 years old experienced lower mortality risks after childbirth.. To explain this result, we should remember the high average age at the first birth that we already noted in the studied area (Rettaroli and Scalone 2012), so the mothers in this category were not so young since it did not include the adolescents who were more frequently experienced the mother-fetus competition for nutrients or difficulties in maternal physical growth. In addition, both number of individuals and women 60 years and over have non/significant effect during these coldest months. As expected, neonatal mortality risks progressively declined according to the neonate’s age. Looking at the multilevel measures of residual variations at family-level, both *u* and ICC decreased from the base to the full model (table 4). As expected, the inclusion of all the other control variables contributed in reducing the residual amount of unexplained variability at mother level.

Table 4 here

Other three models were also examined by interacting temperature at birth and SES respectively for the complete period from 1820-1900 and the two sub-intervals from 1820-1859 and from 1860-1900. Looking at the model for the 1860-1900 period, an unexpected result is the significantly higher neonatal mortality level in San Donnino, since this parish was the nearest one to the urban area. Interestingly, only the landless rural labourers registered a significant interaction with the temperature ate birth for the latter 1860-1900 interval. According to these results, in the last four decades of the nineteenth century, the lower the class of the household, the stronger the effect of the temperature at childbirth was. This result also shows that rural labourers and proletarians experienced a period of increasing difficulties during the second half of the century. It is also interesting to note that multilevel measures of unexplained variations among family decreased from 1820-1859 to 1860-1900 (table 5). So, it seems that in the last forty years of the nineteenth century, the observed variables explained a higher variation of the neonatal mortality, since the ICC decreased from the first to the second models (from 0.317 to 0.047 respectively).

Table 5 here

CONCLUSION AND DISCUSSION

In this analysis, we confirmed that the risk of dying during first month of life varies according to weather conditions, increasing as external temperatures reduce. These results were obtained controlling for several bio-demographic factors, temporal trends, short economic fluctuations and observed and unobserved family characteristics. The highest risk of infant death was found in winter, whereas the lowest risk was in the summer months. Interactions between SES and season were also found significant, revealing a higher neonatal mortality among rural labourers’ families during winter. An interesting result in this analysis is related to the effect of temperature: there is a clear influence of the day of birth’s temperature on neonatal survival, while the temperatures of the days after birth don’t have a significant relation with mortality risks. The results are confirmed suggesting that low temperatures on the day of birth exert a fundamental scarring effect on children survival. It is probable that the newborn burns a great part of his fat reserve to face very cold weather and to maintain its body temperature. Then, for the newborn, a fortiori if he is underweight, it becomes really difficult to maintain and gain weight moving forward (Costa, 1998), increasing the risk of hypothermia and other cold-related causes of death. This fact may also explain why “atrophy” was the most relevant cause of death in that region. So, the scarring effect of very cold weather on the day of birth seems to be linked to the weight loss in the first days after birth.

We also found significant differences in neonatal mortality by SES, demonstrating more pronounced season and temperature effects on landless labourers’ families.

It is likely that the majority of the rural population was not aware of the new modern puericulture practices and theories that were being developed then by academics and doctors. This lack of knowledge generally concerned proper methods of neonate protection from cold and bad weather conditions. This is further confirmed by a report of the Statistical Council of Bologna (Giunta di Statistica Bolognese) on neonatal mortality “because of the transportation habits for the civil registration or the baptism, waiting not more than a few days or just some hours after childbirth, exposing the neonate to low temperatures and bad weather conditions on distances that sometimes – for rural families – were equal to several kilometers as well” (Bertoloni, 1870). Thus, it is probable that new mothers were more frequently influenced by local practices and behaviors. In these terms, we could also interpret the non-significant effect for the older women in the household during the coldest months: even if they could give a helping hand in childrearing, their lack of modern knowledge could not protect the neonates in case of adverse conditions, such as very cold days.

In addition, as said above, we should also recall that in the area under study illiteracy levels were still high while family organization and reproductive behaviors followed norms that were more traditional than innovative (Rettaroli and Scalone, 2012).

To explain the observed differential effect by SES, it should be also recall that among the rural proletarians low quality houses and inadequate or poor clothes made neonates more vulnerable and exposed to cold and adverse weather conditions. Moreover, a worst diet and the resulting maternal state of chronic malnutrition could play relevant roles.

 In these terms, the supposed combination of maternal malnutrition and low birth weight could explain the increase in neonatal mortality risks during adverse weather conditions with low temperatures, when neonates were more vulnerable to cold.

Birth intervals from last child were never found significant. This is probably because miscarriages and stillbirths were never noted in the catholic register, thus making this variable imprecise.

To explain why temperature\*SES interactions were found significantly only in the more recent interval from 1860-1900, it must be remembered that this was a period of prolonged economic crises, increasing prices and unemployment, that particularly hit the agricultural sector (Malanima, 2006). Consequently, rural proletarians experienced a reduction in their living standards and worsening maternal and fetal conditions, while low weight neonates were less able to physiologically withstand against colder temperatures. In these terms, we could also interpret the higher neonatal mortality in the San Donnino parish, the nearest one to Bologna. We already saw that this parish had a higher demographic growth must probably due to the immigration fluxes (Scalone and Del Panta 2008). During a period of growing economic difficulties, we can assume these immigrants were the most vulnerable social groups, suffering the worst living standards, precarious conditions and higher neonatal mortality.

Both these two results reveal that, at least in its initial stages, social and economic progress did not necessarily imply a general improvement in the neonatal levels, since the most vulnerable segment of the rural population could experience a significant worsening of their living standards. Explaining these mechanisms could provide a useful lesson from the past when today policies for economic development are designed and implemented in the poorest countries. Furthermore, the main differences in neonatal mortality among socioeconomic groups could also be related to the notion of physiological capital (Fogel, 2003). Maternal life-long deficiencies in nutrition could directly affect birth weight and neonatal conditions, determining the neonate’s ability to face environmental threats. From this point of view, mothers’ and neonates’ conditions and fates are strictly related, confirming the key role of female conditions in poorer and rural societies.

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| --- | --- | --- | --- | --- |
| Table 1 Distribution of temperatures by months (Celsius degrees)  |  |  |  |  |
|   | 1820-1859 |
| Mese | min | p10 | p25 | p50 | mean | p75 | p90 | max | sd |
| January | -13.8 | -5.3 | -3.0 | -1.0 | -1.2 | 1.0 | 2.8 | 7.1 | 3.2 |
| February | -10.5 | -3.2 | -1.0 | 1.2 | 1.0 | 3.2 | 5.0 | 9.5 | 3.2 |
| March | -5.6 | 0.0 | 2.1 | 4.7 | 4.4 | 6.8 | 8.6 | 13.6 | 3.4 |
| April | -0.6 | 5.0 | 6.7 | 8.8 | 8.7 | 10.7 | 12.5 | 17.0 | 2.9 |
| May | -1.6 | 8.6 | 10.8 | 12.9 | 12.8 | 15.0 | 17.0 | 23.0 | 3.2 |
| June | 7.0 | 13.0 | 15.0 | 16.9 | 16.8 | 19.0 | 20.5 | 27.7 | 2.9 |
| July | 11.6 | 16.0 | 17.9 | 19.9 | 19.7 | 21.6 | 23.3 | 27.0 | 2.8 |
| August | 9.4 | 15.4 | 17.1 | 19.1 | 19.1 | 21.0 | 22.7 | 29.0 | 2.8 |
| September | 6.3 | 12.1 | 14.2 | 16.1 | 16.1 | 18.1 | 19.8 | 24.3 | 2.9 |
| October | 0.0 | 6.3 | 8.5 | 11.0 | 10.9 | 13.3 | 15.0 | 21.0 | 3.4 |
| November | -6.2 | 0.6 | 2.8 | 5.1 | 5.2 | 7.6 | 9.6 | 15.2 | 3.4 |
| December | -12.3 | -4.0 | -1.9 | 0.7 | 0.5 | 3.0 | 5.0 | 10.5 | 3.5 |
|   | 1860-1900 |
| Mese | min | p10 | p25 | p50 | mean | p75 | p90 | max | sd |
| January | -16.9 | -4.9 | -2.5 | -0.6 | -0.8 | 1.3 | 2.9 | 8.1 | 3.1 |
| February | -11.6 | -3.3 | -1.0 | 1.3 | 1.0 | 3.4 | 5.3 | 11.3 | 3.4 |
| March | -5.8 | -0.1 | 2.0 | 4.8 | 4.6 | 7.1 | 9.4 | 16.3 | 3.6 |
| April | -1.0 | 5.0 | 7.4 | 9.6 | 9.5 | 11.9 | 13.8 | 21.0 | 3.3 |
| May | 3.8 | 10.0 | 12.0 | 14.1 | 14.2 | 16.5 | 18.8 | 24.3 | 3.4 |
| June | 9.3 | 14.4 | 16.3 | 18.5 | 18.4 | 20.6 | 22.3 | 28.1 | 3.1 |
| July | 12.1 | 16.6 | 18.8 | 20.9 | 20.7 | 22.5 | 24.0 | 28.4 | 2.8 |
| August | 10.8 | 16.3 | 18.1 | 20.3 | 20.1 | 22.1 | 23.8 | 29.1 | 2.8 |
| September | 6.6 | 12.5 | 14.0 | 16.1 | 16.2 | 18.5 | 20.3 | 24.6 | 3.1 |
| October | 1.9 | 7.5 | 10.0 | 12.3 | 11.9 | 14.0 | 15.6 | 20.3 | 3.0 |
| November | -5.9 | 0.3 | 2.8 | 5.4 | 5.3 | 8.1 | 10.0 | 13.8 | 3.7 |
| December | -12.3 | -3.1 | -1.1 | 1.0 | 1.1 | 3.5 | 5.4 | 10.6 | 3.4 |
| Source: Registers of Astronomical Observatory - University of Bologna / Global Historical Climatology Network - National Climatic Data Center |

|  |  |  |
| --- | --- | --- |
| Table 1 Distribution of temperatures by months (Celsius degrees): minimum, mean, and maximum values, standard deviations and percentiles |  |  |
|   | 1820-1859 |
| Mese | min | mean | max | sd | p10 | p25 | p50 | p75 | p90 |
| January | -13.8 | -1.2 | 7.1 | 3.2 | -5.3 | -3 | -1 | 1 | 2.8 |
| February | -10.5 | 1 | 9.5 | 3.2 | -3.2 | -1 | 1.2 | 3.2 | 5 |
| March | -5.6 | 4.4 | 13.6 | 3.4 | 0 | 2.1 | 4.7 | 6.8 | 8.6 |
| April | -0.6 | 8.7 | 17 | 2.9 | 5 | 6.7 | 8.8 | 10.7 | 12.5 |
| May | -1.6 | 12.8 | 23 | 3.2 | 8.6 | 10.8 | 12.9 | 15 | 17 |
| June | 7 | 16.8 | 27.7 | 2.9 | 13 | 15 | 16.9 | 19 | 20.5 |
| July | 11.6 | 19.7 | 27 | 2.8 | 16 | 17.9 | 19.9 | 21.6 | 23.3 |
| August | 9.4 | 19.1 | 29 | 2.8 | 15.4 | 17.1 | 19.1 | 21 | 22.7 |
| September | 6.3 | 16.1 | 24.3 | 2.9 | 12.1 | 14.2 | 16.1 | 18.1 | 19.8 |
| October | 0 | 10.9 | 21 | 3.4 | 6.3 | 8.5 | 11 | 13.3 | 15 |
| November | -6.2 | 5.2 | 15.2 | 3.4 | 0.6 | 2.8 | 5.1 | 7.6 | 9.6 |
| December | -12.3 | 0.5 | 10.5 | 3.5 | -4 | -1.9 | 0.7 | 3 | 5 |
|   | 1860-1900 |
| Mese | min | mean | max | sd | p10 | p25 | p50 | p75 | p90 |
| January | -16.9 | -0.8 | 8.1 | 3.1 | -4.9 | -2.5 | -0.6 | 1.3 | 2.9 |
| February | -11.6 | 1 | 11.3 | 3.4 | -3.3 | -1 | 1.3 | 3.4 | 5.3 |
| March | -5.8 | 4.6 | 16.3 | 3.6 | -0.1 | 2 | 4.8 | 7.1 | 9.4 |
| April | -1 | 9.5 | 21 | 3.3 | 5 | 7.4 | 9.6 | 11.9 | 13.8 |
| May | 3.8 | 14.2 | 24.3 | 3.4 | 10 | 12 | 14.1 | 16.5 | 18.8 |
| June | 9.3 | 18.4 | 28.1 | 3.1 | 14.4 | 16.3 | 18.5 | 20.6 | 22.3 |
| July | 12.1 | 20.7 | 28.4 | 2.8 | 16.6 | 18.8 | 20.9 | 22.5 | 24 |
| August | 10.8 | 20.1 | 29.1 | 2.8 | 16.3 | 18.1 | 20.3 | 22.1 | 23.8 |
| September | 6.6 | 16.2 | 24.6 | 3.1 | 12.5 | 14 | 16.1 | 18.5 | 20.3 |
| October | 1.9 | 11.9 | 20.3 | 3 | 7.5 | 10 | 12.3 | 14 | 15.6 |
| November | -5.9 | 5.3 | 13.8 | 3.7 | 0.3 | 2.8 | 5.4 | 8.1 | 10 |
| December | -12.3 | 1.1 | 10.6 | 3.4 | -3.1 | -1.1 | 1 | 3.5 | 5.4 |

Figure 1 Neonatal Mortality Rates and Average Temperatures by Months in San Donnino and San Nicoló of Villola, 1820-1900



Table 2 Percentage distribution of neonatal deaths by causes in Emilia, 1888

|  |  |
| --- | --- |
| Causes | % |
| Birth asphyxia and apoplexy | 2.5 |
| Infantile atrophy | 58.6 |
| Convulsions | 2.8 |
| Respiratory diseases | 7.7 |
| Acute pneumonitis | 1.5 |
| Mouth diseases (excluding malignancy ) | 2.9 |
| Diseases of the intestines: enteritis and diarrhea | 8.5 |
| Sclerema (skin inflammations and lesions) | 5.7 |
| Other causes | 9.8 |
| Total  | 100.0 |
| N. of deaths | 10,511 |

Sources: Direzione Generale della Statistica, 1890

Note: "Other causes" includes all other causes of death with a percentage less than 1 %

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Table 3 Logistic regression analysis of the risk of neonatal mortality in in San Nicolò and San Donnino, 1820-1900 |  |  |  |  |  |
|   | Mean/ |   | Base Model |   | Full Model |   | Interaction Model |
|   | Percentage |   | Exp() | SE | *p* |  | Exp() | SE | *p* |  | Exp() | SE | *p* |
| Socio-economic Status |  |  |   |   |   |  |   |   |   |  |   |   |   |
| Landless rural labourers | 12.3 |  | 1.309 | 0.300 | 0.239 |  | 1.085 | 0.269 | 0.743 |  | 0.884 | 0.564 | 0.847 |
| Sharecroppers and farmers (Ref.) | 41.0 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| Artisans, bourgeoisie and others | 46.7 |  | 0.712 | 0.119 | **0.041** |  | 0.692 | 0.125 | **0.042** |  | 1.172 | 0.471 | 0.694 |
| Season |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Winter | 26.4 |  | 2.492 | 0.534 | **0.000** |  | 2.589 | 0.567 | **0.000** |  | 2.384 | 0.851 | **0.015** |
| Spring  | 28.0 |  | 1.873 | 0.406 | **0.004** |  | 1.836 | 0.407 | **0.006** |  | 2.697 | 0.945 | **0.005** |
| Summer (Ref.) | 21.6 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| Autumn  | 24.1 |  | 1.476 | 0.339 | **0.090** |  | 1.426 | 0.337 | 0.132 |  | 2.496 | 0.917 | **0.013** |
| Sex of newborn child |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Male (Ref.) | 52.4 |  |  |  |  |  | 1.000 | - | - |  | 1.000 | - | - |
| Female  | 47.6 |  |   |   |   |  | 0.785 | 0.111 | **0.087** |  | 0.795 | 0.114 | 0.108 |
| Multiple births |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Single (Ref.) | 2.2 |  |  |  |  |  | 1.000 | - | - |  | 1.000 | - | - |
| Twins  | 97.8 |  |   |   |   |  | 20.35 | 8.115 | **0.000** |  | 22.02 | 8.942 | **0.000** |
| Age of mother |  |  |  |  |  |  |  |  |  |  |  |  |  |
| < 25 | 25.4 |  |   |   |   |  | 0.827 | 0.151 | 0.297 |  | 0.833 | 0.154 | 0.322 |
| 25-34 (Ref.) | 48.7 |  |   |   |   |  | 1.000 | - | - |  | 1.000 | - | - |
| >= 35 | 23.5 |  |   |   |   |  | 0.887 | 0.163 | 0.514 |  | 0.881 | 0.164 | 0.495 |
| Unknown  | 2.5 |  |  |  |  |  | 1.543 | 0.770 | 0.385 |  | 1.550 | 0.791 | 0.390 |
| Interbirth interval and survival of last child |  |  |  |  |  |  |  |  |  |  |  |  |  |
| No previous child  | 33.3 |  |   |   |   |  | 1.524 | 0.493 | 0.193 |  | 1.483 | 0.483 | 0.227 |
| < 19 months and still living (Ref.) | 5.9 |  |  |  |  |  | 1.000 | - | - |  | 1.000 | - | - |
| < 19 months and dead  | 6.7 |  |   |   |   |  | 1.184 | 0.462 | 0.665 |  | 1.130 | 0.447 | 0.758 |
| >= 19 months  | 54.1 |  |   |   |   |  | 1.120 | 0.357 | 0.721 |  | 1.126 | 0.361 | 0.712 |
| Number of individuals in household | 9.0 |  |   |   |   |  | 0.968 | 0.019 | **0.090** |  | 0.967 | 0.019 | **0.085** |
| Number of women 60 years and over in the HH | 0.3 |  |   |   |   |  | 0.766 | 0.119 | **0.087** |  | 0.755 | 0.119 | **0.074** |
| Year of birth  | 1,858 |  |   |   |   |  | 0.991 | 0.004 | **0.033** |  | 0.992 | 0.004 | **0.043** |
| Parish |  |  |  |  |  |  |  |  |  |  |  |  |  |
| San Nicolò  | 41.7 |  |  |  |  |  | 1.000 | - | - |  | 1.000 | - | - |
| San Donnino  | 58.3 |  |   |   |   |  | 1.121 | 0.186 | 0.491 |  | 1.120 | 0.189 | 0.500 |
| Price (year-1) | 18.2 |  |   |   |   |  | 1.044 | 0.023 | **0.049** |  | 1.043 | 0.023 | **0.054** |
| Interaction SES \* Season |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Landless rural labourers\*Winter  |  |  |   |   |   |  |   |   |   |  | 3.445 | 2.451 | **0.082** |
| Landless rural labourers\*Spring  |  |  |   |   |   |  |   |   |   |  | 0.813 | 0.597 | 0.778 |
| Landless rural labourers\*Autumn  |  |  |   |   |   |  |   |   |   |  | 0.463 | 0.369 | 0.334 |
| Artisans, bourgeoisie and others\*Winter |  |  |   |   |   |  |   |   |   |  | 0.822 | 0.391 | 0.680 |
| Artisans, bourgeoisie and others\*Spring |  |  |   |   |   |  |   |   |   |  | 0.454 | 0.218 | 0.100 |
| Artisans, bourgeoisie and others\*Autumn |   |  |   |   |   |  |   |   |   |  | 0.356 | 0.182 | **0.044** |
| Clustered frailty |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Sigma u |  |  | 1.007 |   |   |  | 0.904 |   |   |  | 0.927 |  |  |
| Rho |   |  | 0.236 |   |   |  | 0.199 |   |   |  | 0.207 |   |   |
| Log likelihood  |  |  | -903.1 |   |   |  | -852.1 |   |   |  | -843.2 |   |  |
| Overall p  |   |  | 0.000 |   |   |  | 0.000 |   |   |  | 0.000 |   |   |
| Number of neonatal deaths |  |  | 292 |  |  |  | 292 |  |  |  | 292 |  |  |
| Number of births |  |  | 2,786 |   |   |  | 2,786 |   |   |  | 2,786 |  |  |
| Number of mothers |   |   | 947 |   |   |   | 947 |   |   |   | 947 |   |   |
| Source: Parish registers and Status Animarum |  |  |  |  |  |  |  |  |  |  |  |  |  |

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| Table 4 Discrete-time event history analysis of the risk of neonatal mortality in San Nicolò and San Donnino from November to March, 1820-1900 |
|   | Mean/ |   | Base Model |   | Full Model |
|   | Percentage |   | Exp() | SE | *p* |  | Exp() | SE | *p* |
| Socio-economic Status |  |  |  |  |  |  |  |  |  |
| Landless rural labourers | 9.9 |  | 3.706 | 1.286 | **0.000** |  | 1.888 | 0.562 | **0.033** |
| Sharecroppers and farmers (Ref.) | 44.3 |  | 1.000 | - | - |  | 1.000 | - | - |
| Artisans, bourgeoisie and others | 45.8 |  | 0.844 | 0.212 | 0.500 |  | 0.751 | 0.170 | 0.206 |
| Temperature at birth | 2.2 |  | 0.931 | 0.026 | **0.010** |  | 0.911 | 0.028 | **0.003** |
| Temperature | 2.5 |  | 1.018 | 0.024 | 0.436 |  | 1.031 | 0.028 | 0.255 |
| Sex of newborn child |  |  |  |  |  |  |  |  |  |
| Male (Ref.) | 52.8 |  |  |  |  |  | 1.000 | - | - |
| Female  | 47.2 |  |   |   |   |  | 0.837 | 0.146 | 0.309 |
| Multiple births |  |  |  |  |  |  |  |  |  |
| Single (Ref.) | 1.2 |  |  |  |  |  | 1.000 | - | - |
| Twins  | 98.8 |  |   |   |   |  | 14.88 | 6.735 | **0.000** |
| Age of mother |  |  |  |  |  |  |  |  |  |
| < 25 | 26.21 |  |   |   |   |  | 0.555 | 0.131 | **0.012** |
| 25-24 (Ref.) | 49.87 |  |  |  |  |  | 1.000 | - | - |
| >= 35 | 21.72 |  |   |   |   |  | 0.875 | 0.199 | 0.557 |
| Unknown  | 2.19 |  |   |   |   |  | 1.454 | 0.802 | 0.497 |
| Interbirth interval and survival of last child |  |  |  |  |  |  |  |  |  |
| No previous child  | 32.5 |  |   |   |   |  | 1.664 | 0.601 | 0.158 |
| < 19 months and still living (Ref.) | 5.8 |  |  |  |  |  | 1.000 | - | - |
| < 19 months and dead  | 7.7 |  |   |   |   |  | 0.867 | 0.409 | 0.762 |
| >= 19 months  | 54.0 |  |   |   |   |  | 0.923 | 0.324 | 0.820 |
| Number of individuals in household | 9.5 |  |   |   |   |  | 0.961 | 0.023 | 0.104 |
| Number of women 60 years and over in HH | 0.3 |  |   |   |   |  | 0.829 | 0.155 | 0.315 |
| Year of birth | 1,858 |  |   |   |   |  | 0.992 | 0.005 | 0.150 |
| Parish |  |  |  |  |  |  |  |  |  |
| San Nicolò (Ref.) | 41.4 |  |  |  |  |  | 1.000 | - | - |
| San Donnino | 58.6 |  |   |   |   |  | 1.270 | 0.258 | 0.240 |
| Month of birth |  |  |  |  |  |  |  |  |  |
| December (Ref.) | 17.7 |  |  |  |  |  | 1.000 | - | - |
| Jannuary | 20.1 |  |   |   |   |  | 1.018 | 0.286 | 0.949 |
| February | 23.1 |  |   |   |   |  | 0.603 | 0.179 | **0.088** |
| March | 23.4 |  |   |   |   |  | 1.224 | 0.372 | 0.507 |
| November | 15.8 |  |   |   |   |  | 1.024 | 0.349 | 0.946 |
| Price (year-1) | 18.3 |  |   |   |   |  | 1.050 | 0.029 | **0.074** |
| Age (in days) |  |  |  |  |  |  |  |  |  |
| 0-1 | 7.4 |  |   |   |   |  | 5.229 | 1.318 | **0.000** |
| 2-3 | 7.1 |  |   |   |   |  | 4.622 | 1.178 | **0.000** |
| 4-6 | 10.4 |  |   |   |   |  | 3.277 | 0.831 | **0.000** |
| 7-13 | 23.5 |  |   |   |   |  | 1.874 | 0.442 | **0.008** |
| 14+ (Ref.) | 51.7 |  |  |  |  |  | 1.000 | - | - |
| Clustered frailty |  |  |  |  |  |  |  |  |  |
| Sigma u |  |  | 1.750 |   |   |  | 1.003 |   |   |
| Rho |   |  | 0.482 |   |   |  | 0.234 |   |   |
| Log likelihood  |  |  | -1051.4 |   |   |  | -975.0 |   |   |
| Overall p  |   |  | 0.000 |   |   |  | 0.000 |   |   |
| Number of neonatal deaths |  |  | 175 |  |  |  | 175 |  |  |
| Number of child-days |  |  | 32,355 |   |   |  | 32,355 |   |   |
| Number of mothers |   |   | 638 |   |   |   | 638 |   |   |
| Source: As for table 1 and 3 |  |  |  |  |  |  |  |  |  |

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| Table 5 Discrete-time event history analysis of the risk of neonatal mortality in San Nicolò and San Donnino with interactions SES\*temperatures from November to March, 1820-1859 and 1860-1900 |
|   | Mean/ |   | 1820-1900 |   | 1820-1859 |   | 1860-1900 |
|   | Percentage |   | Exp() | SE | *p* |  | Exp() | SE | *p* |  | Exp() | SE | *p* |
| Socio-economic Status |  |  |   |   |   |  |   |   |   |  |   |   |   |
| Landless rural labourers | 9.9 |  | 2.267 | 0.721 | **0.010** |  | 1.042 | 0.608 | 0.943 |  | 3.675 | 1.439 | **0.001** |
| Sharecroppers and farmers (Ref.) | 44.3 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| Artisans, bourgeoisie and others | 45.8 |  | 0.778 | 0.187 | 0.296 |  | 0.789 | 0.272 | 0.491 |  | 0.974 | 0.353 | 0.942 |
| Temperature at birth | 2.2 |  | 0.935 | 0.037 | **0.089** |  | 0.925 | 0.051 | 0.156 |  | 0.960 | 0.055 | 0.479 |
| Temperature | 2.5 |  | 1.029 | 0.028 | 0.286 |  | 1.011 | 0.039 | 0.784 |  | 1.056 | 0.041 | 0.161 |
| Sex of newborn child |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Male (Ref.) | 52.8 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| Female  | 47.2 |  | 0.841 | 0.146 | 0.321 |  | 0.914 | 0.232 | 0.724 |  | 0.776 | 0.184 | 0.285 |
| Multiple births |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Single (Ref.) | 1.2 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| Twins  | 98.8 |  | 15.295 | 6.873 | **0.000** |  | 16.001 | 12.312 | **0.000** |  | 15.813 | 8.301 | **0.000** |
| Age of mother |  |  |  |  |  |  |  |  |  |  |  |  |  |
| < 25 | 51.9 |  | 0.562 | 0.132 | **0.014** |  | 0.607 | 0.206 | 0.142 |  | 0.465 | 0.157 | **0.023** |
| 25-34 (Ref.) |  |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| >= 35 | 46.6 |  | 0.881 | 0.199 | 0.577 |  | 1.122 | 0.349 | 0.711 |  | 0.590 | 0.195 | 0.111 |
| Unknown  | 1.5 |  | 1.364 | 0.755 | 0.576 |  | 1.900 | 3.741 | 0.744 |  | 1.161 | 0.610 | 0.776 |
| Distance from last birth and survival of last child |  |  |  |  |  |  |  |  |  |  |  |  |  |
| No previous child  | 32.5 |  | 1.684 | 0.608 | 0.149 |  | 1.561 | 0.866 | 0.422 |  | 2.049 | 0.949 | 0.121 |
| < 19 months and still living (Ref.) | 5.8 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| < 19 months and dead  | 7.7 |  | 0.896 | 0.424 | 0.817 |  | 0.563 | 0.410 | 0.431 |  | 1.507 | 0.957 | 0.518 |
| >= 19 months  | 54.0 |  | 0.933 | 0.328 | 0.843 |  | 0.858 | 0.448 | 0.769 |  | 1.178 | 0.556 | 0.728 |
| Number of individuals in household | 9.5 |  | 0.963 | 0.023 | 0.120 |  | 0.952 | 0.032 | 0.139 |  | 0.982 | 0.034 | 0.594 |
| Number of women 60 years and over | 0.3 |  | 0.818 | 0.153 | 0.283 |  | 0.892 | 0.325 | 0.755 |  | 0.865 | 0.198 | 0.527 |
| Year of birth | 1,858 |  | 0.993 | 0.005 | 0.170 |  | 1.023 | 0.017 | 0.165 |  | 0.979 | 0.012 | **0.086** |
| Parish |  |  |  |  |  |  |  |  |  |  |  |  |  |
| San Nicolò (Ref.) | 41.4 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| San Donnino | 58.6 |  | 1.266 | 0.256 | 0.244 |  | 0.817 | 0.242 | 0.496 |  | 1.979 | 0.548 | **0.014** |
| Month of birth |  |  |  |  |  |  |  |  |  |  |  |  |  |
| December (Ref.) | 17.7 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| Jannuary | 20.1 |  | 1.035 | 0.292 | 0.903 |  | 0.875 | 0.351 | 0.739 |  | 1.172 | 0.485 | 0.702 |
| February | 23.1 |  | 0.593 | 0.176 | **0.079** |  | 0.474 | 0.204 | **0.083** |  | 0.881 | 0.377 | 0.768 |
| March | 23.4 |  | 1.252 | 0.381 | 0.460 |  | 0.924 | 0.398 | 0.854 |  | 1.676 | 0.753 | 0.251 |
| November | 15.8 |  | 1.038 | 0.353 | 0.914 |  | 0.670 | 0.337 | 0.426 |  | 1.542 | 0.744 | 0.370 |
| Price (year-1) | 18.3 |  | 1.051 | 0.029 | **0.067** |  | 0.980 | 0.051 | 0.696 |  | 1.048 | 0.038 | 0.197 |
| Age |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 0-1 | 7.4 |  | 5.196 | 1.311 | **0.000** |  | 6.315 | 2.191 | **0.000** |  | 4.130 | 1.557 | **0.000** |
| 2-3 | 7.1 |  | 4.603 | 1.173 | **0.000** |  | 3.762 | 1.444 | **0.001** |  | 5.318 | 1.835 | **0.000** |
| 4-6 | 10.4 |  | 3.270 | 0.830 | **0.000** |  | 3.685 | 1.291 | **0.000** |  | 2.812 | 1.043 | **0.005** |
| 7-13 | 23.5 |  | 1.867 | 0.441 | **0.008** |  | 1.825 | 0.619 | **0.076** |  | 1.906 | 0.627 | **0.050** |
| 14+ (Ref.) | 51.7 |  | 1.000 | - | - |  | 1.000 | - | - |  | 1.000 | - | - |
| Interaction SES \* Temperature at birth |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Landless rural labourers\* Temp. at birth |  |  | 0.903 | 0.060 | 0.129 |  | 0.979 | 0.134 | 0.876 |  | 0.830 | 0.068 | **0.023** |
| Artisans, bourg. and others \* Temp. at birth |   |  | 0.978 | 0.046 | 0.635 |  | 1.013 | 0.067 | 0.845 |  | 0.922 | 0.065 | 0.250 |
| Clustered frailty |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Sigma u |  |  | 0.989 |   |   |  | 1.236 |   |   |  | 0.403 |  |  |
| Rho |   |  | 0.229 |   |   |  | 0.317 |   |   |  | 0.047 |   |   |
| Log likelihood  |  |  | -973.8 |   |   |  | -504.9 |   |   |  | -455.2 |  |  |
| Overall p  |   |  | 0.000 |   |   |  | 0.000 |   |   |  | 0.000 |   |   |
| Number of neonatal deaths |  |  | 175 |  |  |  | 89 |  |  |  | 86 |   |   |
| Number of child-days |  |  | 32,355 |  |  |  | 17,378 |   |   |  | 14,977 |   |   |
| Number of mothers |   |   | 638 |   |   |   | 357 |   |   |   | 306 |   |   |
| Source: As for table 1 and 3 |  |  |  |  |  |  |  |  |  |  |  |   |   |

1. The Jacini Report (1885) provided detailed information on the living standards of the rural population in Italy, which also included the studied area. This report was commissioned by the Italian Government in 1877 and represents the most complete and detailed study on Italian agriculture at that time. The report consisted in a survey sent to municipalities on agrarian property, methods of cultivation and living conditions in rural populations. The results were published and referred to twelve subdivisions of country. Information on the studied area was collected from 1877-1879 and published in the final report for the fourth sub-divisions edited by Luigi Tanari (1881). [↑](#footnote-ref-1)
2. Other evident differences were related to clothes, since the rural labourers were more poorly dressed than the sharecroppers. Their children were not sufficiently clothed and, hence, were more exposed to the winter cold. In 1881, Tanari wrote: “For neonates, the lack of good and delicate clothes can cause unhappy development, wounds and imperfections for the rest of their lives”. [↑](#footnote-ref-2)
3. The first Italian chair in obstetrics was instituted in 1804 at the University of Bologna, and obstetric and gynaecological clinics were established in two hospitals in 1860, respectively Ospedale Sant’Orsola and Ospizio degli Esposti (Scalone et al. 2017). [↑](#footnote-ref-3)
4. The exact cause of sclerema neonatorum is not known. It predominantly affects very sick premature infants (James *et al.* 2006). [↑](#footnote-ref-4)
5. Stata 13 was used for the statistical analyses (Stata Statistical Software: Release13, College Station, TX, USA), applying the xtlogit commands with the re option for estimating random effects logistic regression models (Rodrìguez and Elo 2003). [↑](#footnote-ref-5)
6. To detect whether low temperatures only explain death in the first day of life, we have conducted an additional analysis excluding the deaths in birth day. This sensitive check confirms the results of the presented analysis. [↑](#footnote-ref-6)