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Seasonality of livebirths and climatic factors in Italian regions (1863-1933)

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ABSTRACT

Birth seasonality is a phenomenon that characterizes almost all the populations of the world. In spite of this, the causes underlying these seasonal fluctuations represent an as yet unsolved puzzle. Two main theoretical approaches have been proposed to explain birth seasonality. The first encompasses a social explanation and emphasizes the role of social, economic and cultural factors in determining the optimal moment (from a social perspective) for conception (e.g., according to the cycle of agricultural workload, religious festivity, marriage seasonality, etc.). The second theoretical approach encompasses an environmental explanation and focuses on the role that climatic factors (e.g., temperature, rainfall, light intensity, etc.) play in determining the optimal moment of conception from a biological perspective. Our paper may be collocated in the latter strand of the literature. The aim is to investigate the effects of temperature on conceptions, and subsequently on the seasonality of livebirths, while controlling for a possible social confounding effect, i.e. the seasonal pattern of marriage. To achieve this end, we empirically investigate the role of temperature as well as that of marriage seasonality in Italian regions for the period stretching from the Italian unification to the eve of World War II. We find that extreme temperatures (both cold and hot) negatively affect the number of births. At the same time, marriage seasonality also seems to be an important explicative factor of the seasonal fluctuation of live births.

Keywords: Birth seasonality, Marriage seasonality, Climatic factors, Economic development

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1 INTRODUCTION

Birth seasonality characterizes almost all the populations of the world (Lam and Myron 1991, 1994; Doblhammer et al. 1999). Furthermore, this phenomenon has been documented for the populations of the past as well as for today's populations. In spite of this, the causes underlying these seasonal fluctuations represent an as yet unsolved puzzle. This is an obvious reason for interest in the topic, but it is not the only one. Indeed, a better understanding of the seasonality of births may also be useful for other fields of social science. For instance, robust evidence shows that the month of birth has been of crucial importance in determining the probability of survival of new-borns, both in the demographics of the ancient regime and in modern economically underdeveloped societies (Breschi & Livi Bacci 1986, 1997; Dalla, Zuanna & Rosina 2010; Dorelièn 2015; Muñoz-Tuduri & Garcìa-Moro 2008). Furthermore, even in developed economies, the month of birth seems to be a predictor of later-life outcomes, such as educational attainment, earnings and health status (cf. Buckles and Hungerman 2013). For instance, Buckles and Hungerman (2013) report that when parental characteristics are taken into account, the magnitude of the estimated effects of the season of birth on both educational outcomes and on wages of the offspring are reduced by a factor that ranges from 25% to 40%, but that the significance of the month effect is not compromised. This suggests that the better the background of the newborn, the better his/her family is able to help him or her with education and in finding a good job, but this is not sufficient to cancel out the effects of the month of birth.

Regarding possible explanations of birth seasonality, great efforts in the existing literature have been devoted to offering a better understanding of the role played by climatic and other natural factors. For instance, various empirical works (Seiver 1985, 1989; Lam & Myron 1994, 1996), focusing on the US, have highlighted both the existence of heterogeneous seasonal pattern of births among different states and that, starting from the 1960s the magnitude of seasonal fluctuation has begun to decline, especially regarding the white population. For example, even though the maximum concentration of births in all states was in September, the Southern states were characterized by a marked dip in April and May (thus corresponding to a decrease in July and August conceptions). One possible explanation is that the particularly hot temperatures reached in that period of the year in the southern states induced a steady reduction in the number of conceptions both by reducing the frequency of coitus and by negatively influencing spermatogenesis. In particular, a meta-analysis carried out by Levine (1994) seems to confirm that heat can reduce the quantity and mobility of produced sperm. Therefore, this suggests that the April and May dip in the birth rate may be explained by reduced male fertility during the corresponding months of conception. In their empirical analysis, Lam and Myron (1996) offer support to this hypothesis. In particular, they regressed the de-trended number of monthly births that occurred in US southern states on a set of month dummies, in addition to a nine-month lagged measure of temperature, finding both that the variable capturing the effect of temperature is a highly significant predictor of monthly births and that the magnitude of the coefficients tied to the April and May dummies are sensibly reduced in comparison to a model in which only month dummies are inserted. On the same line of research, Seiver (1985, 1989) traced the reduction in the degree of seasonal fluctuation of US births to the vast diffusion of modern systems of air conditioning that began in the 1960s. Despite these encouraging results, Lam and Myron (1996) also found that, when the above-depicted multivariate regression is applied to European countries (France, Sweden, the Netherlands, Spain and England) and to Canada, the effect of temperature on monthly births turns out to be modest or not significant from a statistical perspective. Furthermore, upon analyzing birth seasonality in South Africa, Lam and Myron (1996) were unable to confirm their expectation that a country located on the southern hemisphere should be characterized by a specular model of seasonality with respect to one localized at the same longitude but in the northern hemisphere.

Manfredini (2009) replicated the empirical exercise carried out by Lam and Myron (1996) using Italian data. He concluded that extreme climatic conditions (both heat and cold) can influence conceptions and thus produce a negative effect on the number of births nine months later. He suggested that previous insignificant results obtained in the empirical literature may be due to an erratic specification of the functional form of the relationship between temperature and monthly births. Indeed, to conclude that extreme temperatures cannot influence conceptions, one should include a quadratic term of 9 months lagged temperatures in the estimated equation and test its significance. Also, Roenneberg and Aschoff (1990) concluded that temperature extremes decrease the probability of conception. In particular they explain this finding contending that as well as for other species, even for humans it is reasonable to surmise the existence of an optimal biological period for reproduction, wherein by optimal they refer to an interval characterized by higher survival probability of both parents and offspring. This period should be signalled by an optimal temperature range outside of which a mechanism of conception suppression should start.

In contradiction to this argument a recent paper by Buckles and Hungerman (2013), shows that the expected weather conditions at birth are more important than the actual conditions at conception, thus indicating that parents are choosing when to give birth to their child. Interestingly, they show that in the case of September births in the United States, the temperature at conception is not significant, while the strongest effect is produced by the expected temperature at birth. Despite the fact that these findings are intriguing and their methodology is robust regarding a very wide range of possible statistical biases, their approach neglects the possibility of a quadratic relation between weather at conception and birth seasonality. Consider, for instance, a sample of children born in September in "Birthland" which is a temperate climate area in which the average temperature in December is around 4°C and the average temperature in September is around 16/17°C. Even in the case of "Birthland", it is in practice impossible to say whether it is the temperature at the expected month of birth or the square of the temperature at the month of conception that determines the number of births in September. This eventual counterargument to Buckles and Hungermann therefore represents another reason to test the possible non-linear relationship between temperature at conceptions and monthly births.

Other natural factors that have been analyzed in relation to birth seasonality are the length of the photoperiod (Roenneberg & Aschoff 1990; Wehr 2001; Manfredini 2009) and the level of atmospheric brightness (Cummings 2002, 2007, 2010, 2012). The secretion of melatonin by the pineal gland is in fact inhibited by light, and melatonin does decrease libido in many species of mammals, thus acting as a sort of mechanism, developed through selective pressure, to signal the optimal period for reproduction from a biological point of view. Following Roenneberg and Aschoff (1990), one may argue that the decline in seasonality observed in the US by Lam and Myron (1994) could be, at least in part, explained by the capillary diffusion of artificial light or by heating and air conditioning system which have equalized the number of hours of exposure to light across the year and reduced the influence of temperature (cf. Condon 1991).[1] However, this explanation is also based on the idea that there exists an optimal period for reproduction for humans. It must be said that according to Ellison et al. (2005), even though this idea may seem plausible, no evidence exists to support this claim. Obviously, also the temperature hypothesis is prone to the latter critique. Furthermore, it remains to be established what we mean when we refer to an optimal period for human reproduction: is it the period of gestation, the weaning period or simply the month of birth? Finally, Trovato and Odynak (1993) argued that the photoperiod hypothesis is not compatible with the above-mentioned April and May peaks in the southern states of the US, since these peaks correspond to July and August conceptions, the months of maximum duration of the photoperiod. Manfredini (2009) suggested that in this case, also, the shape of the relation between the duration of the photoperiod and the number of births is not correctly specified, and in particular it is not linear but concave. This, in turn, may explain why some empirical works are unable to find a significant relation between births and photoperiod.

To our knowledge, Manfredini's work is the only empirical exercise focused on the role of climatic factors and other biological factors in Italian regions for the period 1993–2005. However, as this research is focused on a short, recent time period, it is unable to capture broader changes in seasonality patterns due to humans' increased capacity to defend themselves against climatic and environmental factors offered by the diffusion of technological advancements among the Italian population over time (e.g. air conditioning, heating system, the capillary diffusion of artificial light, the availability of effective contraceptives which allows better for control of conception than in the past, etc.). These changes happened thanks to the great economic development experienced in the country during the 1960s. This paper attempts to fill this gap by performing an analysis of the determinants of birth seasonality in Italian regions in the long run, with a particular focus on temperature.

1 Regarding the effect of photoperiod on birth seasonality, Russell et al. (1993, p. 365-366) argued that: "In temperate zones such as Finland, photoperiod may be more important than temperature. When there are two peaks, these are six months apart and triggering by 12:12 hour photoperiod is probable. In evolution, photoperiod is a critical trigger for starting reproduction, and it is likely that the 12:12 photoperiod around the equinoxes is influential in man. When the body senses that day-length is decreasing after 23 September the process is aborted, whereas it is allowed to proceed after 21 March".

2 DATA AND METHODS

Our data sources on the monthly numbers of births are the official statistics formerly produced by the Italian Ministry of Agriculture, Industry and Commerce and later by the Italian Central Office of Statistics (ISTAT). All statistics on the monthly numbers of marriages, births and deaths were collected initially from the volumes of 'Movimenti della popolazione secondo gli atti dello stato civile' supplied until 1926 by the office of statistics of the Italian Ministry of Agriculture, Industry and Commerce. After 1926, these statistics were supplied by the new government body, ISTAT. From 1953 to 1988 the name of the volumes was changed to 'Annuari di statistiche demografiche', while after 1989 the birth statistics were collected in ad hoc volumes. The period covered by our analysis spans from 1862 (Italy was unified in 1861) to 2011 for Italy as a whole, while for Italian regions data availability on both births and temperatures requires us to limit our analysis to 1933.

To give a first description of how seasonality evolved over the last 150 years in Italy (considered as a whole), we calculated the Henry index of seasonality as it follows:

$$I_{t;t+10} = \frac{\sum_{t}^{t+10} N_{i,t}}{\sum_{t}^{t+10} \sum_{i=1}^{i=12} N_{i,t}} * 1200 \qquad (1)$$

Where $N_{i,t}$ is the number of births (excluding stillbirths) for the month i in the year t.[2] Note that the index is calculated for non-overlapping ten-year periods, and it is constructed in a such way that the mean of the monthly indices in the decade t, $t+10$ is equal to 100, thus, a value of $I_{i;t,t+10}$ above/below 100 indicates that in the period $t,t+10$ the concentration of births in month i was above/below the average. Table 1 reports the results of this first descriptive analysis. The bold characters indicate the month of maximum concentration for each decade, while the minima are underlined. To have an idea of the different seasonal models at the regional level in the period 1863-1913 the reader is referred to Sanna et al. (2013).

Table 1 *Seasonality of births in Italy. 1862-2011*

Years	Month of birth											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Presumed month of conception											
	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1862-1871	107.1	**113.5**	110.8	106.5	95.7	89.1	90.7	93.2	99.7	97.9	98.6	97.2
1872-1881	104.3	**110.1**	108.7	104.1	96.6	90.4	93.8	96.9	101.8	98.2	98.5	96.5
1882-1891	108.3	**113.7**	110.8	104.9	97.2	91.0	93.1	95.8	100.1	95.7	95.3	94.1
1892-1901	109.3	**111.8**	109.5	104.8	98.1	92.3	92.6	94.6	100.2	97.5	97.2	92.1
1902-1911	**111.1**	111.0	106.6	102.0	95.4	91.4	93.5	96.1	102.1	99.7	98.8	92.1
1912-1921	**121.9**	112.8	104.7	100.5	94.5	89.8	89.2	90.4	99.3	102.3	102.2	92.2
1922-1931*	**122.6**	115.2	107.8	101.0	94.4	91.3	92.6	93.1	97.8	98.0	97.7	88.5
1932-1941	**112.8**	111.0	106.0	101.8	97.0	93.3	94.0	94.5	101.1	98.5	96.9	93.1
1942-1951	**120.2**	110.0	106.7	100.3	95.0	95.0	96.2	96.1	101.1	98.3	96.3	84.8
1952-1961	**110.9**	107.8	104.5	99.8	97.8	96.1	97.4	96.8	101.9	100.3	96.6	90.1
1962-1971	103.3	101.4	101.5	98.7	100.1	102.7	**105.3**	100.9	102.4	98.6	94.4	90.8
1972-1981	99.4	98.3	100.2	100.1	105.5	105.8	**107.5**	102.1	102.5	97.1	92.1	89.5
1982-1991	96.0	94.3	97.2	97.4	103.6	105.2	**108.7**	103.1	105.6	100.6	95.3	93.0
1992-2001	97.4	96.3	96.1	97.2	103.0	102.1	106.9	101.7	**107.3**	102.0	96.2	93.9
2002-2011	98.9	97.4	95.4	90.9	99.0	97.2	102.7	102.2	**110.6**	107.4	100.6	97.5

Note: bold characters indicate the maxima, underlined characters highlight the minima

2 The number of births in each month has been adjusted to account for the varying number of days in each month.

It is possible to distinguish three main patterns of seasonality on the basis of the similarity of values assumed by the seasonal indicators. The model of seasonality for the period 1862-1901 is characterized by a peak in the winter month of February, followed by a decline towards June (the month of minimum concentration of births), after which we find a slow recovery up to the relative maximum of September, which is in turn followed by a steady decline in the number of births. Note that the winter peaks in the number of live births coincide with peaks of conceptions in spring, thus, the months characterized by fairly mild weather conditions. The decline of births from October to December reflects a wane in the conceptions during the cold months of January, February and March. It should be noted that this model of seasonality is very similar to that described by Crisafulli et al. (2000) for southern Italy. It must also be said that, at least for the first decades under investigation, the low number of births in December and the very high number registered in January may be due to the Italian custom of postponing the birth date of those born at the end of December with the aim of delaying compulsory military service by one year. Crisafulli et al. (2000) observed that even though this problem was probably present in the data, the number of births in January continued to be higher than those registered in December even in the second part of the twentieth century when the hospitalization of births was common and thus the fraudulent postponement of registration was impossible.

In the most recent period 1962-2011, we have a reversal of the seasonal pattern with a peak of births in summer months (alternatively July or September) and a decline in winter ones (especially in December). The period 1902-1961 represents an intermediate situation between these two seasonal models, i.e. the months of maxima are still the winter months (January and February) as in 1862-1901, while the month of minimum becomes December after the decade 1922-1931.

This first descriptive analysis seems to suggest that after the so-called "Italian economic miracle" (ten years after the World War II), the timing of birth was completely transformed. However, this change cannot be automatically attributed to the increased possibility of combatting extreme climatic conditions offered by technological and economic progress (i.e. the availability of modern system of both heating and air conditioning, more sophisticated contraceptive methods, etc.).

Even though for the period 1862-1901, this first descriptive analysis seems to be in line with the idea that milder temperature favor conceptions, we are not able to test the hypothesis on the non-linear effect of temperature at the country level, because this will require a method to aggregate the weather data at this level. That is, we have temperature registered in several Italian cities that, with some degree of approximation, may be representative of the territory around them, but to calculate a country-level mean we need to choose an appropriate system of weight for these localities. Various weighting schemes have been proposed to tackle this problem but as suggested by Hanigan et al. (2006): "there is no consensus about which is the best to use, some methods are computationally intensive and some commercially available options are expensive". Given the complexity of the problem we preferred to limit our attention and analysis to the regional level, and we will give some considerations on this later on.

Thus, to formally test our idea regarding the effect of climatic factors on birth seasonality, we therefore run the following regressions for 11 Italian regions for which we have historical data on temperatures:

$$b_{i,t} = \sum_{s=1}^{s=12} \alpha_s d_s + \beta_1 Temp_{i-9,t} + \beta_2 Tempsq_{i-9,t} + \beta_3 Z_{i-9,t} + \varepsilon_t \text{ with t = 0,...,f} \qquad (2)$$

$$b_{i,t} = \sum_{s=1}^{s=12} \alpha_s d_s + \beta_1 Temp_{i-9,t} + \beta_2 Tempsq_{i-9,t} + \beta_3 Z_{i-9,t} + \varepsilon_t \text{ with t = f+1,...,T}$$

where

$$b_{i,t} = \log\left(N_{i,t} \Big/ \sum_{m=i-6}^{m=i+5} N_{m,t} \right)$$

is the log of de-trended the monthly number of live births in month *i* of the year *t* and it is obtained applying a 12-terms moving average filter.

The specification of each regression follows that proposed by Manfredini (2009). We estimated equation (2) both splitting the analysis into two time intervals (before and after f=1904) and for the entire time interval for which we have data at the regional level (1879-1933).

Temp indicates the temperature measured at the presumed time of conception (i.e. nine months before the observed number of births). These historical time series are obtained from the SCIA dataset collected by the Italian Institute for Environmental Protection and Research (Istituto Per la Protezione e la Ricerca Ambientale, ISPRA).[3] For each region, we approximated the average regional temperature using the temperature registered in each capital town. We are aware that this represents a limit of our analysis given the imprecision of this measure, which does not take into account regional climatic variability. This is perhaps the most simplistic way of treating the problem of weather data aggregation, but it represents, in part, a forced choice due to the limited territorial coverage offered by the meteorological stations in the aftermath of Italian Unification. In addition, we believe that despite its simplicity, this choice is also the most transparent. Indeed, in this way, we can exclude that our results are somehow driven by the weight that we have chosen for each meteorological station. The square of the temperature (*Tempsq*) enters the regression to account for the possible non-linear relation with birth seasonality, as suggested by Manfredini (2009).

The term d_s indicates the dummy associated with the month s (with s ranging from 1 to 12), α_s are the coefficients associated to each month dummy. Z stands for the other control variables that may influence birth seasonality. In particular, we include as a possible control for the social determinant of birth seasonality, an index of marriage seasonality (lagged by nine months).[4] Indeed, in the demographic literature, it is well known that in pre-industrial society, the seasonality of marriages strongly reflected the seasonal pattern of the agricultural workload. The latter should influence birth seasonality by making the energy balance (e.g., difference between the calories intake and the consumed calories) negative in periods when the workload was very intense and thus, according to Ellison et al. (2005), reducing the ovarian function in females, which in turn reduces the probability of conception in a given cycle. In addition to the agricultural calendar, marriage seasonality is also influenced by religious norms. In particular, marriage seasonality has been recently used to measure the degree of religious secularization in Catholic countries (Lesthaeghe & Lopez-Gay 2013; Ruiu & Breschi 2015). Up until the Second Vatican Council, the Catholic Church forbade the solemnization of marriages during the period of spiritual preparation for Easter and Christmas. Thus, the extent of respect for this ban should reflect the extent to which religious norms were observed in a society. Returning our attention to birth seasonality, one may therefore surmise that, in a non-secularized society, spouses may tend to abstain from sexual intercourse during the periods of religious penance – specifically Lent and Advent.

Other scholars (Matsuda & Kahyo 1994; Grech et al. 2003) found that the seasonal movement of marriage is related to the seasonal movement of first-order births. In traditional societies, one may assume that the first sexual intercourse between spouses happens after the marriage, therefore this may explain the observed correlation. However, according to Trovato and Odynak (1993) even though it seems reasonable that the seasonal movement of marriages could influence the seasonality of first order births, this does not explain why high parity births show a similar pattern of seasonality, or in some cases an even more pronounced seasonal movement (cf. Régnier-Loilier & Divinagracia 2010). With our data, we are not able to distinguish the birth parity, however, it may be argued that in a natural fertility society high order births should dominate first order births and thus should be considered as the force behind the seasonal profile of overall births. So, it is difficult to argue that an eventual relationship between the seasonal movements of overall births and marriages is driven mainly by first order births. Regarding the Lent effect, if it is present, then, this may influence all the parities and not only first births. Thus, this control is inserted in equation 2 to avoid a possible omitted variable bias. That is, suppose that we omit marriage seasonality from the analysis. On one hand, we have that marriages were avoided during summer months because of the intense workload (cf. Ruiu & Gonano 2015), the latter in turn influences the energy balance mechanism and thus produces a negative effect on the probability of conception. On the other, hot temperatures may also produce negative effects on conceptions. Thus, if we exclude marriage seasonality, intended as a proxy for the calendar of the workload, from the specification of equation 2, it is impossible to establish if we are catching the temperature effect or the workload seasonality effect.

3 See Desiato et al. (2006, 2007, 2011) for details on the construction of these measures.
4 In this case, additionally, we de-trended the monthly number of marriages by applying a 12-term moving average.

Equation 2 is estimated using two alternative approaches: 1) pooling together regional data to form a panel dataset and using it to run the random coefficient model proposed by Swamy (1970); and 2) running a separate regression for each region with and without the Newey-West (1994) correction for the standard errors.

The general form of the random coefficients model is:

$$b_i = x_i \beta_i + u_i$$

Where to simplify notation, we are indicating with x_i the regressors included in equation 2.
Swamy's model is based on the following assumptions:

$$\beta_i = \beta + v_i$$

Where:

$$E(v_i) = 0$$

$$E(v_i x_i) = 0$$

$$E(v_i v_j) = \begin{cases} \sigma_i^2 \text{ if i=j} \\ 0 \text{ if i} \neq \text{j} \end{cases}$$

So, the parameters are allowed to vary from a region i to another j depending on the error specific term v_i, and have a common mean equal to β.

The two alternative approaches are proposed as a robustness check of our results. Indeed, in the Swamy's random coefficients model, the idiosyncratic error v_i is permitted to be heteroskedastic over the units (the regions in our case), allowing an inference that is robust to this kind of heteroskedasticity but not to the eventual presence of auto-correlation. Instead, the Newey-West standard errors are robust in the presence of heteroskedasticity and autocorrelation in residuals, but are also efficient in the case of homoskedasticity.

Figure 1 Regions used in regression analysis

At the moment, we are only able to present results for the period 1879-1933 for 11 Italian regions (Piedmont, Emilia Romagna, Tuscany, Umbria, Marche, Latium, Abruzzi, Campania, Calabria, Sardinia and Sicily) for which we have collected data. The time series on temperatures at the regional level have in some cases different length. For instance, in the case of Campania, the time interval spans from 1865 to 1933, while for Calabria we have data for the period 1879-1993. For this reason, when we pool together regional data (approach 1) we decided to focus on the common period 1879-1933, while when we estimate equation 2 for a single region, we use all of the available data for that region. In this way, we will be able to both exclude the possibility that our results are conditioned by the choice of the interval 1879-1933, and to avoid multicollinearity due to co-movement over time among the explanatory variables which may be exacerbated by the small sample size. It may also be noted that the reduction of multicollinearity problems is in fact a reason for Hsiao et al. (1989) to recommend the use of the random coefficients model instead of separated regression models for each panel unit.

Even though our regional sample is not complete (we are indeed working to extend our data for the period after the 1933), we will try to offer some comparison by discussing the results obtained by Manfredini (2009) for the period 1993-2005. The map of Italian regions (the borders of which are those that were in force before the Great War) reported in Figure 1 highlights both the regions considered for our analysis and the cities for which we have collected the data on temperature (note that for Marche and Tuscany, they are not the capital towns).

3 REGIONAL RESULTS FOR THE PERIOD 1879-1933

We now focus on the 11 regions for which we have collected data on temperature and thus on the results of the estimation of equation 2.

In Table 2, we report the results of the estimation of equation (2) for two non-overlapping temporal windows: before 1904 and after 1904. Specifically, the results associated to the methodology proposed by Swamy (1970) are presented in Table 2. Note also that, at the end of the table, we report a test of parameter constancy among regions. If we reject the null hypothesis, the random coefficient model should be preferred to the pooled OLS. The baseline model is that which includes only month dummies (columns 1 and 2), after which we include the temperature and test for both a linear and a quadratic relation (columns 3 to 6) and finally our indicator of marriage seasonality is introduced (columns 7 and 8). In column 9 we report the model estimated over the whole period 1879-1933. In column 10, for comparative purposes, we report the coefficients associated with *Temp* and *Tempsq* estimated for the period 1994-2005 by Manfredini (2009). As mentioned, the first year for which we have data on both monthly births and temperature for all the eleven regions is 1879. This required us to limit the pooled analysis only for the common period 1879-1933. In Table 4, in the appendix, we report the average temperatures measured in Celsius degrees together with the associated standard deviations, registered in February, May, August and November from 1876 to 1925 in Turin (capital town of Piedmont), Rome (capital town of Latium) and Palermo (capital town of Sicily) to give an idea about the North-South climatic heterogeneity in the four seasons.

We confirm Manfredini's findings regarding the U-reversed shape of the relation between temperature and the seasonality of live births. It must be noted that the number of regions (and their borders) used in our analysis is not perfectly comparable with that used by Manfredini, comprising all Italian regions (with the exception of Basilicata, Molise and Aosta Valley) which has obvious implications for the comparability of the results. With this note of caution in mind, it is suggestive that the coefficients estimated by Manfredini (column 10) are lower in terms of magnitude than those estimated in the current analysis (column 6), thus suggesting that technological progress (i.e. the availability of better means of protection against climatic factors) may have weakened the impact of temperature on births' seasonality, though without changing the shape of the relation. Hot and cold temperatures are still able to influence seasonality as highlighted by Manfredini, but with less influence than in the past, as shown by our analysis.

Regarding the nine-months lagged monthly indicator of marriages, we find that a one percentage point increase in marriage seasonality leads to an approximate 0.05% increase in the seasonal indicators of live births. The latter result is in line with the idea that, in agriculture-based economies, marriages tended to be concentrated in periods characterized by low workload intensity, in which the constraints of limited resource availability were less binding, thereby making these periods optimal (in terms of availability of energy) for conceptions as well as marriages.

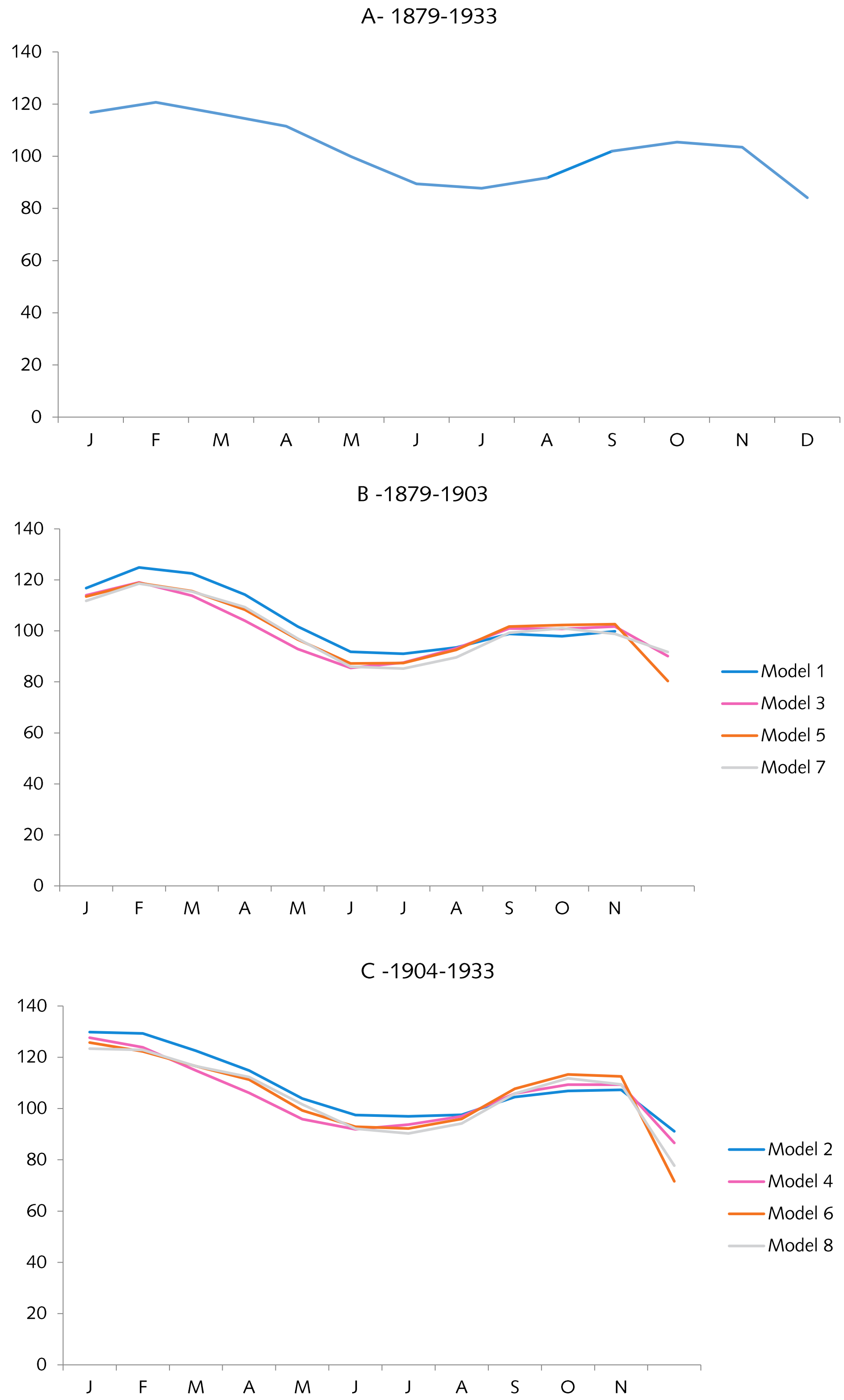
Table 2 *Results from the random coefficients model, 1879-1933*+

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	<1904	≥1904	<1904	≥1904	<1904	≥1904	<1904	≥1904	1879-1933	1994-2005++
Jan	0.155***	0.261***	0.131***	0.244***	0.126***	0.229***	0.111***	0.210***	0.155***	
	(0.019)	(0.044)	(0.020)	(0.046)	(0.019)	(0.044)	(0.017)	(0.045)	(0.027)	
Feb	0.222***	0.257***	0.174***	0.214***	0.172***	0.201***	0.170***	0.206***	0.188***	
	(0.027)	(0.025)	(0.023)	(0.028)	(0.022)	(0.025)	(0.023)	(0.026)	(0.021)	
Mar	0.203***	0.203***	0.129***	0.138***	0.145***	0.153***	0.143***	0.153***	0.150***	
	(0.046)	(0.024)	(0.029)	(0.021)	(0.031)	(0.020)	(0.032)	(0.020)	(0.024)	
Apr	0.133**	0.138***	0.039	0.059**	0.080**	0.107***	0.089**	0.116***	0.109***	
	(0.058)	(0.031)	(0.035)	(0.024)	(0.037)	(0.023)	(0.039)	(0.023)	(0.031)	
May	0.017	0.038	-0.074**	-0.042	-0.034	0.008	-0.031	0.016	-0.002	
	(0.052)	(0.030)	(0.034)	(0.027)	(0.035)	(0.024)	(0.037)	(0.026)	(0.030)	
Jun	-0.086**	-0.026	-0.157***	-0.085***	-0.137***	-0.074***	-0.151***	-0.082***	-0.112***	
	(0.038)	(0.027)	(0.030)	(0.029)	(0.032)	(0.028)	(0.034)	(0.030)	(0.030)	
Jul	-0.094**	-0.031	-0.133***	-0.065**	-0.135***	-0.081***	-0.160***	-0.102***	-0.131***	
	(0.038)	(0.027)	(0.037)	(0.030)	(0.038)	(0.030)	(0.043)	(0.033)	(0.036)	
Aug	-0.067*	-0.025	-0.071**	-0.031	-0.077**	-0.041	-0.110***	-0.060**	-0.087***	
	(0.035)	(0.027)	(0.036)	(0.028)	(0.037)	(0.029)	(0.041)	(0.030)	(0.034)	
Sep	-0.012	0.044*	0.009	0.057**	0.017	0.074***	-0.008	0.057**	0.019	
	(0.030)	(0.025)	(0.033)	(0.023)	(0.033)	(0.023)	(0.035)	(0.022)	(0.028)	
Oct	-0.021	0.066***	0.008	0.089***	0.023	0.125***	0.010	0.111***	0.053***	
	(0.021)	(0.025)	(0.023)	(0.023)	(0.022)	(0.021)	(0.022)	(0.023)	(0.018)	
Nov	-0.002	0.070***	0.017	0.089***	0.026*	0.118***	-0.012	0.090***	0.034*	
	(0.017)	(0.027)	(0.015)	(0.025)	(0.014)	(0.025)	(0.016)	(0.026)	(0.019)	
Temp			0.006***	0.006***	0.022***	0.032***	0.020***	0.031***	0.026***	0.0115***
			(0.002)	(0.001)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	
Temp_sq					-0.001***	-0.001***	-0.000***	-0.001***	-0.001***	-0.0005***
					(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
Lag_ marriage							0.067***	0.043***	0.049***	
							(0.014)	(0.010)	(0.010)	
Constant	-0.048**	-0.093***	-0.104***	-0.144***	-0.219***	-0.334***	-0.087***	-0.252***	-0.173***	
	(0.022)	(0.018)	(0.036)	(0.022)	(0.027)	(0.044)	(0.032)	(0.040)	(0.034)	
N	3698	3372	3698	3372	3698	3372	3692	3372	7064	

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
+ See the Appendix for more detail on data availability on each region.
++ See Table 2 model 2 in Manfrendini (2009).

Continued from Table 2: test of regional parameter constancy
Mod. 1: Test of parameter constancy: chi2(120) = 9149.94 Pr > chi2 = 0.000; Mod. 2: Test of parameter constancy: chi2(120) = 3778.07 Pr > chi2 = 0.000;
Mod. 3: Test of parameter constancy: chi2(130) = 9695.41 Pr > chi2 = 0.000; Mod. 4: Test of parameter constancy: chi2(130) = 3932.55 Pr > chi2 = 0.000;
Mod. 5: Test of parameter constancy: chi2(140) = 9121.48 Pr > chi2 = 0.000; Mod. 6: Test of parameter constancy: chi2(140) = 3871.75 Pr > chi2 = 0.000;
Mod. 7: Test of parameter constancy: chi2(150) = 9310.80 Pr > chi2 = 0.000; Mod. 8: Test of parameter constancy: chi2(150) = 4085.62 Pr > chi2 = 0.000;
Mod. 9: Test of parameter constancy: chi2(150) = 9927.97 Pr > chi2 = 0.000.

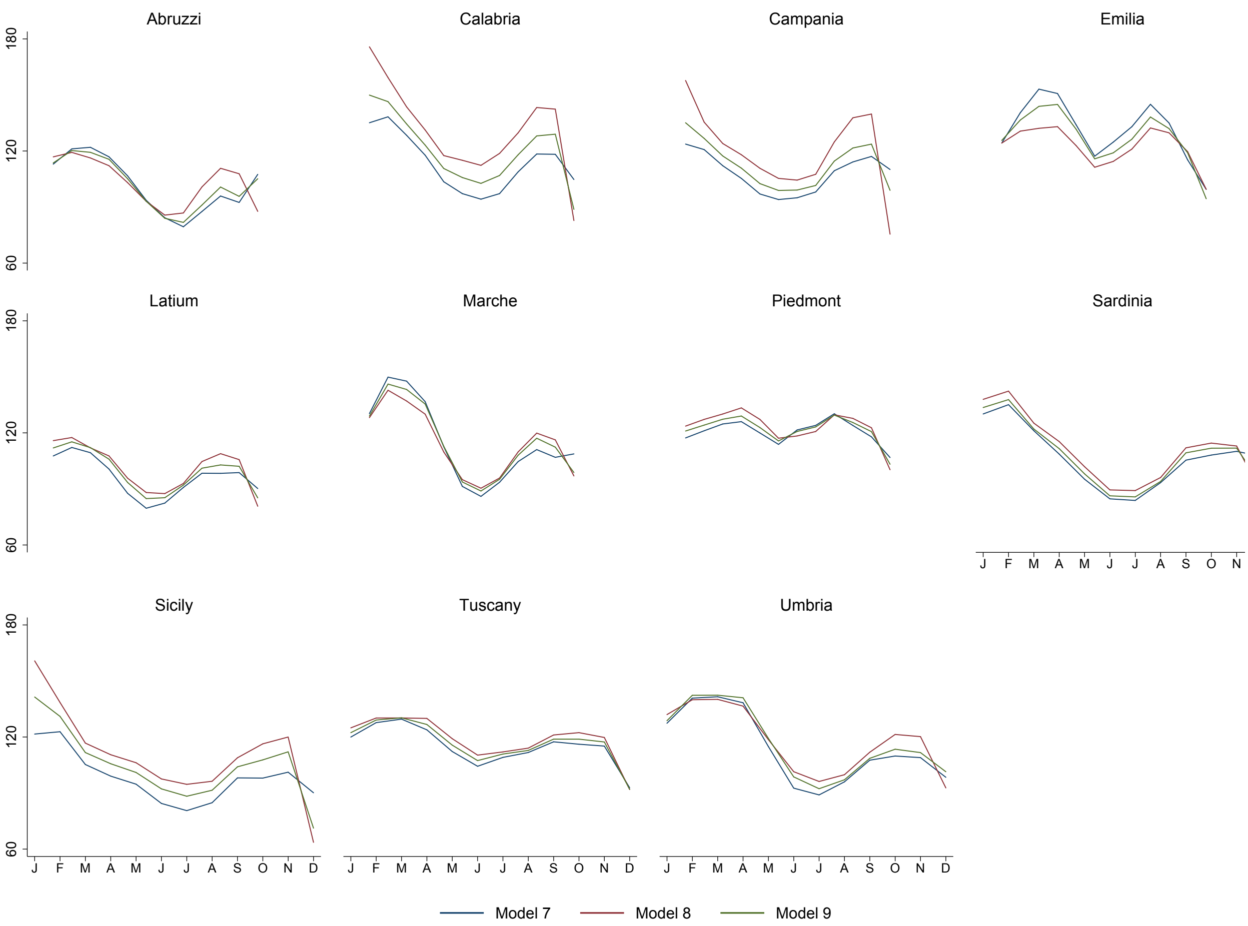
Figure 2 Seasonality curve resulting from the random coefficients model, 1879-1933



In Figure 2 (panel a) we plot the seasonality curves resulting from the coefficients estimated for month dummies in column 9 (we exponentiated the coefficients and then multiplied the result by 100 to make the seasonal indicator reported in Table 1), whilst in Figure 2 (panel b and c) we report the curves of seasonality resulting from the dummy coefficients estimated in models 1, 3, 5 and 7, and in models 2, 4, 6 and 8, respectively. From Figure 2 it is evident that, when the controls for temperatures and seasonal fluctuation of marriages are included in the regression, the magnitude of the coefficients associated with month dummies are reduced in the first six months of the year. This suggests that these two factors play a role in determining both the peak in February and March (the January result is in part influenced by the above-mentioned custom of postponing the registration of births occurring in the last days of December) and the June-July trough. Indeed, in the first case, the peak in the number of births approximately corresponds to May and June conceptions, months in which the climatic conditions do not imply extremes of hot or cold, whilst in the second case the decline of live births after the month of March is compatible with the hypothesis that fewer conceptions happen in the summer months when weddings were avoided due to the intense workload.

In Table 5 in the appendix, we report regional specific coefficients associated with lag_marriage, *Temp* and *TempSq*, estimated in models 7, 8 and 9, respectively. Note that in Piedmont, which was the most economically advanced region of those considered in this analysis, the effects of both marriages and temperatures seem to be weaker than in other places, although still statistically significant. Finally, in Figure 3 we report the seasonal curves resulting from the estimated regional specific coefficients in models 7, 8 and 9. As a robustness check, we also run the models separately for each region. In Tables 3 (panel a, b and c) we report the model estimated for Piedmont (northern Italy), Latium (central Italy) and Sicily (southern Italy). In each regression, we report also the result of the Newey-West (1994) procedure to estimate standard errors that are robust in the presence of heteroskedasticity and autocorrelation.[5] The results associated with the remaining regions are reported in the appendix in Table 6. The results obtained about the quadratic relationship between temperature and birth seasonality are generally confirmed by this alternative approach.

Figure 3 Regional seasonal curves resulting from the random coefficient model, 1879-1933



Note also that in Table 3, we also include a dummy GWAR equal to that recorded when the year of analysis is within the interval 1915-1919 (Italy entered the war one year after its start). This was

5 So this analysis is carried out to ensure that our inference is robust to different possible violations of the standard assumptions on which regression analysis is based.

done to control for the possible disturbing effects of the Great War. Even though the war ended in November 1918, we extend our dummy to 1919 to also capture the effect of the Spanish flu. In particular, Palloni (1988) has developed a general framework that describes the demographic changes after dramatic events which imply a mortality crisis, such as wars or epidemics. In particular, according to Palloni's scheme we observe a huge decrease in fertility levels due to the dramatic increase of marriage dissolution that is in turn caused by the rising mortality. Only with some lag with respect to the return of mortality to pre-mortality-crisis levels, we observe a rebound in fertility to higher levels than pre-crisis times. With the inclusion of the dummy GWAR, we therefore want to take into account the fact that the depression in fertility due to the war may also magnify seasonal differences by furtherly depressing the number of conceptions in "non optimal" months.

In the case of Piedmont (table 3), it can be noted that the statistical significance of the coefficients associated with the lagged measure of marriage seasonality is weakly statistically significant (only in column 2). Given that Piedmont was one of the first Italian region (together with Liguria and Lombardy) in which industrialization took place, the fact that the relationship between marriage seasonality and birth seasonality is weak may suggest that the economic development of this part of Italy had probably slowed down before the relation between agricultural working intensity and marriage fluctuation.

Table 3. *Regional level regression using Newey-West standard errors: Piedmont, Latium, Sicily*

	A-Piedmont (Northern Italy) 1866-1926		B-Latium (Central Italy) 1872-1933		C-Sicily (Southern Italy) 1876-1933	
	(1) OLS	(2) OLS with Newey-West s.e.	(1) OLS	(2) OLS with Newey-West s.e.	(1) OLS	(2) OLS with Newey-West s.e.
Temp	0.0067***	0.0067***	0.0271***	0.0271***	0.0441***	0.0441***
	(0.0019)	(0.0022)	(0.0048)	(0.0055)	(0.0075)	(0.0077)
Tempsq	-0.0002***	-0.0002***	-0.0008***	-0.0008***	-0.0013***	-0.0013***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Lag.marriage	0.0074	0.0074*	0.0411***	0.0411***	0.0343***	0.0343***
	(0.0048)	(0.0045)	(0.0075)	(0.0087)	(0.0097)	(0.0105)
GWAR	-0.0156**	-0.0156	-0.0179**	-0.0179**	-0.0072	-0.0072
	(0.0064)	(0.0099)	(0.0079)	(0.0086)	(0.0092)	(0.0100)
N	716	716	717	717	676	676
adj. R^2	0.405	0.405	0.742	0.742	0.842	0.842

Month dummies included in all the columns
Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4 DISCUSSION AND CONCLUDING REMARKS

Using historical data on 11 Italian regions, we confirm the findings of Manfredini (2009) in which the relation between the monthly number of births and temperature assumes a U-reversed shape. This means that extreme temperatures (both cold and hot) negatively affect the number of births. This result is robust to various specifications of the statistical model used to infer this correlation, and to the inclusion of one of the possible social determinants of birth seasonality, i.e. the seasonal pattern of marriage.

A large interdisciplinary body of literature has found that one's month of birth is associated with various later life outcomes (instances of health problems, lifespan, educational attainment, earnings, etc.), even in modern societies. This implies that a better understanding of the forces underlying birth seasonality is relevant to a broad audience of social scientists. The role of climatic factors, and more specifically of temperature, on the seasonal pattern of births has been widely discussed and questioned in literature. On one hand, the climatic explanation seems to be valid for the U.S.A. (Lam & Myron 1996; Seiver 1989) but not for European countries. On the other, from a theoretical point of view, even though it seems very reasonable that for humans, as for other animal species, a signalling mechanism, tied to environmental conditions, of the optimal period (in terms of surviving probability for both mother and newborn) for reproduction should emerge thanks to evolutionary pressure, this is only a conjecture which is far from established in biological literature (cf. Ellison et al. 2005). Furthermore, if there is a biological basis for the effect of temperature on conception, then the correlation should emerge in all the countries characterized by temperate climates and thus by a significant temperature changes from one season to another.

Our analysis contributes to this debate by showing that in Italy, a European country characterized by mild climatic conditions, at least before the advent of economic progress which may have favoured the diffusion of a system of protection against adverse climatic conditions, the seasonal pattern of births was compatible with the idea that both cold and hot may discourage conceptions. Furthermore, if one considers the economic gradient between Italian regions, then we have that in Piedmont, the more developed territory under our analysis, the effects of environmental factors seem to be, although strongly significant from a statistical point of view, weaker in terms of magnitude with respect to less developed Southern regions. Another channel through which economic development may have contributed to weaken the relationship between climate and birth seasonality is education. For instance, Bobak and Gjonca (2001) in their analysis of seasonality in Czech Republic in 1989-1991 conclude that in modern times seasonality seems to be driven by wanted births from high educated married mothers, and thus by parents' preferences. In general our analysis shows that the timing of the birth seasonality reversal for Italy, considered as a whole, appears to be consistent with the idea that after the Italian economic miracle, social determinants may have gained more and more importance in determining the seasonal pattern of births, both because people are better protected against environmental factors and better able to program births thanks to modern contraceptives.

Despite of this, as underlined by Manfredini "while social and cultural factors have undoubtedly limited the influence of climatic conditions on birth seasonality, nevertheless about 40% of the total variability in logged births is actually explained by length of day and temperature at the moment of conception" (2009, p. 233). In our opinion, it is therefore worthwhile to continue to dig deeper into the relationship between environmental factors and conceptions to both offer a better understanding of which climatic factors are important, and of course to provide a solid theoretical motivation of these effects. To this end, in future research we plan to further extend our analysis to the period 1950-1990, for which other environmental variables (e.g. the sunshine duration and the light brightness) and regional areas are also available.

A limit, and possible weakness, of the present analysis is the usage of the temperature registered in each capital town of the regions as a proxy for their average temperature. This may have introduced some attenuation bias in the coefficient associated with temperature due to the presence of a measurement error in the explanatory variable (cf. Wooldrige 2002). In any case, it can be shown that the direction of the eventual bias is toward zero, that is, the plim $(\beta_k) = \lambda\beta$ where β_k is the estimated parameter, β is the true parameter, and $0 \leq \lambda \leq 1$ is an attenuation factor, so the eventual presence of this problem should work against our hypothesis by making the coefficient associated to the square of temperature closer to zero, even when it is negative.

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Appendix tables

Table 4. Average temperature (°C) in February, May, August, November, in Turin, Rome and Palermo, 1876-1925

Year	February			May			August			November		
	Turin	Rome	Palermo	Turin	Rome	Palermo	Turin	Rome	Palermo	Turin	Rome	Palermo
1876	2.2 (4)	9.2 (2.4)	12.4 (1.7)	14.5 (2.9)	17.6 (1.5)	19.2 (2.3)	22.6 (2.6)	24.1 (2.2)	25 (1.4)	5.2 (2.4)	10.5 (2.8)	15.2 (2.4)
1877	5.3 (2.2)	8.7 (2)	11.4 (1.9)	15.1 (2)	16.5 (1.5)	18 (1.8)	23.7 (1.9)	25.4 (1.6)	25.9 (1.6)	8.1 (2.3)	12.3 (2.5)	14.7 (1.9)
1878	5.7 (2.9)	7.8 (2.1)	10.1 (1.6)	18 (2.3)	19.2 (1.5)	19.3 (1.7)	22.2 (1.5)	24.7 (1.4)	24.8 (1.1)	4.8 (1.4)	11.7 (2.2)	16.5 (1.8)
1879	5.1 (1.8)	10.8 (1.6)	13.1 (2)	12.9 (2.4)	14.1 (2.3)	15.1 (2.5)	24 (1.6)	25.5 (0.9)	25 (1)	4.9 (2.5)	. (.)	14.5 (3)
1880	4 (1.5)	8.8 (1.7)	11.1 (1.1)	16.3 (3.6)	17.7 (1.8)	17.5 (2.1)	20.9 (1.7)	23.7 (1.7)	25.6 (2.3)	7.1 (1.3)	13.8 (2.5)	16.6 (2.3)
1881	3.9 (2.4)	9.1 (2.1)	11.4 (1.9)	16.3 (3)	16.8 (2.9)	16.5 (2.4)	23.1 (2.6)	25.1 (1.7)	26 (1.7)	6.7 (1.4)	11 (2.2)	14.7 (1.7)
1882	4.9 (2.6)	7.3 (2.5)	9.8 (2.1)	16.5 (3.4)	18.1 (2.9)	18 (2.1)	21.5 (1.7)	23.9 (1.1)	24 (1.3)	7.3 (3.3)	11.9 (3)	15.3 (2)
1883	5.9 (2.5)	10 (1.6)	11.1 (0.9)	16.5 (3.3)	17.2 (2.3)	17.3 (2.4)	21.6 (1.7)	23.6 (0.9)	23.6 (1.3)	6.3 (2.9)	11.8 (2.6)	15.3 (1.8)
1884	5.3 (1.7)	8.8 (2.1)	11.5 (1.5)	18.1 (2.2)	19.4 (2.3)	18.2 (2.4)	22.6 (2.4)	23.8 (1.8)	24.1 (1.1)	5.5 (3.6)	8.6 (3)	13.8 (2.2)
1885	3.3 (2.2)	10.5 (2.4)	11.5 (2.4)	15.7 (3.7)	17.2 (2.8)	17.2 (2.1)	21.7 (2.1)	25.7 (2)	27.3 (1.6)	8 (1.9)	13.3 (1.6)	15.6 (1.5)
1886	2.8 (1.8)	8.7 (1.8)	11.2 (1.6)	16.8 (2.8)	17.4 (3.6)	17.3 (3.2)	21.7 (2)	23.6 (1.3)	24.2 (1)	7.8 (2.8)	12.9 (4)	15.2 ()
1887	0.7 (2.7)	6.8 (2.4)	10.2 (1.4)	14.7 (2.5)	16.9 (2.2)	17.4 (1.4)	23 (2.6)	25 (2.5)	25.8 (1.7)	6.4 (2)	12.8 (2)	16.2 (2.5)
1888	1 (2.3)	7.4 (2.4)	10.7 (1.8)	17.4 (2)	18.5 (1.7)	18.8 (1.7)	21.2 (2.6)	23 (1.4)	23.9 (1.2)	7.1 (2.7)	11.3 (2.6)	15.8 (2.6)
1889	2.3 (1.8)	7.3 (2.1)	11.4 (2.4)	16.6 (1.9)	19.1 (1.7)	18.7 (1.9)	21.9 (2.5)	24 (1.8)	24.6 (1.2)	6.4 (4.4)	10.9 (3.3)	14.7 (1.9)
1890	2 (2.4)	7.8 (2.9)	10.5 (2.4)	15.8 (2.9)	18.1 (2.3)	18.2 (2.9)	22.4 (2.5)	25.3 (1.7)	25.1 (1.2)	5.9 (2)	11.6 (1.8)	13.8 (1.9)
1891	1.1 (3.2)	6.7 (1.4)	8.9 (1.6)	15.2 (2.3)	18.3 (2.3)	18 (1.8)	20.5 (2)	23.7 (1.5)	24.6 (1.2)	6 (2.1)	13 (3.3)	15.8 (2.7)
1892	4.3 (1.8)	10.2 (3.1)	12.5 (2)	17.2 (4.5)	18 (3.3)	17.3 (2.5)	23 (1.9)	24.6 (1.6)	24.3 (1)	6.2 (4.1)	12.6 (3.5)	15.7 (2.2)
1893	3.4 (2.9)	8.7 (2.8)	11.3 (2.8)	16.2 (2.8)	18.4 (2)	18.2 (1.9)	23.3 (2.6)	25.1 (1.6)	24.7 (1.5)	6.6 (3.1)	13.5 (3)	17.6 (3.1)
1894	2.7 (2.2)	8.1 (2.1)	10.7 (1.4)	15.8 (2.4)	18.1 (2)	18.2 (2.3)	22.2 (2.2)	24.6 (1.7)	24.7 (1.2)	7.7 (3)	12.8 (2.8)	16 (1.5)
1895	-3.2 (1.7)	7.7 (3.1)	11.5 (3.3)	16.1 (2.5)	17.8 (1.3)	18 (1.9)	22.3 (1.4)	23.7 (1.3)	24.4 (1)	8.9 (4)	13.5 (4.1)	17.8 (1.9)
1896	4.7 (2.7)	7.1 (1.1)	10.4 (1.9)	15.5 (2.7)	16.6 (2.5)	16.5 (1.5)	19.5 (2.1)	23.1 (2.5)	. (.)	6.1 (2.7)	11.9 (3.1)	15.8 (3.2)
1897	6.1 (3.3)	9.8 (1.7)	11.8 (1.8)	16.5 (2.1)	17.2 (2.4)	17.8 (2.2)	22.1 (1.5)	24 (1.1)	24.2 (1)	5.8 (2.9)	10.9 (2.3)	14.7 (2.1)
1898	5 (2.5)	8.8 (2.7)	11.4 (2.7)	15 (1.8)	17.3 (1.7)	17.1 (1.6)	23.3 (2)	24.8 (1.6)	24.6 (0.7)	9.6 (2.2)	15.1 (2)	17.9 (1.3)
1899	5.5 (2.4)	9.6 (2.6)	12.1 (2.1)	16.5 (2.5)	17.5 (2.3)	18.7 (1.8)	23.1 (1.3)	24.1 (1.7)	24.6 (1.2)	7.8 (3.8)	11.4 (3.4)	15.9 (3)

1900	4.6 (2.9)	10.6 (1.9)	13 (2)	16 (2.3)	17.9 (1.7)	17.7 (1.7)	21.5 (1.6)	23.5 (1.4)	23.7 (1.3)	8.1 (2.2)	13.2 (2)	16 (1.6)
1901	-1.9 (2)	5.9 (2.8)	10 (2.2)	16.1 (2.9)	17.1 (2.4)	16.3 (2.2)	22 (1.9)	24.6 (1.1)	24.9 (1.3)	4.8 (2.3)	11.2 (3.5)	14.4 (1.9)
1902	2.1 (1.9)	10.1 (2.1)	12.8 (2.3)	13.7 (2.9)	15.2 (2.3)	15.9 (1.5)	21.4 (1.7)	24.4 (1.9)	25 (1.5)	5 (4.3)	10.9 (2.1)	15 (1.7)
1903	4.8 (2.9)	9.1 (1.6)	10.6 (1.7)	15.6 (3.5)	18.1 (2.3)	18 (1.9)	22 (1.6)	24.2 (1.4)	24.1 (0.9)	7.4 (3.2)	11.8 (2.7)	14.7 (2.2)
1904	4.8 (1.8)	10.1 (2.9)	12.7 (2.4)	18.3 (3.2)	18.5 (2.2)	18.1 (2)	22.7 (2.8)	24.9 (2.5)	24.8 (1.7)	5.9 (3.6)	10.1 (3.4)	13.1 (2.5)
1905	1.9 (1.4)	7.1 (1.7)	8.9 (1.9)	14 (2.9)	17.3 (1.8)	17.5 (2.1)	21.4 (1.8)	25 (1.1)	24.8 (1)	6 (1.8)	13.4 (2.9)	15.6 (2.5)
1906	2 (1.7)	6.9 (2.1)	9.7 (2.3)	16.3 (3.8)	17.3 (2.6)	16.5 (2)	23.3 (2.2)	25.1 (2.1)	24.3 (1.6)	7.3 (2.4)	13 (2.5)	15.7 (2.4)
1907	0.9 (2.7)	7.3 (1.5)	9 (2.1)	15.8 (3.5)	18.3 (3.1)	17.2 (2.6)	22 (2.1)	24.6 (1.9)	24.3 (1.6)	6.5 (2.7)	12.7 (3.1)	15.6 (2.8)
1908	4.5 (2.8)	7.9 (2.2)	10.2 (1.8)	18.2 (2.8)	19.6 (2.3)	18.3 (2)	20.9 (1.6)	23.8 (1)	23.9 (1.4)	5.4 (2.2)	10.4 (2.7)	14.3 (2.5)
1909	0.4 (2.3)	5.5 (1.9)	8.8 (1.7)	15.6 (3.5)	18.3 (3.7)	17.4 (2.4)	21.5 (2.4)	24 (2.2)	23.8 (1.3)	5.3 (3.1)	11.5 (3.9)	15 (3.2)
1910	4.3 (1.7)	9.1 (2.1)	10.7 (1.7)	14.2 (3.4)	16.9 (2.9)	16.1 (2.4)	20.8 (1.7)	23.3 (1)	23.2 (1.3)	5.1 (2.9)	10.8 (3.9)	14.7 (3.5)
1911	1.1 (3.8)	7.1 (3.2)	9.7 (2.6)	15.5 (2.4)	17.5 (1.5)	16.5 (1.7)	23.5 (1.7)	25.7 (1.5)	25.6 (0.8)	8.5 (1.6)	14.1 (1.9)	16.5 (2.3)
1912	5.4 (3.5)	11.3 (2.3)	13.1 (2.6)	16.7 (3.3)	17.8 (2)	17.6 (2.4)	19.2 (1.1)	22.9 (1.3)	23.5 (1.3)	3.7 (1.7)	9.9 (2.3)	13 (1.9)
1913	2.3 (2.4)	8.1 (2.9)	10.3 (2.4)	15.8 (3.3)	17.5 (2.1)	17.6 (2)	21.1 (1.9)	23.5 (1.4)	23.4 (1.3)	8 (2.4)	13.1 (2.5)	16 (1.9)
1914	4.5 (1.8)	9.3 (2.4)	11.3 (1.8)	14.9 (2.8)	17.7 (2.1)	18.2 (2.2)	21.3 (2.2)	23.3 (1.5)	22.4 (1)	6.4 (4)	11.3 (3.5)	13.9 (2.5)
1915	0.6 (1.8)	8.5 (2.4)	10.5 (3.2)	17.3 (1.9)	18.9 (1.9)	18 (1.8)	21.7 (1.8)	23.5 (1.2)	23.8 (1.3)	5.4 (3.4)	11.7 (4)	14.8 (3)
1916	4.3 (2.7)	9 (2.2)	12.1 (2.3)	17.2 (2.7)	18.6 (1.5)	18.3 (1.5)	22.2 (2.5)	23.5 (1.6)	23.8 (1.4)	7.2 (3)	13.3 (1.9)	14.5 (1.4)
1917	0.7 (2.8)	7.6 (1.7)	10.8 (1.4)	16.9 (2.8)	19 (1.6)	18.6 (1.9)	21.5 (1.5)	24.8 (1.2)	25.1 (1.2)	6.3 (2.1)	10.8 (2.3)	13.6 (2)
1918	5.3 (3)	7.3 (1.8)	9.7 (1.5)	17.6 (3.3)	17.9 (1.9)	17.5 (2)	22.5 (1.6)	23.4 (1.3)	24.3 (1.1)	5.9 (4.7)	11 (3.9)	15.8 (3.3)
1919	3.1 (4.3)	8.1 (3.4)	12.4 (3.3)	16.5 (2.1)	15.9 (2)	16 (2)	23.3 (2)	25 (1)	24.2 (0.9)	3.3 (2.1)	12.5 (3.2)	14.6 (3.5)
1920	5.2 (1.9)	9 (2)	11.2 (1.9)	19.7 (2.9)	21.6 (2.7)	19.9 (2.6)	20.9 (2.3)	24.1 (2.5)	24.8 (1.8)	. (.)	11.7 (2.7)	14.9 (2)
1921	3.8 (1.7)	8.5 (1.2)	11.2 (1.4)	16.8 (3)	19 (3.3)	18.9 (2.8)	22.6 (3.3)	24.5 (2.4)	25.2 (1.4)	6.4 (3.7)	11.5 (2.6)	14.6 (2.5)
1922	3 (3.2)	8.5 (2.8)	11.9 (2)	19 (5.1)	20.6 (3.2)	19.1 (3)	24.3 (2.1)	25.9 (1.8)	25.8 (1.3)	4.6 (2.6)	10 (2.8)	13.5 (2.7)
1923	4.1 (1.4)	8.9 (1.7)	11.4 (1.5)	18.3 (2.5)	19.5 (2.4)	18.6 (2.3)	24.5 (3.3)	27.1 (2.1)	25.7 (1)	7.7 (3.6)	14.1 (1.9)	17 (1.5)
1924	3.1 (1.9)	7.9 (1.8)	11.3 (2)	18.5 (3)	20.2 (2.5)	19.8 (2.2)	. (.)	23.2 (1.8)	24.7 (2)	6.7 (3.8)	11.7 (3.6)	15.7 (3)
1925	3.9 (1.7)	9.5 (2)	12.7 (2.7)	15.9 (3)	18.2 (2.4)	18.1 (2)	. (.)	24.1 (2.2)	25.8 (1.9)	7.2 (3.1)	12.7 (3.2)	15.5 (2)

Standard dev. in parenthesis

Table 5 The effect of temperature on birth seasonality: regional specific coefficients

Region	**Macro-Area**	**Variable**	**Model 7**		**Model 8**		**Model 9**	
			Coeff.	**Sig.**	**Coeff.**	**Sig.**	**Coeff.**	**Sig.**
Piedmont	North	Lag_marriage	0.0244	0.006	0.0181	0.001	0.0109	0.025
		Temp	0.006	0.001	0.0135	0.001	0.0074	0.001
		Tempsq	-0.0001	0.058	-0.0004	0.001	-0.0002	0.001
Emilia_Romagna	North	Lag_marriage	0.1032	0.001	0.0337	0.001	0.0296	0.001
		Temp	0.0142	0.001	0.0136	0.001	0.0163	0.001
		Tempsq	-0.0001	0.122	-0.0003	0.001	-0.0004	0.001
Tuscany	Center	Lag_marriage	0.0175	0.101	0.033	0.001	0.0212	0.001
		Temp	0.0263	0.001	0.0267	0.001	0.0267	0.001
		Tempsq	-0.0006	0.001	-0.0007	0.001	-0.0007	0.001
Latium	Center	Lag_marriage	0.0373	0.002	0.0524	0.001	0.0413	0.001
		Temp	0.0219	0.001	0.0325	0.001	0.0278	0.001
		Tempsq	-0.0005	0.001	-0.0009	0.001	-0.0007	0.001
Marche	Center	Lag_marriage	0.0849	0.001	0.0492	0.001	0.0577	0.001
		Temp	0.0146	0.001	0.0312	0.001	0.0276	0.001
		Tempsq	-0.0001	0.428	-0.008	0.001	-0.0006	0.001
Umbria	Center	Lag_marriage	0.0448	0.031	0.0316	0.001	0.0598	0.001
		Temp	0.0169	0.001	0.0242	0.001	0.0166	0.001
		Tempsq	0.0001	0.617	-0.0004	0.001	-0.0001	0.044
Abruzzi	South	Lag_marriage	0.1146	0.001	0.0323	0.008	0.1165	0.001
		Temp	0.0093	0.001	0.0227	0.001	0.0137	0.001
		Tempsq	-0.0001	0.424	-0.0007	0.001	-0.0003	0.001
Calabria	South	Lag_marriage	0.1264	0.001	0.1002	0.001	0.0694	0.001
		Temp	0.0322	0.001	0.0316	0.001	0.0327	0.001
		Tempsq	-0.0008	0.001	-0.0006	0.001	-0.0008	0.001
Campania	South	Lag_marriage	0.0409	0.006	0.0264	0.003	0.033	0.001
		Temp	0.016	0.001	0.0469	0.001	0.0232	0.001
		Tempsq	-0.0003	0.001	-0.0012	0.001	-0.0005	0.001
Sardinia	South	Lag_marriage	0.0617	0.001	0.0512	0.001	0.0597	0.001
		Temp	0.0343	0.001	0.0507	0.001	0.049	0.001
		Tempsq	-0.0011	0.001	-0.0015	0.001	-0.0014	0.001
Sicily	South	Lag_marriage	0.0713	0.001	0.0361	0.001	0.0397	0.001
		Temp	0.0314	0.001	0.0473	0.001	0.043	0.001
		Tempsq	-0.0009	0.001	-0.0137	0.001	-0.0012	0.001

Note: These are the regional coefficients associated to the estimation reported in table 2.

Table 6 Regional level regression using Newey-West standard errors: other regions

	Toscana (Central Italy) 1866-1933		Umbria (Central Italy) 1876-1933		Marche (Central Italy) 1876-1933	
	(1) OLS	(2) OLS with Newey-West s.e.	(1) OLS	(2) OLS with Newey-West s.e.	(1) OLS	(2) OLS with Newey-West s.e.
Temp	0.0299***	0.0299***	0.0184***	0.0184***	0.0268***	0.0268***
	(0.0038)	(0.0042)	(0.0042)	(0.0040)	(0.0040)	(0.0050)
Temp_sq	-0.0008***	-0.0008***	-0.0002	-0.0002*	-0.0007***	-0.0007***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Lag_marriage	0.0188***	0.0188***	0.0704***	0.0704***	0.0622***	0.0622***
	(0.0059)	(0.0072)	(0.0115)	(0.0132)	(0.0105)	(0.0135)
GWAR	-0.0143**	-0.0143**	0.0406***	0.0406***	0.0112	0.0112
	(0.0071)	(0.0072)	(0.0117)	(0.0143)	(0.0101)	(0.0090)
N	788	788	669	669	676	676
adj. R^2	0.646	0.646	0.859	0.859	0.871	0.871

	Abruzzi (Southern Italy) 1879-1933+		Calabria (Southern Italy) 1879-1933+		Campania (Southern Italy) 1865-1933	
	(1) OLS	(2) OLS with Newey West s.e.	(1) OLS	(2) OLS with Newey West s.e.	(1) OLS	(2) OLS with Newey West s.e.
Temp	0.0133***	0.0133***	0.0327***	0.0327***	0.0242***	0.0242***
	(0.0030)	(0.0042)	(0.0096)	(0.0091)	(0.0051)	(0.0050)
Temp_sq	-0.0003**	-0.0003*	-0.0008***	-0.0008***	-0.0006***	-0.0006***
	(0.0001)	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0001)
Lag_marriage	0.1311***	0.1311***	0.0808***	0.0808***	0.0428***	0.0428***
	(0.0177)	(0.0196)	(0.0206)	(0.0166)	(0.0116)	(0.0142)
GWAR	.	.	.	.		0.0154
						(0.0094)
N	493	493	451	451	699	699
adj. R^2	0.826	0.826	0.820	0.820	0.758	0.758

	Sardinia (Southern Italy) 1879-1933		Emilia Romagna (Northern Italy) 1879-1933	
	(1) OLS	(2) OLS with Newey-West s.e.	(1) OLS	(2) OLS with Newey-West s.e.
Temp	0.0495***	0.0495***	0.0178***	0.0178***
	(0.0066)	(0.0071)	(0.0031)	(0.0036)
Temp_sq	-0.0015***	-0.0015***	-0.0005***	-0.0005***
	(0.0002)	(0.0002)	(0.0001)	(0.0001)
Lag_marriage	0.0639***	0.0639***	0.0314**	0.0314***
	(0.0137)	(0.0235)	(0.0122)	(0.0118)
GWAR	-0.0038	-0.0038	-0.0022	-0.0022
	(0.0081)	(0.0072)	(0.0097)	(0.0088)
N	629	629	550	550
adj. R^2	0.879	0.879	0.657	0.657

Standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
+ Data on temperature are not available from 1915 jan to 1925 apr for Abruzzi and from 1909 jan to 1924 dec for Calabria.
Month Dummies included in all the estimations.