TRACING DEMOGRAPHIC EVENTS THROUGH THE SEASONS IN 18TH AND 19TH CENTURY BOLOGNA

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Abstract. This study explores the seasonality of demographic events, focusing on birth seasonality in Bologna from 1729 to 1860. Utilizing monthly data series, the research investigates the impact of meteorological conditions, specifically rainfall and temperature, on birth trends. The analysis employs Henry's seasonality indicators and OLS regression models to examine the effects of lagged precipitation and temperature on birth rates. The findings reveal a consistent pattern of birth seasonality, with births peaking in the early months of the year and declining in summer. The study concludes that weather conditions had a significant, albeit modest, impact on birth seasonality, highlighting the historical interplay between environmental factors and demographic trends in pre-transition settings.

1. Introduction

This study examines the seasonality of births throughout historical periods, specifically through a dataset that begins in 1729, well before the demographic and epidemiological transition, and extends to 1860. The monthly birth series cover the urban area of Bologna and the surrounding countryside. Bologna was a significant city in Northern Italy, located at the boundary between the southern part of the Po Valley and the Apennine Mountain range. It should be noted that previous studies on birth seasonality in a long historical perspective have focused on entire countries or broad regions, often overlooking the climatic variations that can exist within individual states or regions (e.g. Baroni, 1964). The contribution of this article to existing literature is significant due to the nearly century-and-a-half span of the series.

The data series were collected by Athos Bellettini in the 1960s and are part of a broader project to reconstruct the population of Bologna, drawing from ecclesiastical sources (Bellettini, 1961). In addition to the comparative perspective achieved by examining Henry's seasonality indexes, we will assess how much of the observed birth seasonality was due to temperature and rainfall impacts. Through specific regression models, we will evaluate the impact of meteorological factors on monthly births, accounting for monthly temperatures and precipitation and other potential confounding factors, such as epidemics, which could be linked to seasonality.

2. Area

The study area, Bologna and its environs, is located in a northern Italian region bridging the Po Valley's last stretch and the Apennines' initial hills. Bologna's network of canals, essential to the city's industrial and social fabric, powered proto industries such as silk production and leather tanneries, which were renowned across Europe during the 18th century. However, these industries struggled to adapt to the advancements of the Industrial Revolution, leading to a decline by the mid-19th century.

Before Italy's National Unification in 1861, it was part of the Papal States, characterized by restrictive economic policies, including high customs duties and limited capital flow, alongside challenging transportation conditions. Agriculture remained the cornerstone of Bologna's economy, supplemented by craftsmanship and a handful of local industries that managed to withstand significant national and international competition (Kertzer and Hogan, 1989).

Throughout the 19th century, the suburban zone around Bologna was purely agricultural, with urbanization not beginning until the 20th century. During the period under study, from the 18th century until the National Unification, the countryside of the Bologna area saw sharecropping households contributing to an economy where farming coexisted with manufacturing labor. Despite sweeping socio-economic and political changes, the sharecropper population in the Bologna area remained significant, focusing on profitable crops like wine, silkworms, hemp, and wheat (Rettaroli and Scalone, 2012; Scalone *et al.*, 2017; Scalone and Samoggia, 2018).

3. Bologna's Climate

The climate in the Bologna area within Emilia-Romagna is characterized by a temperate subcontinental pattern, with the Bologna plain experiencing varied weather phenomena due to its geographic and climatic positioning. This area undergoes periods of rain and dryness, interspersed with occasional weather events such as snow, frost, hail, and fog during the colder months. Summers are warm and humid, conditions that can favor the growth of insects and mold, potentially affecting crops. This heat is accompanied by high humidity levels, making the climate somewhat challenging. The occurrence of thunderstorms, resulting from the clash of cold and warm air masses, offers temporary relief, which is quickly balanced by strong sunlight and the area's distance from the sea. The unpredictable shift between seasons made agricultural labor somewhat uncertain.

Winter brings its own set of conditions with cloudy skies and intermittent clear spells, alongside dense fog that envelops the plain. This fog, beginning in the lower regions near the Po River, eventually blankets the entire area, contributing to the overall cold winter experience. Precipitation during this season is less common, highlighting the region's subcontinental climate influences. The Bologna plain, therefore, represents a unique climatic zone where the interplay between geography and atmospheric conditions creates varied and distinctive weather patterns, reflecting the broader climatic diversity of the Emilia-Romagna region (Scalone and Samoggia, 2018).

4. Influences on Birth Seasonality in Pre-Industrial Italy

Research indicates that birth seasonality in Southern Italy during the Ancient Regime exhibited a consistent unimodal pattern, with a notable minimum in the summer months, a trend that persisted until the 1960s (Crisafulli, Zuanna and Solero, 2000). This seasonality is significantly influenced by agricultural workload intensity and climatic conditions. Evidence suggests that these factors have a reduced impact in more industrialized regions, where the rhythm of life and work is less directly tied to the agricultural calendar (Breschi and Ruiu, 2020).

The energy balance mechanism plays a crucial role in birth seasonality. Female ovarian function is highly sensitive to energy balance, particularly in agricultural economies where intense workloads and insufficient nutrition during certain seasons are common. This sensitivity can lead to variations in birth rates, aligning them closely with the agricultural cycle and seasonal food availability (Ruiu and Breschi, 2020).

Furthermore, birth seasonality is shaped by both environmental factors, such as temperature, and social factors, such as marriage seasonality. Extreme temperatures, whether hot or cold, have been found to reduce birth rates (Ruiu and Breschi, 2017). This is likely due to the physiological stresses placed on the human body, as well as changes in social behavior and activity patterns during these periods (Ruiu and Breschi, 2017). Social customs, such as the timing of marriages, also play a critical role in determining birth seasonality, as they directly influence conception patterns (Bonneuil and Fursa, 2018).

Studies such as Lam and Miron (1996) found that temperature affects human fertility, with higher temperatures generally reducing conception rates. Additionally, Lam, Miron, and Riley (1994) developed models to describe the seasonality in fecundability, conceptions, and births, highlighting the complex interplay between environmental and biological factors.

Research by Cummings (2010) found that sunshine and environmental light intensity significantly impact birth seasonality, with higher light intensity correlating with increased conception rates. Cummings (2007) provided additional confirmation of this effect, emphasizing the role of environmental light in influencing human conception patterns. Further, Cummings (2002) explored the relationship between cloud cover, melatonin, and the seasonality of human births, demonstrating how variations in light exposure can affect hormonal regulation and birth patterns. Moreover, Barreca, Deschenes, and Gulid (2018) showed that temperature shocks can cause dynamic adjustments in birth rates, underscoring the importance of climatic factors in reproductive behavior.

5. Data

For the city of Bologna and its surrounding countryside, demographic data sources were exclusively ecclesiastical at least until the early 19th century, as the city and its surrounding territory were part of the Church's territorial domain. So our study utilized data from Bellettini's extensive work, derived from these ecclesiastical sources, to trace birth events through the seasons in 18th and 19th century Bologna. Specifically, we used the Monthly Birth Series (1729-1860) from parish registers, encompassing both the town and countryside of Bologna (Bellettini, 1961), enabling us to observe long-term trends and seasonal variations in birth counts. The source used for this analysis consists of 367 volumes in which the baptized individuals are progressively transcribed and numbered month by month (Bellettini, 1961). The data refer to baptisms that occurred within a territory that remained entirely stable over the centuries[1]. The city of Bologna, indeed, is encircled by walls whose boundaries have not changed since the 13th century. Unlike the other demographic events, such as deaths and marriages, which were recorded in individual parishes, baptisms took place at a single baptismal font where newborns from the city, and often those from the countryside, were brought. The territory considered includes the parishes of the walled city and the suburbs, which certainly did not undergo significant changes until at least 1918. Only for the suburbs might there be some variation in the series, due in part to the granting of autonomy in baptismal matters to certain parishes further from the city.

[1] The debate regarding the representativeness of these records for the actual number of births is still ongoing. Among the most frequently considered aspects are: a) the possible non-coincidence between the day of birth and the day of baptism, a negligible issue for Bologna, b) the failure to register live births of infants who died before baptism, c) the exclusion of births from other confessions, such as Judaism, or d) variations in the territories from which the births originated.

To provide an idea of the average order of magnitude of the monthly birth counts in the area analyzed in this article, it can be noted that the average number of births per month from 1729 to 1860 is 246.6.

Furthermore, we incorporated precipitation and temperature data from the University Observatory of the Specola, originally recorded as daily series for the period from 1812 to 1860, and subsequently processed and disseminated as monthly average minimum temperatures and monthly total precipitation by the "HISTALP" and the “GHCNd” projects[2]. By integrating these historical datasets, we conducted a comprehensive preliminary historical analysis, exploring the influences on birth seasonality in pre-industrial Bologna through the integration of demographic and environmental variables.

6. Methods

The analysis was conducted using birth counts for the city of Bologna between the early 18th and mid-19th centuries. However, data for several years were either partially or entirely unavailable and were excluded from the analysis[3].

The analysis was divided into two main parts: firstly, the presence of seasonality in the birth counts was assessed by considering the H index in three time periods. Secondly, Regression Models were fitted to examine the relationship between birth counts and monthly average minimum temperature and monthly total precipitation, utilizing data from 1814 onwards, as meteorological records were only accessible from that year.

6.1. Seasonality Indexes

The presence of seasonality in the birth counts was assessed by using Henry’s indexes (Ruiu, 2017). This method is based on the following equation:

$$H_m = \frac{\frac{B_m}{D_m}}{\frac{\sum_{m=1}^{12} B_m}{\sum_{m=1}^{12} D_m}} \qquad (1)$$

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[2] The monthly total precipitation datasets for Bologna are available at this website: Historical Instrumental Climatological Surface Time Series Of The Greater Alpine Region, https://www.zamg.ac.at/histalp/index.php. The monthly average minimum temperatures are available at this website: Global Historical Climatology Network daily, https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily.

[3] Due to gaps and partial information in the records, we excluded the following years from the analysis: 1816, 1817, 1835-38, 1841-45.

where B_m is the birth count in a given month and D_m is the number of days in that month; therefore, it's possible to compute an index for each month and each year or period. A value of 1 for H_m indicates no evidence of seasonality, while values lower or higher than 1 signify lower or higher birth counts in the *m*-th month compared to the rest of the year.

6.2. A Regression Model

To examine the relationship between birth counts and meteorological variables, we employed regression models using the Newey-West correction to account for autocorrelation and heteroskedasticity (Stock and Watson, 2007). The analysis utilized monthly birth data from 1814 to 1860, considering both absolute values and first differences over 12 months.

For the regression models with absolute levels, the dependent variable was the number of births at time *t*. The independent variables included lagged total monthly precipitation (*Prec*) and average monthly minimum temperatures (*Temp*) at 9, 10, 11-month lags, along with controls for the month of birth, the presence of major epidemics[4] (*Epid*), and period categories (*Per*) based on the year of birth (1814-1820, 1821-1830, 1831-1840, 1841-1850, 1851-1860).

$$Births(t) = \alpha_0 + \sum_{i=1}^{12} \delta_i \, Month(t) + \sum_{p=1}^{5} \varphi_p \, Per(t) + \sum_{j=1}^{k} \omega_j \, Epid_j(t) + \sum_{i=9}^{11} \beta_{i-8} \, Prec(t-i) + \sum_{i=9}^{11} \gamma_{i-8} \, Temp(t-i) + \varepsilon_t \quad (2)$$

For the regression models with first differences, the dependent variable was the change in births over 12 months *ΔBirths*(t,12). The independent variables were the changes in total precipitation and average minimum temperatures over 12 months at 9, 10, 11-month lags, along with the same controls as the absolute level models.

$$\Delta Births(t,12) = \alpha_0 + \sum_{i=1}^{12} \delta_i \, Month(t) + \sum_{p=1}^{5} \varphi_p \, Per(t) + \sum_{j=1}^{k} \omega_j \, Epid_j(t) + \sum_{i=9}^{11} \beta_{i-8} \, \Delta Prec(t-i,12) + \sum_{i=9}^{11} \gamma_{i-8} \, \Delta Temp(t-i,12) + \varepsilon_t \quad (3)$$

The Newey-West correction accounts for autocorrelation of residuals at a first lag for the model with absolute levels, while it considers a lag of 12 for the model with first differences[5] (Stock and Watson, 2007). This approach addresses potential issues of autocorrelation in the time series data.

[4] The series of epidemics was extracted from the chronology of events that occurred in Bologna from 1796 to the present, available at this website: https://www.bibliotecasalaborsa.it/bolognaonline/cronologia-di-bologna/1796.
[5] The lag correction for absolute levels and 12-month differences for the autoregression of residuals in the regression models, estimated using the Newey-West approach, was determined based on the exploration of the residuals' autocorrelogram.

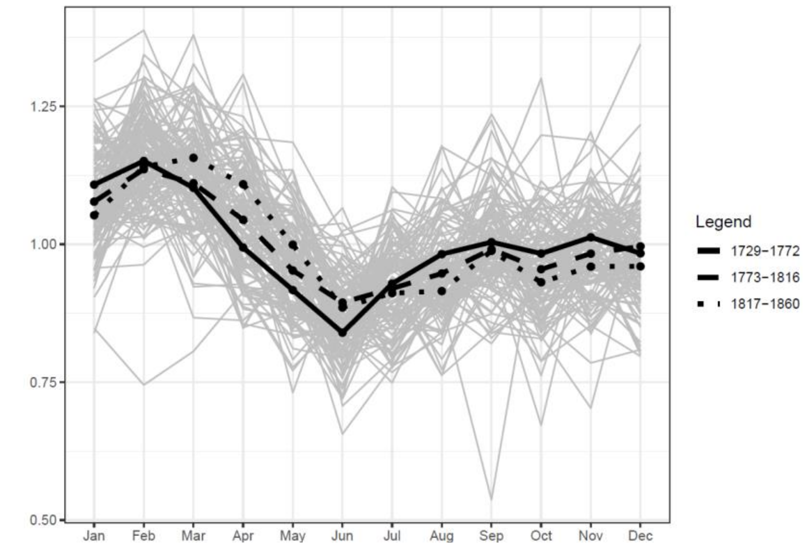
7. Results

This section presents the findings from our analysis of birth seasonality and the impact of meteorological variables on birth counts in Bologna from 1729 to 1860.

7.1. Descriptive Findings

The analysis of birth seasonality in Bologna from 1729 to 1860 reveals typical seasonal patterns. The consistent seasonality pattern shows that births generally peaked in the early months (January to March) and dipped during the summer (May to July). This pattern remained stable from 1729 to 1860, with only subtle changes in the magnitude of the peaks and troughs over time. The persistence of these trends underscores the significant role of both environmental conditions and social customs in shaping birth seasonality (figure 1).

Figure 1 – *Henry Index – Births from 1729 to 1860 in Bologna*.



7.2. Regression Results

In Table 1, we present the effects of months, temperatures, precipitation, and other control variables on the number of births in Bologna from 1814 to 1860. The table includes two types of models: absolute levels and first differences. For each type, we show both a base model without temperature and precipitation variables and a full model that includes these meteorological variables.

In the models with absolute levels, by comparing the base and full models, we first demonstrate the effect of months (seasonality) on births. Then, we show the same effect while controlling for monthly average minimum temperatures and monthly total precipitation. This approach highlights how much of the seasonality can be attributed to variations in meteorological conditions. Several months show significant coefficients, indicating strong seasonal effects on birth counts. For instance, March shows a positive and significant coefficient (15.56), suggesting a peak in births. Conversely, months like June (-53.80) and July (-27.26) show negative coefficients, indicating a decline in births during these periods. However, when controlling for precipitation and temperature, significance remains only for June and December. All period categories show positive and highly significant coefficients, with the later periods (e.g., 1851-1860) showing the highest coefficients (47.26). This indicates an overall increase in birth counts over time. Significant positive coefficients for epidemics like 1818 (22.94) and 1855 (17.86), indicating an increase in births following these events, potentially as a recovery effect.

In the models with first differences, the effect of months and period trends disappears because the series are detrended. However, these models are still valuable as they provide insight into the impact of temperatures and precipitation. The effect of these variables appears reduced in terms of coefficient size. However, it is important to consider that temperature and precipitation are measured in degrees Celsius and millimeters, respectively. Thus, the regression coefficient represents the variation in the number of births for a change of one degree Celsius or one millimeter of precipitation.

The analysis reveals that higher temperatures have a significant positive effect on birth counts at a 9-month lag, with coefficients of 2.39 and 2.23 in both models, suggesting that increased temperatures lead to more births. However, the temperature effects at other lags are not significant. In contrast, the coefficients for precipitation are negative, especially at the 9-month lag, with values of -0.05 in absolute levels and -0.08 in first differences. This indicates that higher precipitation tends to reduce birth counts, and the significance in the first differences model highlights the sensitivity of births to precipitation variations.

Table 1 – *Effects of Months, Temperatures, Precipitation and Other Control Variables on the Number of Births in Bologna from 1814 to 1860.*

	Absolute Level				12-Month Differences			
	Base		Full		Base		Full	
	Coef.	Pvalue	Coef.	Pvalue	Coef.	Pvalue	Coef.	Pvalue
Month								
Januaray	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
February	-0.17	0.974	-8.34	0.239	1.25	0.874	1.43	0.850
March	29.81	0.000	15.56	0.160	-1.22	0.864	-2.80	0.702
April	6.47	0.247	-11.82	0.425	-1.41	0.849	-0.19	0.980
May	-9.37	0.095	-24.20	0.148	-1.23	0.874	-0.60	0.940
June	-50.95	0.000	-53.80	0.001	-1.57	0.785	-0.39	0.947
July	-36.42	0.000	-27.26	0.059	0.40	0.950	0.56	0.932
August	-35.78	0.000	-12.78	0.314	0.12	0.984	-0.08	0.988
September	-25.28	0.000	3.14	0.789	-1.10	0.851	0.56	0.915
October	-31.95	0.000	-4.52	0.692	-1.57	0.805	-4.51	0.499
November	-34.42	0.000	-15.33	0.089	-0.49	0.942	-3.52	0.595
December	-25.39	0.000	-16.79	0.012	-0.02	0.998	-1.61	0.806
Period								
1814-1820	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
1821-1830	24.38	0.000	24.63	0.000	3.66	0.558	0.16	0.984
1831-1840	16.38	0.000	18.94	0.000	0.37	0.957	-3.64	0.658
1841-1850	27.01	0.000	28.31	0.000	5.89	0.640	0.65	0.957
1851-1860	42.42	0.000	47.26	0.000	2.52	0.721	-2.39	0.778
Epidemics								
1818	24.09	0.006	22.94	0.010	59.46	0.000	57.52	0.000
1822	2.04	0.807	-6.37	0.461	7.45	0.279	-0.69	0.925
1828	-2.21	0.707	-4.16	0.512	-13.05	0.064	-17.14	0.042
1849	-7.42	0.220	-6.81	0.189	-11.19	0.356	-7.13	0.502
1855	-17.66	0.005	-17.86	0.003	17.76	0.003	18.64	0.001
Temp. Lag 9			2.39	0.003			2.23	0.007
Temp. Lag 10			-0.14	0.839			-0.04	0.955
Temp. Lag 11			-0.53	0.416			-1.21	0.097
Precip. Lag 9			-0.05	0.067			-0.08	0.003
Precip. Lag 10			-0.04	0.049			-0.04	0.114
Precip. Lag 11			-0.02	0.453			-0.01	0.742
Constant	257.40	0.000	238.90	0.000	-1.12	0.883	3.54	0.692
N	432		415		384		361	

8. Conclusion

This study offers a detailed exploration of birth seasonality in Bologna from 1729 to 1860, providing insights into the influence of environmental and social factors on demographic trends. By analyzing extensive historical data, we observed distinct seasonal patterns in birth rates, with peaks in early spring and declines during the summer months. Our regression analysis revealed that meteorological variables, particularly temperature and precipitation, significantly impact birth counts, albeit their effects are relatively modest. Higher temperatures showed a positive effect on birth counts at a 9-month lag, while increased precipitation tended to reduce births. These findings highlight the sensitivity of birth rates to climatic conditions, reflecting the broader socio-economic and environmental context of the time.

The increase in birth rates during periods of better weather at the time of conception, characterized by higher temperatures and less rainfall, may be due to improved agricultural working conditions in pre-industrial agricultural societies, which could lead to a greater predisposition for procreation. This hypothesis will be further tested in future research, where we will assume nonlinear effects for temperature and precipitation series, and distinguish between urban and rural areas.

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