Max-Planck-Institut für demografische Forschung
Max Planck Institute for Demographic Research
Doberaner Strasse 114 · D-18057 Rostock · GERMANY
Tel +49 (0) 3 81 20 81 - 0; Fax +49 (0) 3 81 20 81 - 202;
http://www.demogr.mpg.de

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Seasonality of Birth in Nineteenth and Twentieth Century Austria: Steps toward a Unified Theory of Human Reproductive Seasonality

Gabriele Doblhammer, MPIDR
(doblhammer@demogr.mpg.de)
Joseph Lee Rodgers, University of Oklahoma
Roland Rau MPIDR

The first two authors are listed alphabetically, and contributed equally to this paper.

This working paper has been approved for release by: James W. Vaupel (jwv@demogr.mpg.de) Head of the Laboratory of Survival and Longevity.

Seasonality of Birth

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Steps toward a Unified Theory of Human Reproductive Seasonality

Gabriele Doblhammer-Reiter, Max Planck Institute for Demographic Research*

Joseph Lee Rodgers, University of Oklahoma*

Roland Rau, Max Planck Institute for Demographic Research

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Abstract

We present an analysis of birth seasonality in nine geographical regions within Austria for two time periods, 1881-1912 and 1947-1959. In the early period, geography, climate, and agricultural patterns were related to birth seasonality. By the later time period, these factors were no longer related to birth seasonality.We propose a "resilience hypothesis," which suggests two levels of causal influences on birth seasonality. First, underlying the three significant features of birth seasonality patterns around the world are only a small number of major causes. But, second, there are a multiplicity of minor causes that result in small perturbations in the patterns.

Introduction

A fertility phenomenon that has received less attention from demographers than might be expected is the consistent seasonal patterns in human births. Lam and Miron (1991) document the demographic significance of these seasonal patterns. Among their many examples are ones that show seasonal patterns as dramatic as those underlying the U.S. post-war baby boom. They note that “the typical May to September change in births in Georgia is at least as great as the difference between the average birth rate in the mid-1950's, the peak of the baby boom, and the mid-1970's, the trough of the baby bust” (Lam and Miron 1991: 53). Given the size, consistency, and demographic nature of birth seasonality patterns, it seems that demographers would have great interest in identifying the causes of this phenomenon. While many explanatory models have been proffered, the real causes of birth seasonality patterns are still regarded as a “puzzle” and a “mystery” (see Seiver 1985, among many others).

Consistent patterns of birth seasonality have occurred in virtually all geographic locations, often with remarkable stability across time and during extraordinary social and cultural changes. For example, most structural aspects of fertility might be expected to change during demographic transition; but the peaks and valleys in birth seasonality patterns have maintained (see Shimura et. al. 1981,who documented stable trends in the northern U.S. since at least the middle of the 18th century, and Lam and Miron’s 1991 presentation of Wrigley and Schofield’s 1981 British data). During and after the introduction of oral contraceptives and other reliable forms of birth control, seasonality patterns have remained stable (e.g., Seiver 1985). Through wars, through social upheaval, through government-supported programs of fertility control, through tremendous changes in marriage and divorce patterns, through both strengthened and weakened government control over abortion, birth seasonality patterns in most parts of the world have remained constant.

This pattern of results would appear perfectly consistent with an explanatory process arising from non-volitional biological factors. For example, gestational length has remained relatively stable across all of the demographic and cultural changes defined above as well, and no one is particularly surprised that such a strongly biological process -- with little volitional human input (save the potential for induction of birth) -- has not responded to social processes. What makes birth seasonality particularly intriguing, however, is that there are substantially different seasonality patterns at different places around the world.

If we were observing an evolutionary vestige of a time when humans were closer in biological and social structure to other animals (many species of whom display virtually fixed and extremely strong birth seasonality patterns), we might expect patterns to be similar among humans throughout the world (as is gestational length). However, we would certainly not expect the patterns to change as we crossed the border from the northern U.S. into Canada (Werschler and Halli 1992). We would not expect patterns that in some important ways were exactly opposite when we cross the ocean from the U.S. to Europe (Lam and Miron 1991). We would not expect, in unusual circumstances, for the patterns to change dramatically over the course of as little as two decades (James 1990). We would not expect, again in unusual circumstances, for seasonal patterns to dampen out completely (Brewis, Laycock and Huntsman 1996).

These facts alone would tend to discount any strongly biological interpretation of birth seasonality, at least those whose nature depended on stability across humans around the world. Seasonality patterns are anything but stable in comparison across geographic regions. On the other hand, they are quite stable for comparisons *within* geographic regions, defined across time (with a very few notable exceptions). The variation around the world in the nature of birth seasonality would seem to point to geographical or cultural differences that are maintained throughout a geographical region.

What might the causal factors underlying the intriguing birth seasonality patterns be? Although several classes of explanations have been offered (and will be reviewed shortly), we still don't know. It seems unlikely that one or even several obvious sources underlie a complete explanation of birth seasonality patterns. Otherwise these would have been noticed, evaluated, and formally specified long ago. On the other hand, the persistence of these patterns across time, the similarity of patterns from disparate locations, and certain structural features that do appear across many geographic boundaries point to a finite and explainable set of causes. As Lam and Miron (1991) concluded after reviewing empirical and theoretical literature on birth seasonality, "... no single explanation receives strong, consistent support from the data. Instead, the variation in seasonality patterns across countries and time periods poses a challenge to virtually all existing explanations, without decisively rejecting any of them" (p. 51). But the search is still on, and should become more active as the corpus of literature on the topic grows.

Sometime soon, the time will be ripe for a new inductive research effort to integrate the many individual pieces of information on birth seasonality, the goal of which will be a coherent and clear cross-cultural explanatory model explaining the causes of birth seasonality patterns. Such inductive efforts have been presented in past work, with revealing results but no generally accepted conclusions that synthetically describe patterns from many places and times. Lam and Miron (1991), and Roenneberg and Aschoff (1990) provided what are probably the most exhaustive of this type of effort. Lam and Miron (1991) emerged from their analysis believing that weather patterns had a great deal to do with birth seasonality. In later research (Lam, Miron, and Riley 1994; Lam and Miron 1996) they demonstrated the ability of weather to account for substantial portions of the variance in birth seasonality, but admittedly fell short of providing a unifying theory. Roenneberg and Aschoff (1990) allowed sociological and biological explanations to compete, and concluded that “the seasonal component in human reproduction is based on biological factors” (p. 195). More specifically, they found support for a photoperiod effect, correlated with latitude, as a strong contender for this biological explanation. However, again, their photoperiod/latitude explanation fell short of a unifying theoretical explanation.

The basic patterns that such explanations are attempting to explain fall into two categories. The pattern characterized by a peak early in the year (usually in early spring), with declining births each month for the rest of the year, is widely referred to as the “European Pattern” (although this pattern also occurs in other parts of the world as well). The pattern characterized by a trough in the spring (usually around April), with increasing births each month into the early autumn, followed then by declining births again, is usually referred to as the “American pattern” (although, again, this pattern occurs in other parts of the world as well). In addition, both patterns often show either a global or a local peak in September. Thus, there are basically three major features that explanatory models must explain, an early spring peak in some places, a spring valley in different places, and a September peak that is widely observed throughout the world.

The current paper will present evidence using a data source from an area that has not previously been evaluated. Such data sources are particularly valuable when they apply to a location or time period that has not previously been studied, and our presentation crosses both geographical and temporal boundaries. Our study of historical and more contemporary Austrian birth patterns contain some intriguing and valuable information for seasonality researchers. In the next section we will review explanations that have been offered to explain human birth seasonality. This review will help to motivate our choice of independent variables that will be evaluated in relation to Austrian birth patterns. In the next section, we will describe our data and present the methods that will be used in our analysis. Following, we discuss the results, in two ways. First, we discuss the findings themselves, in relation to stability and change within Austria from the 19th to the 20th centuries. Next, we discuss the implications these findings have for seasonality research.

Previous Explanations of Human Birth Seasonality

Researchers have looked in many different places in attempts to find the causes of human birth seasonality. Some have looked in the external physical environment. General weather patterns were considered by Lam and Miron (1996). Other weather-related factors have also been treated, including air conditioning (Seiver 1989) and sperm motility related to summer work patterns (Levine et al. 1988; Saint Pol et al. 1989). Photoperiod has also been investigated as a possible external cause (e.g., Roenneberg and Aschoff 1990), with the pineal gland as the presumed biological mechanism underlying responses to photoperiod effects (Ehrenkranz 1983). A relatively new explanatory source comes from Bailey (1992), whose model links rainfall to food production, then ultimately to ovarian function related to nutrition and finally to fertility. This explanation uses an external (and relatively local) climatic factor, rainfall, along with an internal nutritional mechanism. Support for this theory is summarized in Brewis et al. (1996), who found examples of non-seasonality around the equator that are consistent with the theory (although they emphasize that the rainfall patterns are not a critical link in the theory, but rather that any lifestyle leading to consistent patterns of “subsistence activities” should lead to non-seasonality).

Other researchers have looked at seasonality in processes preceding birth for the causes of human birth seasonality. Seasonality in puberty has been documented by Valsik (1965) and Rodgers and Buster (1994), although not in a way that would influence birth outcomes. Seasonality in sexual behavior has also been investigated (e.g., Naeye 1980; Rodgers, Harris and Vickers 1992; Udry and Morris 1967), with only tenuous relation to birth outcomes. Rodgers and Udry (1988) tied the pattern of contraception cessation in U.S. women to birth seasonality. Also studied were empirical patterns in spontaneous abortion (Kallan and Enneking 1992) and induced abortion (Peterson and Alexander 1992; Parnell and Rodgers 1998). Rodgers and Parnell (1999) presented a schematic organizing other reproductive processes in relation to pregnancy seasonality. Pregnancies can be resolved into spontaneous abortion, induced abortion, or live births. They showed that the induced abortion can influence seasonality of births by dampening the peaks and valleys in U.S. birth patterns; thus, without induced abortion, the peaks and valleys would be even higher. Their conclusion was that birth seasonality originates with seasonality of conception (also see Warren, Gwinn and Rubin 1986).

A highly related category to the second reviewed directly above is one accounting for explanatory mechanisms related to the echo of other demographic processes. Kallan and Udry (1989) investigated whether birth seasonality is caused by fluctuations in the size of the female population at risk of being pregnant, but ended up rejecting this explanation as providing an important piece of the puzzle. Others have investigated the link between marriage seasonality and birth seasonality, again without much success (Lam and Miron 1991; Mathers and Harris 1983; Rosenberg 1966).

A final category of explanatory mechanisms has arisen from the specification of social/cultural correlates of seasonality patterns. Rosenberg (1966) noted a relation between seasonality of births and SES (also see James 1971). Agricultural cycles relate to birth seasonality as well (Knodel and Wilson 1981; Levy 1986). Holidays have been suggested as a cause of human birth seasonality, with particular relevance for the link between the Christmas/New Year holiday and the September birth peak in most Christian cultures (James 1971; Lam and Miron 1991; Rosenberg 1966). Laridon (1986) was able to tie the September birth peak to conceptions occurring at the end of December, even more strongly implicating reproductive behavior occurring around the holiday.

In many cases, the nature of available data has had a major impact on the type of explanatory mechanisms that are investigated. For example, medical data are required for the study of hormonal causes of seasonality, while demographic data are required for the study of the link between marriage and births. In our current study, the data we will use come from aggregate-level vital statistics data, which require aggregate-level explanatory mechanisms. Consistent with investigative efforts described above, and to match the level of the information we have, we will investigate the role of agricultural activity, the role of longitude/latitude, and the role of weather in producing human birth seasonality patterns in historical Austria.

Data and Method

Our analysis covers the years 1881-1912 and 1947-1959 and is based on the monthly numbers of births for the respective years that are published by the Central Bureau of Statistics. Between 1881 and 1912 the Austro-Hungarian Empire still consisted of 17 regions - from Salisia in the North to Triest and Dalmatia in the South. After World War I, Austria-Hungary was carved into several independent states. The German speaking regions (with the exception of South Tyrol) formed the Republic of Austria. After World War II, in 1945, the republic was restored and since then has consisted of nine different federal states.

The regions on which we will focus for our analysis are those from the period 1881-1912 that were still part of Austria after 1945, which include Vienna, Lower Austria, Upper Austria, Styria, Carynthia, Tyrol, Salzburg, and Vorarlberg. In those regions we can present historical comparisons that cover a 78-year period. Regional boundaries did not change between the two periods with the exception of Tyrol. In addition, one other region -- Burgenland -- also maintained boundaries during this period, although monthly birth data are only available for the second time period. Table 1 shows the total number of births in each region in the two time periods.

-------------------------- Figure 1 about here ----------------------------

-------------------------- Table 1 about here ----------------------------

In its present boundaries, Austria extends 300 km (185 miles) from north to south and about 560 km (350 miles) from east to west. It covers an area of 83,850 square km (32,380 square miles), which is approximately the size of the U.S. state of Maine or South Carolina. Austria can be divided into three physiographic regions. The Alpine region in the south-west occupies about two-thirds of the territory. The highland region covers about one-tenth of the total land area; the lowland lies almost entirely in the eastern fourth of the country. A humid continental climate (cold winters and warm or hot, humid summers) characterizes the northeastern part of Austria and contrasts with the Alpine climate in the southern and western mountains.

To evaluate physical influences on birth seasonality patterns in Austria, we tested for the impact of latitude and longitude, of four climatic measures, and of the proportion of people employed in the agricultural sector on the monthly number of births. The Austrian population is very unevenly distributed, especially in the alpine regions. All regional measures were therefore defined in relation to the population centers, rather than the geographical centers. In the second time period the change in the boundaries of Tyrol has been taken into account. Longitude and latitude measures were obtained directly from maps of Austria.

To construct measures of climate, we used the following four variables:

1) Temperature in July, averaged over the years 1901-1950;

2) Proportion of sunshine in summer, average over the years 1928-1950;

3) Proportion of sunshine in winter, average over the years 1928-1950;

4) Beginning of spring -- the average date when snowdrops (Schneeglöckchen) and liverworts (Leberblümchen) start blooming (the maximum difference between the regions is approximately one month).

Considerable differences between the Austrian regions existed in both time periods in the degree of industrialization. As a result, the percentage of people employed in the agricultural sector may act as a proxy for social factors that may have influenced the seasonal distribution of births. For the first time period figures are based on the census of the year 1890 (Volks- und Berufszählung 1890), for the second time period, of the year 1961. Table 2 contains the values of the covariates.

-------------------------- Table 2 about here ----------------------------

The correlation structure of the variables revealed that the variable 'beginning of spring' is negatively correlated with the variables 'temperature in July' (Pearson correlation r= -0.81, p<.05) and 'proportion of sunshine during summer' (r= -.81, p<.05). 'Latitude' is negatively correlated with the variables 'proportion of sunshine during winter' (r= -.76, p<.05) and 'percentage of people employed in the agricultural sector' (r= -.79, p<.05). All other variables are statistically uncorrelated.

For each region we removed the time trend in the number of births by applying a 12-month moving average (Lam and Miron 1996):

$$b_{tyr} = \frac{B_{tyr}}{\sum_{m=t-5}^{t+6} B_{myr}} \qquad (1)$$

where B_{tyr} are births per day in month t of year y in region r.

Applying the following linear regression model we then tested the impact of the seven explanatory variables on b_{tyr} :

$$\ln b_{tyr} = \alpha_0 + \sum_{s=1}^{11} \beta_s d_s + \sum_{i=1}^{11k} \gamma_i x_i \qquad (2)$$

$$k=1,2,3,\ldots,7.$$

The coefficients β_s measure the impact of the monthly indicator variables d_s on the logarithm of the detrended number of births. The monthly indicators assume the value one for month t and zero otherwise. The seven sets of interaction variables, the x_i's, are derived by multiplying the monthly indicator variables with the values of the climatic, geographic and social variables for each region. June is considered as the reference month and excluded from the model. Thus, the parameter estimates give the difference in the monthly number of births as compared to June. Several regression models with different numbers of explanatory variables are estimated. The final model is selected on the basis of the R^2 statistics.

Results

The peaks and the valleys of the birth distribution are the same in historical -- late 19th century/ early 20th century -- and in more recent -- mid 20th century -- times. In both periods births generally peak in February and are lowest in the second part of the year.

Figures 2a - 2h show the monthly deviations from the average number of births for the two time periods. Despite the predominance of the early spring-peak and the winter-trough, considerable differences in the birth distributions of the seven regions did exist in historical times.

In the 30 years around the beginning of the 20th century, the seasonal fluctuations in the monthly number of births are less pronounced in the western part of Austria than in the eastern part. Upper Austria and Salzburg revealed an intermediary September peak, which was not present in the other regions. These patterns are all consistent with those from other parts of Europe. One interesting exception existed, however; the historical birth distribution of Tyrol followed the American pattern rather than the European pattern.

-------------------------- Figure 2a-2h about here ----------------------------

In the second time period regions tended to become more similar to one another. They all had a peak in February of approximately ten percent compared to the annual average; the intermediary September peak was present in all regions with the exception of Burgenland. And, surprisingly, the monthly birth distribution of Tyrol appeared to transform from the American pattern into the European pattern.

To test whether climatic, geographic, or agricultural differences accounted for the differences in the variation in regional birth distributions, we began by estimating two reference models that only included the monthly indicator variables. All other models were then compared to the respective reference model. In Table 3 we present the coefficients for the monthly indicator variables of the two reference models; they reflect an increase in the spring peak over time, while the winter trough became less pronounced. In the first time period only a small intermediary peak in September is noticeable; it becomes much more salient in the later time period.

-------------------------- Table 3 about here ----------------------------

Seventeen models were estimated for the historical time period (and only uncorrelated independent variables were included in these models). Table 4 presents the variance explanations (R^2 and adjusted R^2) for each of the estimated models. The reference model accounted for 25 per cent of the variance; the two best-fitting models explained 37 per cent of the variation. Model XV included the variables “longitude”, “temperature in July”, and “proportion of people employed in the agricultural sector”; Model XVI included “longitude”, “latitude”, and “temperature in July”. As the regional variation in “latitude” is rather small compared to the regional variation in the agricultural variable we chose model XV to be our best model.

-------------------------- Table 4 about here ----------------------------

We found that each of the three variables in model XV contributed substantially differently to the final shape of the birth distribution (Fig 3). Including the agricultural variable resulted in suppression of the September peak: The larger the proportion of people employed in the agricultural sector, the lower became the number of births in late summer. When ‘longitude’ was accounted for, then the birth-distribution followed the US pattern. The variable ‘temperature in July’ dampened the original pattern, but did not change the pattern.

-------------------------- Figure 3 about here ----------------------------

We find that the seasonal pattern in births was much stronger in historical than in modern times when we account for all three variables simultaneously. This suggests that the effect of variation in agriculture, in climate, and in longitude is to dampen the seasonality that would have occurred if all of these factors had remained constant. Furthermore, the September peak shows up even stronger in the first time period than in the second (Fig. 4).

Results for the modern period are shown in Table 5. The reference model explained 34 per cent of the variance; none of the additional variables contributed significantly to the variance explanation. In other words, none of the differences across regions in the explanatory variables were related to differences in seasonality patterns. We have already noted that the regions became much more similar to one another in birth seasonality patterns in the later time period, so that there was much less variance to explain in the first place. It seems important to note that all of the important features of the seasonality patterns in Figure 4 -- the peaks and the troughs -- are the same in the three portrayals. However, the ones for the more recent time period fall mid-way between those of the earlier patterns unadjusted and the earlier patterns with the covariates adjusted out of them.

-------------------------- Table 5 about here ----------------------------

-------------------------- Figure 4 about here ----------------------------

Discussion

Seasonality researchers have directed their efforts toward several different goals, often without explicitly separating those efforts. First, some have been interested in identifying the environmental, social, and biological correlates of the patterns (whatever those patterns might be). Rosenberg's (1966) article identifying a number of such correlates is a prototype of this approach. Second, others have been interested in identifying the causes of shifts in seasonality patterns over time (even if those shifts leave the prevailing peaks and troughs intact). Seiver's (1986) analysis showing dampening of the April birth valley (caused by more summer conceptions) in the southern U.S. after the introduction of air conditioning is exemplary of this type of research. Third, others have been interested in the basic underlying causes of the peaks and valleys themselves. Lam and Miron's (1996) analysis of climatic effects on seasonality patterns worldwide is one notable effort (out of many) that falls into this category. Evidence from each of these categories can be used by inference in application to the other categories as well.

Our analysis contains components that fall into each of these three categories. We investigated climatic, geographic, and agricultural correlates, and identified in Tables 2 and 3 the ones most related to differences in seasonality patterns across regions of Austria. In the earlier time period, "longitude," "temperature in July," and "proportion of people employed in agriculture" provided a model that fit well and was interpretable (in addition, a model replacing the agriculture variable with "latitude" provided an equivalent excellent fit). In the later time period, none of the covariates improved on the prediction built into the baseline seasonality model itself. The comparison between these two results falls into the second category, because they imply that the influence of geography, climate, and agriculture disappears in explaining seasonality patterns. It appears that the influence of these variables may have been reduced because of increasing homogeneity in the seasonality patterns themselves across the regions.

The third goal — that of specifying the fundamental causes of seasonality patterns — is also addressed by our findings. We will use our results to propose and develop a “Resilience Hypothesis” of human reproductive seasonality. The basic statement of this hypothesis is that there are a very few *fundamental* causes of seasonality patterns in human reproductive behavior. It is these causes that result in three basic prevailing phenomena — the peak in births early in the year associated with the so-called European pattern, the trough in spring associated with the so-called American pattern, and the September peak that occurs in both patterns.

But, on top of these fundamental causes, are a multiplicity of additional correlates that cause slight changes and shifts in the size of those peaks and troughs, and that can even move the peaks and troughs one or more months in either direction. Our results are completely supportive of this interpretation. The fundamental structure of the seasonality patterns in Austria is the same across regions and across time; there is a peak early in the year, with a systematic decline as the year progresses, except with a local peak in September. It appears that climate, geography, and agricultural patterns may have acted in combination to dampen that fundamental pattern (although their individual effects were more idiosyncratic). But the basic causes of the early global peak and the local September peak were resilient even in the presence of strong dampening effects. Figure 5 shows clearly that the unadjusted pattern is not as strong, but is still structurally the same, as the pattern with these three factors adjusted out. Then, over a half century later, the influence of these external factors had mitigated, allowing the resilient basic pattern to show through even without needing to adjust out other processes.

So what are these basic causes that are affected by, but still resilient to, the many other correlates? There is considerable evidence that the September peak (which is the one that appears most ubiquitous across both time and geography) is caused by increased conceptions occurring around the Christmas holiday and New Year. Many others have provided empirical evidence and interpretations that support this view (e.g., Lam and Miron 1991; Parnell and Rodgers 1998; Rosenberg 1966; Leridon 1986). Lam and Miron (1991) noted that the September peak is characteristic of all Christian cultures in which it has been evaluated, but the "holiday theory" is confronted with explaining a September peak in Israel and India as well. However, even in India and Israel the New Year occurs at this time of year, providing cultural support for holiday activity and leisure time even in non-Christian countries.

The Austrian pattern we have identified in which births decline systematically from a February peak (which in some other European countries is shifted slightly to a month or two later; see Lam and Miron 1991, Figures 3 and 5) has a less obvious fundamental explanation. These births are caused by an increase in conceptions in late spring and early summer. While we encourage much additional research on this topic, we will offer a speculative explanation (which, admittedly, leads to difficulty explaining the third of the prevailing dominant seasonality features). Our conjecture is that these births are caused by a women/couples operating actively on a desire (either implicit or explicit) for spring births. Spring has several advantages over the rest of the year for giving birth. First, it is associated in our minds with "rebirth," as the physical world is reborn every spring. Second, the difficulty of dealing with hot or cold weather late in a pregnancy is mitigated. Third, there is an obvious nutritional advantage, since the most difficult time for obtaining food is recently past. Basso (1995) found that European women preferred summer as the starting time for planning pregnancies (suggesting the goal of spring births). Using a sample of U.S. college students, Rodgers and Udry (1988) found the same preference for spring births. Thus, to posit that European women/couples simply aim for spring births in disproportionate numbers seems to be a reasonable conjecture. Further, the possibility that human birth seasonality is caused by volitional human behavior — contraceptive cessation and/or active proception associated with pregnancy planning — is a relatively unexplored domain. So far, Rodgers and Udry (1988) are the only ones to build pregnancy planning and reproductive decision making into a theoretical explanation of birth seasonality. This direction seems promising, because a number of the more heavily investigated explanations have not resulted in an ultimate unifying theoretical statement.

The major challenge for a volitional hypothesis accounting for the global peak is the difference between U.S. and European birth patterns in the spring. If preference for spring births is a fairly universal phenomenon (and results from Basso et al. 1995, and Rodgers and Udry 1988 suggest this to be the case), then why is the American pattern characterized by a spring trough? And why does this trough also show up in patterns as disparate as those from Israel, India, and South Africa (Lam and Miron 1991, Figure 4)? In addressing this question, we are obviously stepping outside the empirical domain of our current study, but not outside the biggest goal underlying our study and others like it. Rodgers and Udry (1988) suggested that the April trough in the U.S. is caused by the contraception cessation behavior of women/couples aiming to avoid winter births; given the positively skewed nature of the lag-to-pregnancy distribution, they postulated that those aiming to avoid winter actually contributed to the trough in the spring. However, simulations from both Rodgers and Udry and also from Lam et al. (1994) cast doubt on the ability of this explanation to completely account for the April trough. Further, it is difficult to understand why European women would be able to accurately and consistently time their births for the spring, while American (and other women in well-developed countries) would not. Lam et al. point to lower conceptions caused by the extreme heat in the summer as a possible explanation for the spring valley, an effect consistent with the amplitudes of the spring valley in comparing the southern U.S. to other regions. However, states in the northern U.S. show the spring valley as well, suggesting that this explanation is one from the second category of explanations, accounting for changes in the size of the fundamental features rather than the presence or absence. It appears that the lack explanation for the April trough in the American pattern is certainly one of the major obstacles to the development of a unifying theory.

We note that neither weather nor photoperiod plays a role in our theoretical speculations. This is because both appear to account for important variance in seasonality differences around the world, but they fall into the second category identified above, rather than the third. That is to say, they explain differences between patterns at different geographic locations, but they do not account for the most basic fundamental structural features of the patterns themselves. In other words, climate and photoperiod appear to explain shifts in the amplitude of the peaks and troughs across region, but not the fundamental presence of the peaks and troughs in the first place. If photoperiod were a “category three” explanation, then seasonality patterns would rise and fall exactly in relation to latitude, especially when other patterns were controlled for. But they don’t. Similarly, while Lam and Miron (1986) show climate to account for much of the variance in seasonality patterns, climatic variables do not explain the two peaks and one trough that characterize the two fundamental patterns.

Thus, in conclusion, we suggest that the search is still on for a complete statement of a “unifying theory of human birth seasonality.” Some pieces of the theory appear to be in place. The results from our historical study of Austrian birth pattern analysis suggest the “resilience hypothesis” that is defined above, that a multiplicity of small causes slightly shift, dampen, and enhance the patterns, which are themselves caused by a very few resilient and much stronger causes that can explain remarkable stability over time and place. The major challenge in defining these few major causes is the existence of two basic patterns at difference locations in the world.

Specification of such a “unifying theory” requires that seasonality researchers be extremely careful about separating seasonality research into the three categories identified above. Previous research has been effective in identifying critical factors related to the amplitude of the three major seasonal features in human birth rates around the world. However, specification of the fundamental causes of those three features in the first place is still an ongoing — and fascinating — research endeavor.

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Captions:

Figure 1: Map of Austria

Figures 2a-2d: Monthly birth distribution based on the de-trended number of births by region for the periods 1881-1912 and 1947-1959.

Figures 2e-2h: Monthly birth distribution based on the de-trended number of births by region for the periods 1881-1912 and 1947-1959.

Figure 3: Comparison of the standardized regression coefficients of the monthly indicator variables of the reference model with the coefficients of the monthly indicator variables adjusted for the impact of the variables agriculture (3a), longitude (3b), latitude (3c), and temperature in July (3d); 1881-1912.

Figure 4: Standardized regression coefficients of the monthly indicator variables estimated from the two reference models for the time periods 1881-1912 and 1947-1959, and from model XV which adjusts for the impact of agriculture, longitude and temperature in July in the time period 1881-1912.

Table 1: Number of births in each region in the periods 1881-1912 and 1947-1959.

Region	Births	
	1881-1912	1947-1959
Lower Austria & Vienna	2.462,438	488,413
Upper Austria	666,915	282,059
Salzburg	154,756	86,010
Styria	1.082,049	270,102
Carynthia	314,430	134,464
Tyrol	674,129	113,407
Vorarlberg	94,664	55,618
Burgenland		69,959

Table 2: Regional covariates included in the regression models

Region	Covariates													
	Longitude		Latitude		Temperature in July (C°)		% sunshine in summer		% sunshine in winter		1st day of spring		% employed in agriculture	
	1881/1912	1947/1959	1881/1912	1947/1959	1881/1912	1947/1959	1881/1912	1947/1959	1881/1912	1947/1959	1881/1912	1947/1959	1881/1912	1947/1959
Lower Austria and Vienna	16:10	-	48:10	-	19	-	60	-	25	-	70	-	24	-
Upper Austria	14:00	14:00	48:10	48:10	18	18	50	50	25	25	80	80	50	22
Styria	15:30	15:30	47:05	47:05	17	17	55	55	35	35	80	80	63	24
Salzburg	13:20	13:20	47:30	47:30	17	17	45	45	30	30	100	100	48	17
Carynthia	14:10	14:10	46:40	46:40	18	18	55	55	30	30	70	70	63	19
Vorarlberg	9:50	9:50	47:20	47:20	17	17	50	50	35	35	100	100	42	12
Tyrol	11:10	11:24	46:35	47:16	20	18	55	55	50	45	65	77	64	20
Burgenland	-	16:31	-	47:51	-	18	-	70	-	30	-	70	-	38
Lower Austria	-	16:10	-	48:10	-	19	-	55	-	30	-	65	-	24
Vienna	-	16:25	-	48:15	-	20	-	70	-	25	-	65	-	1

Table 3: Standardized regression coefficients of the monthly indicator variables in the reference models for the two periods 1881-1912 and 1947-1959.

	1881-1912		1947-1959	
	Coefficient	p-value	Coefficient	p-value
January	0.138	0.000	0.168	0.000
February	0.254	0.000	0.367	0.000
March	0.151	0.000	0.306	0.000
April	0.060	0.016	0.178	0.000
May	0.057	0.023	0.145	0.000
June (RG)	0		0	
July	0.001	0.952	-0.068	0.020
August	-0.062	0.013	-0.111	0.000
September	-0.031	0.218	0.092	0.002
October	-0.123	0.000	-0.096	0.001
November	-0.154	0.000	-0.115	0.000
December	-0.276	0.000	-0.088	0.003

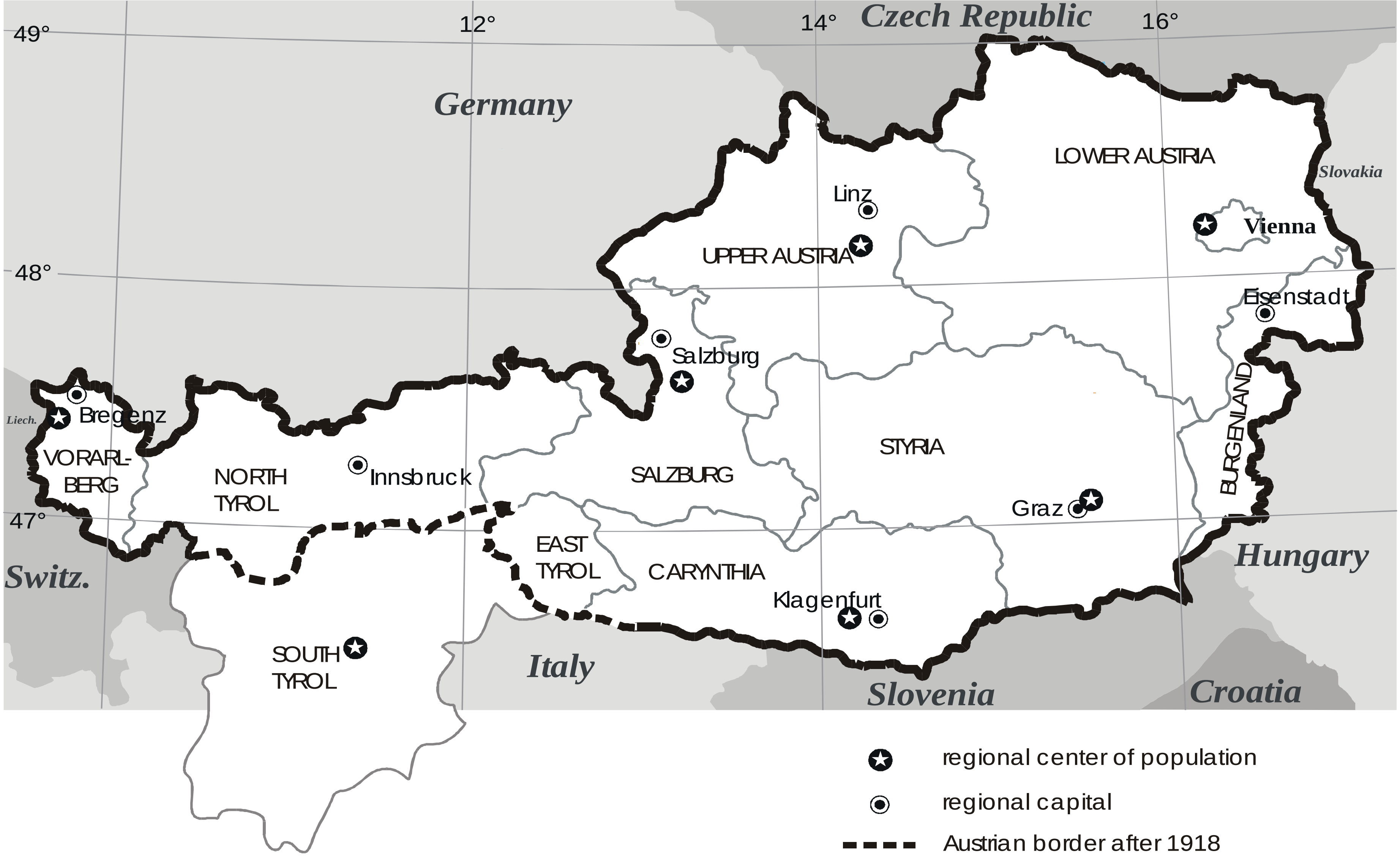
Table 4: Variance explanation (R^2 and adjusted R^2) of the eighteen regression models estimated for the historical period 1881-1912.

Model	Variables included in the model	R^2	Adj. R^2
I	monthly indicators (Reference Model)	0.254	0.250
II	monthly indicators, longitude	0.331	0.324
III	monthly indicators, duration of sunshine during winter	0.310	0.303
IV	monthly indicators, temperature July	0.282	0.275
V	monthly indicators, agriculture	0.270	0.262
VI	monthly indicators, duration of sunshine during summer	0.267	0.260
VII	monthly indicators, latitude	0.265	0.258
VIII	monthly indicators, beginning of spring	0.261	0.254
IX	monthly indicators, longitude, duration of sunshine during winter	0.345	0.335
X	monthly indicators, longitude, temperature in July	0.358	0.348
XI	monthly indicators, longitude, agriculture	0.355	0.346
XII	monthly indicators, longitude, duration of sunshine during summer	0.340	0.330
XIII	monthly indicators, longitude, latitude	0.353	0.343
XIV	monthly indicators, longitude, beginning of spring	0.340	0.330
XV	**monthly indicators, longitude, temperature in July, agriculture**	**0.382**	**0.369**
XVI	**monthly indicators, longitude, temperature in July, latitude**	**0.385**	**0.373**
XVII	monthly indicators, longitude, temp. July, summer	0.373	0.360
XVIII	monthly indicators, longitude, temp. July, winter	0.367	0.354

Table 5: Variance explanation (R^2 and adjusted R^2) of the eighteen regression models estimated for the historical period 1881-1912.

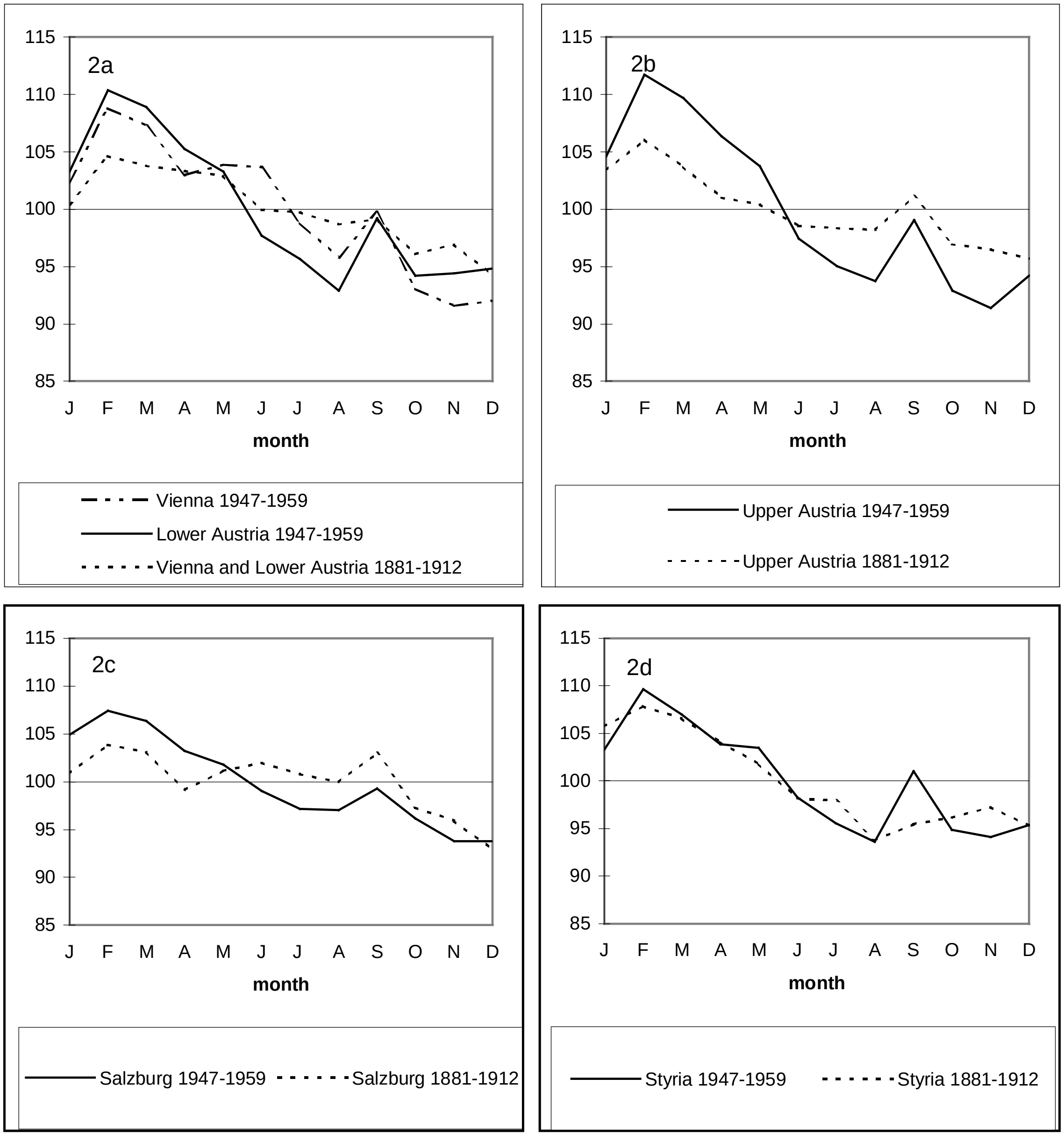
Model	Variables	R^2	Adj. R^2
I	monthly indicators (reference model)	0.343	0.338
II	monthly indicators, beginning of spring	0.351	0.341
III	Monthly indicators, beginning of spring, agriculture	0.358	0.343

Figure 1



Czech Republic
Germany
12°
14°
16°
49°
48°
47°
LOWER AUSTRIA
Slovakia
Linz
Vienna
UPPER AUSTRIA
Eisenstadt
Salzburg
Liech.
Bregenz
VORARL-
BERG
NORTH
TYROL
Innsbruck
SALZBURG
STYRIA
BURGENLAND
Graz
EAST
TYROL
CARYNTHIA
Klagenfurt
Hungary
Switz.
SOUTH
TYROL
Italy
Slovenia
Croatia
regional center of population
regional capital
Austrian border after 1918

Figures 2a - 2d:



Figures 2e-2h:

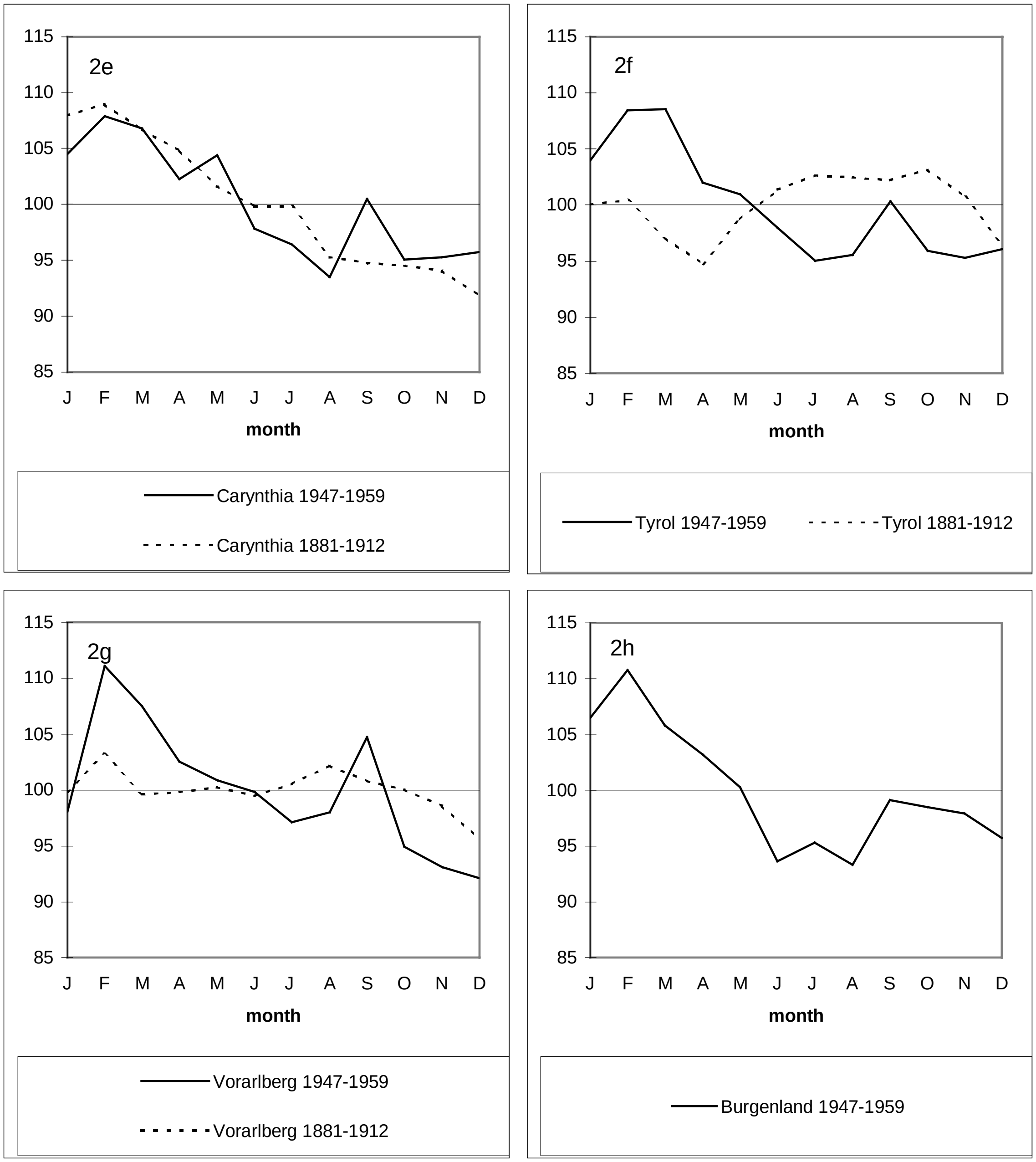


Figure 3

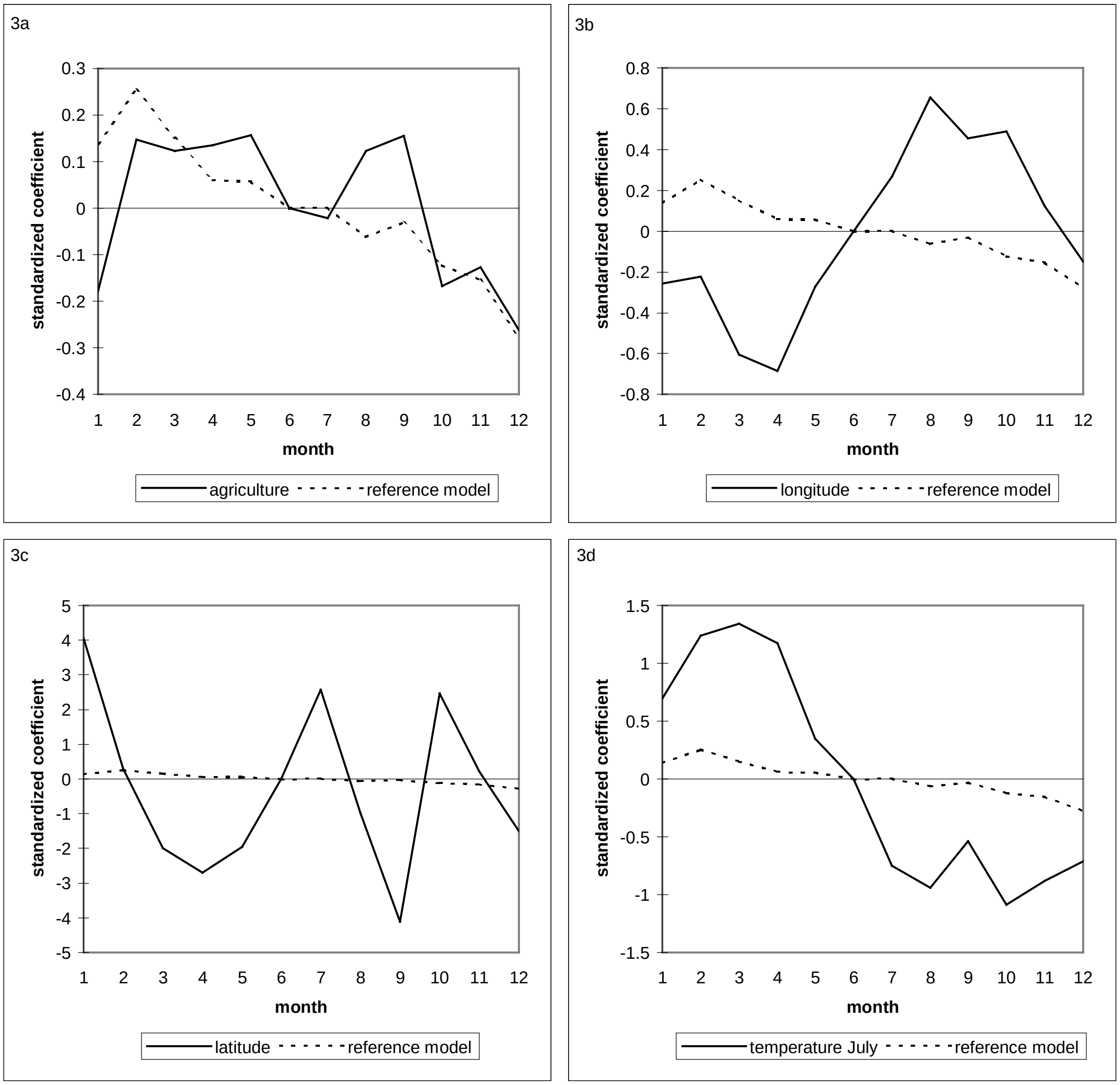
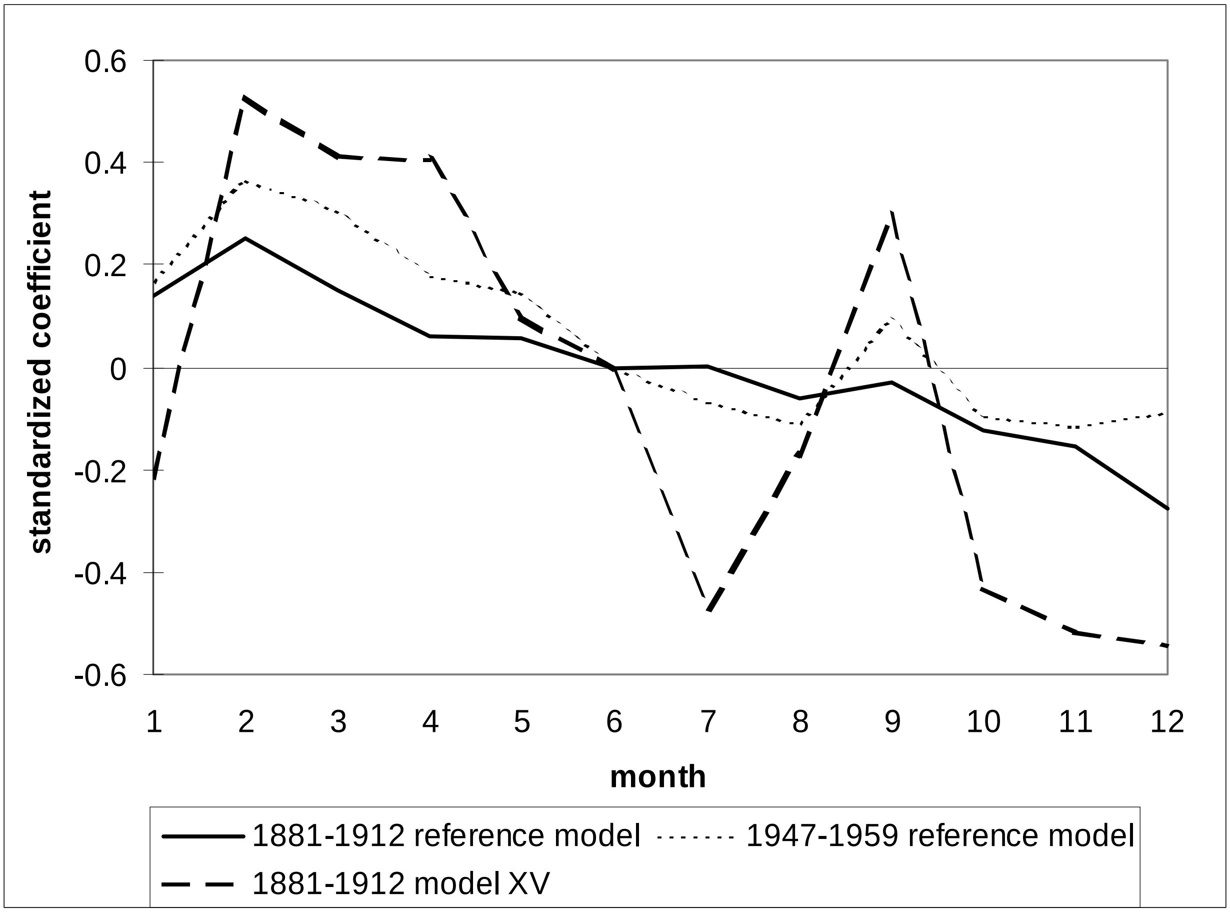

3a
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
standardized coefficient
1 2 3 4 5 6 7 8 9 10 11 12
month
agriculture
reference model
3b
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
standardized coefficient
1 2 3 4 5 6 7 8 9 10 11 12
month
longitude
reference model
3c
5
4
3
2
1
0
-1
-2
-3
-4
-5
standardized coefficient
1 2 3 4 5 6 7 8 9 10 11 12
month
latitude
reference model
3d
1.5
1
0.5
0
-0.5
-1
-1.5
standardized coefficient
1 2 3 4 5 6 7 8 9 10 11 12
month
temperature July
reference model

Figure 4:


0.6
0.4
0.2
0
-0.2
-0.4
-0.6
standardized coefficient
1
2
3
4
5
6
7
8
9
10
11
12
month
1881-1912 reference model
1947-1959 reference model
1881-1912 model XV