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The Seasonality of Births in Canada and the Provinces, 1881-1989: Theory and Analysis

Frank Trovato and **Dave Odynak**
The University of Alberta
Edmonton, Alberta, Canada

Abstract

Seasonality of births has been observed in virtually all historical and contemporary populations. In general, two distinct patterns have been identified in modern populations: (1) the American pattern, characterized by a trough in April-May, and a peak in September; (2) the European pattern, with an excess of births during spring and summer, and a secondary peak in September. Many countries fall within these two general types; however, some nations demonstrate patterns of seasonality that are intermediate to these distributions.

We analyze Census and Vital Statistics data for Canada and the provinces for 1881 and from 1926-1989, with a time-varying covariate regression model to address four questions: (a) what is the Canadian pattern of seasonality in births; (b) how has it changed over time; (c) how does it compare to the American pattern; and (d) how can the Canadian seasonal distribution of births be explained.

Our results indicate that the Canadian pattern closely approximates the European model, but only since the early part of this century. Prior to 1926, the monthly distribution of births in Canada as a whole was actually closer to the contemporary American distribution. Thus, a radical change took place between the late 1880s and the early part of this century.

Since 1926, Canada's pattern of birth seasonality has remained fairly stable; however, the first eight months of the year have been declining in their relative contribution to seasonality, while the latter part of the year has been contributing an increasing proportion of births over time. Notwithstanding these shifts, most births occur in spring and early summer, with August being an average month, and September a global maximum. Relatively few births occur between October and February. Therefore, the contemporary Canadian pattern of seasonality is substantially different from that of the United States. A common feature of both countries is that they share a September rise in births.

Exogenous type explanations for birth seasonality can be classified under two main headings: sociocultural and environmental. Within the former rubric, the role of social class, marriage, holidays, and agricultural cycles have been implicated as determinants of the seasonality phenomenon. Within the environmental class of hypotheses, temperature (heat) and photoperiod (length of daylight over the seasons) have received much attention in the biometeorological literature.

We attempt to assess the evidence for Canada against such hypotheses. The pattern of results from our analysis suggests that: (1) urbanization is probably the underlying factor for the major change in the seasonality of births between 1881 and 1926; (2) seasonality of marriage may account for some of the observed patterns of seasonality of births; (3) the role of holidays is strongly supported by the September peak in births (Christmas season conceptions); (4) temperature does not seem to be of importance in this phenomenon for Canada; (5) photoperiod may be a factor, as relatively few conceptions occur in the winter months (except for the Christmas effect), while most conceptions occur in spring-summer; (6) however, this pattern ascribed to photoperiod may actually reflect the effect of a "month of birth" preference that most couples share in contracepting societies. The excess of spring-summer births is probably a result of conscious family planning by parents and not due to photoperiod.

We formulate a theoretical model which delineates the complex causal web of variables implicated in the social science and biometeorological literature on the topic of this paper. The model demonstrates that most "exogenous" factors (e.g., holidays, temperature, SES, marriage, etc.) must affect birth seasonality through a series of proximate fertility variables (e.g., breastfeeding, contraception, conception wait, abortion, stillbirths, etc.). Although not comprehensive in the idiographic sense, the theory we propose can take us closer to a full explanation of the seasonality of births phenomenon.

Résumé

La saisonnalité des naissances est un phénomène qui a été observé dans presque toutes les populations historiques et contemporaines. En général, on relève deux tendances dans les populations modernes : 1) le modèle américain caractérisé par un creux en avril-mai et un nombre record en septembre; 2) le modèle européen, avec une recrudescence des naissances au printemps et en été, et un second point culminant en septembre. Beaucoup de pays appartiennent à l'une ou l'autre catégorie. Dans certains cas, cependant, les oscillations saisonnières sont intermédiaires.

Nous avons analysé les données du Recensement et de l'état civil du Canada et des provinces pour 1881 et de 1926 à 1989, à l'aide d'un modèle de régression à covariance variant dans le temps afin de répondre à quatre questions : a) quelle est la tendance canadienne de la saisonnalité des naissances; b) comment a-t-elle changé dans le temps; c) comment se compare-t-elle à la tendance américaine, et d) comment peut-on expliquer la distribution saisonnière des naissances au Canada.

Nos résultats indiquent que le modèle canadien ressemble de près au modèle européen, mais seulement depuis le début du siècle. Avant 1926, la distribution mensuelle des naissances canadiennes ressemblait beaucoup plus à la distribution américaine contemporaine. Un changement important a donc eu lieu entre la fin des années 1880 et le début du siècle.

Depuis 1926, le modèle canadien est resté relativement stable; cependant, les huit premiers mois de l'année ont diminué en terme de contribution relative à la saisonnalité, alors que la deuxième moitié de l'année contribue de plus en plus au pourcentage des naissances dans le temps. Malgré ces changements, la plupart des naissances ont lieu au printemps et au début de l'été - août étant un mois typique et septembre un maximum global. Un nombre relativement réduit de naissances ont lieu entre octobre et février. Le modèle canadien contemporain est donc substantiellement différent du modèle américain. La caractéristique commune aux deux pays est qu'ils partagent une augmentation des naissances en septembre.
Les explications de type exogène peuvent être classées en deux catégories principales : socio-culturelles et environnementales. Dans le premier cas, le rôle de la classe sociale, du mariage, des vacances et des cycles agricoles sont évoqués à titre de déterminants du phénomène de saisonnalité. Dans le second cas, la température (chaleur) et la photopériode (durée quotidienne du jour, considérée du point de vue des effets biologiques) suscitent beaucoup d'intérêt dans la recherche biométéorologique.

Nous avons tenté d'évaluer les données canadiennes qui vont à l'encontre de cette hypothèse. La distribution des résultats de notre analyse suggère que : 1) l'urbanisation est probablement le facteur sous-jacent du changement notable qui s'est produit dans la saisonnalité des naissances entre 1881 et 1926; 2) la saisonnalité du mariage pourrait expliquer certains des modèles de saisonnalité des naissances; 3) le nombre record de naissances relevé en septembre révèle le rôle important que jouent les vacances (conceptions à l'époque de Noël); 4) la température ne semble pas constituer un phénomène déterminant au Canada; 5) la photopériode pourrait jouer un rôle, vu le nombre relativement bas des conceptions durant les mois d'hiver (mis à part l'effet de Noël), la plupart des conceptions se produisant au printemps et en été; 6) cependant, la distribution attribuée à la photopériode pourrait en réalité manifester l'effet d'une certaine préférence pour un que la plupart des couples semblent partager dans une société qui pratique la contraception. Le nombre record des naissances au printemps et en été est probablement dû à une planification familiale consciente plutôt qu'au photopériodisme.

Nous avons formulé un modèle théorique qui décrit le réseau complexe de variables que relèvent les chercheurs uvrant en sciences sociales et en biométéorologie sur le sujet dont nous traitons ici. Le modèle démontre que la plupart des facteurs exogènes (ex : vacances, température, statut socio-économique, mariage, etc.) doivent influer sur la saisonnalité des naissances par une série de variables de fertilité immédiates (ex : allaitement, contraception, délai de conception, avortement, mortinatalité, etc.). Bien qu'elle ne soit pas exhaustive au sens idiographique, la théorie que nous proposons peut contribuer à nous rapprocher d'une explication complète du phénomène de la saisonnalité des naissances.

Key Words: seasonality of births, moving average, time-varying covariate model, time-series, theory.

Introduction

Seasonality is a ubiquitous phenomenon in both the natural world and in human societies. The importance of the season in the occurrence and timing of biological events has been recognized by diverse disciplines. Medical scientists have documented circannual rhythms in humans and have shown that hormone levels fluctuate on the basis of the month (Roennenberg and Aschoff, 1990a, 1990b; Reinberg, 1974; Reinberg et al., 1978; Pengelley, 1974; Kobayashi, Lobotsky and Lloyd, 1966; Tjoa, et al., 1967; Levine, 1991; Spira, 1991). Biometeorologists have observed that temperature is associated with fecundability in both humans and in animal species (Chang, et al., 1963; MacFarlane, 1970; MacFarlane and Spalding, 1960; Tromp, 1963). There is indication that photoperiod may also be a factor in this relationship (Becker, 1991; Ehrenkranz, 1983). Cyclical patterns in the incidence of schizophrenia, depression, cancer risk, criminality, insanity, genius and even death have been documented on the basis of birth month (Huntington, 1938; Eastman, 1945; Rubin, 1979; Rotton and Frey, 1985; Bradbury and Miller, 1985; Rosenwaike, 1966; Land and Cantor, 1983; Kevan, 1979; Prener and Carstensen, 1990; Abas and Murphy, 1987; Warren, Smith and Tyler, 1983).

An intriguing aspect of this literature is the seasonality of births. Recognition of this phenomenon can be traced back to the late 1800s and the early part of this century (Quetelet, 1826; Villerme, 1831; Gini, 1912; Huntington, 1938). A recent overview by Lam and Miron (1991a) delineates some interesting facts about this phenomenon. It appears that no single explanation receives strong, consistent support from their data on a large number of countries observed over historical time. Fluctuations in the seasonal distribution of births are quantitatively large, and the basic timing of peaks and troughs, as well as the approximate magnitudes of the fluctuations within nations remain essentially constant over long periods. They also state that no overall conclusion can be advanced concerning the temporal change in seasonality, as in some countries the amplitude in the monthly incidence of births increases over time, while in others it decreases. Roennenberg and Aschoff (1990a, 1990b), however, conclude on the basis of 3000 years of monthly birth rates for over 166 regions of the globe, that in spite of the many social influences, the seasonality of human reproduction is based on biological factors. Of course, it is no easy task to specify with any degree of certainty the biological factors and their causal mechanisms for the phenomenon in question.

A complete explanation of seasonality has eluded researchers. The reason underlying this fact is largely a function of not having a well-specified theoretical framework. A comprehensive analysis of birth seasonality would require information on a host of exogenous macro variables as well as on a large number of social and biological micro variables. Becker (1991) has already indicated this problem and has called for the necessity of incorporating proximate variables of fertility in the analysis of seasonality. We agree with this view. The seasonality phenomenon entails a complex web of interrelationships among exogenous factors (e.g., weather, temperature, holidays, marriage, agricultural cycles, photoperiod and others) and a large number of intermediate variables (e.g., seasonality of infant mortality, ovulatory capacity, contraceptive practices, breastfeeding discontinuation, and others).

Becker (1991) has directed our attention to another fundamental problem inherent in the literature. Most studies rely on Vital Statistics data to delineate patterns of birth seasonality in human populations, and attempt to establish uniformities in the patterns to see if some hypotheses can be supported by the data (Lam and Miron, 1991a, 1991b; Roennenberg and Aschoff, 1990a; 1990b; Cowgill, 1965; Becker, 1991; Seiver, 1985, 1989; Underwood, 1991). Vital Statistics data allow for an examination of the phenomenon with a minimum of sampling fluctuation, but are limited in the number of variables available (see Anderson and Silver (1988) on other limitations). Usually, such data allow analysts to fit a regression model containing parameters for month and time. The author will then proceed to make sense of the patterns derived from their model. We take this approach in our statistical analysis.

Survey or hospital data (records) are superior in that more variables can be extracted for analysis, but, such data suffer from sampling fluctuation and can lead to inconsistent results. For example, Halli (1989) used sample data from the Canadian Fertility Survey and found that the seasonality pattern was statistically insignificant. However, in a subsequent analysis based on Vital Statistics counts, Halli and Werschler (1992) report a definite pattern of births by month for Canada from 1980 to 1989. Clearly, the inconsistency is due to the type of data used.

In this study we utilize Vital Statistics data for Canada and the provinces over a long period of time (from 1881 to 1989) and therefore minimize potential problems of sampling error. However, we encounter the limitation identified earlier concerning the number of variables that can be entered in the statistical model. We can only focus on the role of what Lam and Miron (1991a, 1991b) call "exogenous factors" of the seasonality of births phenomenon. A second task of this study is to develop a theoretical model of this phenomenon to complement our interpretation of the statistical results. The model is constructed from knowledge presented in the literature, ranging from the biomedical and biometereological to the social psychological. Our statistical analysis relies on a time-varying covariate regression model to answer the following questions: (1) what is the pattern of seasonality of births in Canada; (2) how has it changed over time; (3) how does it compare to that of the United States; (4) how can the Canadian seasonal distribution of births be explained. ,

Exogenous Type Explanations of the Seasonal Pattern in Births

The determinants of the seasonality of births are not well understood. Many hypotheses have been proposed in the literature ranging from sociocultural factors such as marriage customs, holidays, and nutrition cycles to biometeorological factors such as day length, climate and temperature fluctuations. In this overview of the literature, we focus on the evidence accumulated thus far with respect to "exogenous" type variables. Much of this discussion is aided by the recent overviews provided independently by Lam and Miron (1991a, 1991b), Becker (1991), and by Roennenberg and Aschoff (1990a, 1990b).

In general, we can identify three broad sets of explanatory variables for the observed pattern of seasonality of births. The first set may be called sociocultural because the emphasis is on relating the role of exogenous variables such as marriage cycles, frequency of sexual intercourse and holidays to the seasonal distribution of conceptions and births. The second class of variables pertain to exogenous environmental factors such as temperature and photoperiod. The third class of predictors are endogenous proximate determinants of conception and pregnancy outcomes.

Sociocultural Variables

In historical populations, agricultural cycles have been assumed important in the explanation of the distribution of births over the seasons (Thomas, 1941; Lee, 1981; Richards, 1983; Knodel and Wilson, 1981). It has been hypothesized that births were avoided during harvest months due to the peak in labour demand associated with this time of the year (Mosher, 1979; Levy, 1986). Another explanation is that the agricultural cycle was associated with nutritional cycles. In poor times, there would be less nutrition, while in bountiful times nutrition would be sufficient. Poor nutrition following a poor harvest would reduce conception rates, leading to a trough in births nine months later. Another thesis connected to agriculture is that in the past, there was much seasonal separation by couples due to the necessity for men to seek work outside of their communities (van de Walle, 1975). Menken (1979) has demonstrated that spousal separations of eight months can have a depressing effect on birth probabilities of up to 43%. Massey and Mullan (1984) derived further support for this effect.

Notwithstanding this evidence, the effects of agricultural cycles on birth seasonality does not appear to be very significant in the contemporary industrialized world. Cowgill (1965, 1966b) noted that in many countries the passage of time has the effect of reducing the magnitude of seasonality. She argued that urbanization is responsible for this effect. Lam and Miron (1991a) cast further doubt on the agricultural cycles explanation by pointing out a number of discrepant patterns in historical populations and on the fact that both rural and urban populations tend to exhibit a similar pattern in the monthly distribution of births. Furthermore, they indicate that the historical continuation of this urban-rural similarity into the contemporary context in countries such as Sweden provides further proof that agriculture is not a factor of the seasonality phenomenon.

Kevan (1979) conducted a comprehensive review of the literature and concluded that the urbanization thesis, which assumes increasing homogeneity in standards of living and a corresponding reduction in birth seasonality over time, is not supported by the available data as in Canada and the United States there has been little change in the pattern and amplitude in the seasonality of births (Seiver, 1985, 1989; Ashley, 1988). Unfortunately, these studies do not consider a sufficiently long series of observations extending to the turn of the century, so they are limited in testing for the possibility of early shifts in the society's pattern of the monthly distribution of births (Roennenberg and Aschoff, 1990a; 1990b).

Research based on local areas aimed at testing the relationship of socioeconomic status on the seasonality of births has provided conflicting results. In some cases, authors have documented two distinct patterns. The less affluent in the United States show a marked pattern of seasonality, while the relatively wealthy do not demonstrate much of a birth pattern over the seasons (Pasamanik, Dinitz, and Knoblock, 1959, 1960). Further analysis by Zelnick (1967) shows that the social classes do not differ significantly in their patterns of seasonality of births. However, Chowdhury (1972) sheds further light on these discrepant findings and supported the Pasamanik et al. result in that the upper classes of both races (white and black) in the locality studied, do indeed have a rectilinear pattern of seasonality, and only among whites is there a difference in birth seasonality by SES. More recent research by Warren and Tyler (1981) and Kestenbaum (1987) provide further support for Pasamanik and colleagues' original results. The upper classes show a random pattern, while the lower economic classes demonstrate a more definite pattern of births over the year. Kestenbaum (1987) found that, as has been reported by Seiver (1985, 1989) and others (Rosenberg, 1966; Lam and Miron, 1991a, 1991b; Becker, 1991) the distribution of births in the United States peaks between June and October with a global maxima in September, and that the lower classes show a greater degree of seasonality than the upper classes.

These results are interesting because they contradict the conclusions of Lam and Miron (1991a) regarding the role of economic factors on the seasonality of births phenomenon, while at the same time supporting Cowgill's (1965, 1966b) thesis of urbanization. That is, as the standard of living improves, seasonality in births should become less evident in society. The research of Pasamanik and colleagues (1959, 1960), Chowdhury (1972), Warren and Tyler (1987) and Kestenbaum (1987) support the idea that socioeconomic improvements lead to a decline in the seasonality pattern. This suggests that the poorer the country or the subgroup within a country, the more it will be affected by variables associated with economic status in producing a pattern of seasonality. Since the less affluent have limited access to a good diet, nutrition and adequate home heating, they are more subject to disease and complications of pregnancy on a seasonal basis. For example, lack of adequate heating in the winter months could lead to infection of both mother and fetus which could result in miscarriage or stillbirth in the spring. In other words, observed seasonality patterns may be linked to the deleterious effects of poor diet, nutrition and an unhealthy environment among the lower classes. The same could be proposed for relatively deprived nations in relation to more advantaged regions.

Given the evidence on socioeconomic factors, it would appear that the level of analysis is important in determining what results emanate from the data.

On the one hand, macro level studies of whole populations tend to refute any standards of living thesis as reflected in the consistency of the seasonality pattern over the course of a country's modernization process. On the other hand, studies based on local areas relying on hospital cases or individual records, tend to suggest a socioeconomic basis in the seasonality of conceptions and therefore births.

According to James (1971) a major reason for seasonality of births is seasonality in sexual activity. In contrast to the findings of other researchers (e.g., Udry and Morris, 1967), he shows that in England and Wales the upper classes have a more permanent pattern of seasonality of births. He argues that this is largely a consequence of the timing of holidays among the wealthy and the high correlation between holidays and increased sexual activity. Since the poor cannot afford the luxury of holidays in the same manner and degree as the upper classes (e.g., escape to serene environments for relaxation and leisure), their level of sexual activity does not vary much over the year. For the upper classes, sexual activity is increased during summer holidays. He contends that "one might suppose that a carnival spirit would then militate against efficient contraceptive usage" during summer holidays, resulting in a peak in births in the spring.

According to Lam and Miron (1991a), there is at least a local September peak in births in almost every Christian country in either hemisphere. Also, in a large number of European countries, births tend to peak in the spring months. Both these patterns are consistent with the holiday thesis that the frequency of sexual intercourse increases during holiday times. The September peak is observed in a large number of nations including Canada and the United States, providing strong indirect evidence for a Christmas/New Year effect on conceptions. Being a period of leisure and relaxation, the Christmas season is conducive to an increased frequency of sexual relations and therefore conception rates, culminating in a September peak in births nine months later. Kevan (1979) suggests that this effect is most likely a spontaneous one rather than planned; couples are less diligent in their contraceptive use during this time because the Christmas season is too short a vacation to involve much planning in the form of conception. If this is true, the implication would be that many conceptions in late December are unplanned.

Concerning the summer holidays effect, it is interesting to note that the United States does not show the expected above average number of births in the spring time, while in Canada this part of the year is associated with a rise in births. Clearly, the summer holiday effect cannot explain this divergence in patterns. The September peak in both countries can be understood by a

Christmas/New Year effect, but it would seem that summer holiday vacations have opposing results in the probability of conceptions in the two countries. Most Americans take vacations in the summer and yet conceptions are at their lowest during that time of year, culminating in an observed trough in the spring, particularly in April and May which correspond to July and August conceptions (Seiver, 1985). In Canada, the frequency of births is high during the spring-summer months of March to July, corresponding to conceptions occurring between June and October which encompass the peak in summer holiday times. The similar consistent spring peak in European countries provides further consistency with the summer holiday hypothesis. The September peak in births (attributed to Christmas holidays) cannot be explained by weather effects since it appears in both northern and southern hemispheres (Lam and Miron, 1991a; Becker, 1991).

Holidays may explain a portion of the birth seasonality phenomenon, but not all, as indicated by the discrepant birth patterns of Canada and the United States. Additional evidence from other countries also casts some doubt on the relative importance of holidays. For example, Udry and Morris (1967) did not find a correlation between the seasonal variation in coital rates and conception dates, suggesting that even though the frequency of sexual intercourse may increase during a certain part of the year, it does not necessarily follow that conception rates will show a corresponding increase nine months later. Becker, Chowdhury, and Leridon (1986), in an extensive analysis based on the seasonal patterns of reproduction in Matlab, Bangladesh (mainly a natural fertility society), discovered that seasonal variations in the frequency of sexual intercourse is only partially related to the seasonality of fecundability. While the peaks of the two curves coincide in March and April, there is a secondary peak of sexual intercourse during September and October which occurs at the time of lowest observed fecundability.

Cyclical fluctuations in marriages have been thought to be correlated with the cyclical pattern of births (Kevan, 1979; Lam and Miron, 1991a; Roennenberg and Aschoff, 1990a, 1990b; Underwood, 1991; Chang et al., 1963). The influence of marriage on birth seasonality must, of course, operate through frequency of sexual intercourse and conception probabilities. A peak in marriage during a certain part of the year should correlate with a rise in birth approximately nine months later, while a dearth of marriages in a given month should correspond to a low period for births nine months later.

While this is an enticing thesis, the evidence compiled based on a number of studies in various parts of the world provides little support for this effect (Kevan, 1979; Becker, 1991). The contemporary seasonal pattern of marriage in Canada and the United States is very similar, with peaks in the months of June and July, and yet, as discussed earlier, these nations' seasonality of births are quite different. Moreover, the marriage hypothesis is weakened by the fact that the observed seasonality of births in a number of populations is very similar for first and higher order births (although see Elster and Bleyl (1991) for contrasting evidence for the United States). The thesis would predict a strong seasonality in first order births, but not for higher order ones. Also, this explanation runs into serious difficulty since both legitimate and illegitimate births show similar seasonal distributions (Mathers and Harris, 1983).

Clearly, sociocultural variables cannot explain all of the variability in the observed pattern of seasonality of births in human populations. Other factors must also be considered. In the following section, we discuss the evidence concerning environmental variables.

Environmental Variables

Variables such as climate cycles, heat, photoperiod, and even altitude affect humans' physiology resulting in certain physiological responses. Meteorological conditions have been implicated to affect physiological and reproductive performance (Roennenberg and Aschoff, 1990a; 1990b; Tromp, 1963; Huntington, 1938; Criss and Marcum, 1990; Mathers and Harris, 1983; Chang et al., 1963; Reinberg, 1964; Shimura, Richter and Micura, 1981; Underwood, 1991).

Concerning the role of weather cycles, Richards' (1983) analysis of the situation in France between 1740 and 1909 reveals that seasonal fluctuation in births can be better predicted by considering the fluctuations in the price of wheat rather than changes in meteorological variables (weather), as they seldom reach statistical significance. However, Lee's (1981) study of short-term fluctuations in vital rates, prices and weather in historical England reveals that warm winters and cool summers were associated with more births nine months later.

In fact, Chang and colleagues (1963) suggest that there is a range of temperature that is conducive to conception, the most beneficial being 60° F. This view is also strongly supported by Roennenberg and Aschoff's extensive analysis (1990a; 1990b). Temperatures above 80° F suppress conception probabilities. The Chang et al., (1963) study indicates that, indeed, in Hong Kong there is a very strong inverse correlation (r=-.97) between temperature fluctuation over the year and conception rates. Conceptions peak in December-January when temperature is relatively low, but there is a trough in pregnancies during the months of June-August when temperature is at its yearly maximum.

Seiver (1985) explains the observed trough in American births during April and May as a consequence of extreme heat in the peak summer months of July and August, and the rise in births during July through October to a cooling effect of temperature during October to January. He also documents that the April-May trough in birth is more pronounced in the southern region of the country, while it tends to diminish and even disappear in the northernmost states, providing further indication of a heat effect on conception. Seiver (1985) shows that there has been a diminution of the April-May trough over time in certain parts of the United States and this change can be explained by the spread of air conditioning since the early fifties.

Becker (1991) classified the American states on the basis of July mean maximum temperatures (< 88° F, > 88° F) and cross-classified with the magnitude of the trough in births during April-May (< 5%, > 5%). He found a very high level of agreement between these two variables. States above 88° F show a larger trough in births during April-May, and states below 88° F display a reduced trough during these months. Thus, as discovered by Seiver (1985, 1989), the amplitude of seasonality reduces with latitude (the farther one moves north, the lower the seasonal amplitude in births).

This pattern associated with latitude has also been recorded in the southern hemisphere (Cowgill, 1965, 1966; Lam and Miron, 1991a, 1991b; Becker, 1991). In Australia, Mathers and Harris (1983) observed that between 1911 and 1940, as well as 1962-1979, the northern states show a lower degree of seasonality in fertility than do the southernmost areas of the country. In northern Australia, the peak in births is observed in February-March; in the south, a majority of births occur during September-October. This is similar to the American pattern but reversed by six months, taking into account the different timing of the seasons across the two hemispheres.

If weather is an important factor in the explanation of the seasonality of birth phenomenon, an explanation is needed about the causal mechanisms involved in this association. Chang and associates (1963) argued that high temperature is a key external (exogenous) factor in effecting conception rates, probably through gonadal functioning (see also Roennenberg and

Aschoff, 1990a, 1990b).

Spira (1991), in his review of the epidemiological aspects of the relationship between temperature and male reproduction, suggests that scrotal temperature may indeed inhibit sperm count, motility, and morphology, and exposure to elevated heat as a consequence of fever or prolonged exposure to heat may have deleterious effects on hormonal states, fertility and spontaneous abortion, and even congenital malformations. Elevated ambient temperature is also assumed to have negative effects on sperm counts in men (Kandell and Swerdloff, 1988).

Levine (1991) studied seasonal variation in human semen quality and concluded that "there can be little doubt that sperm concentration in non-equatorial regions is in fact reduced during summer." According to Becker, Chowdhury and Leridon (1986) high temperatures affect spermatogenesis and the capacity of sperm to fertilize. Moreover, it may reduce ovulatory capacity in females. Thus, extreme heat may have inhibiting effects on both male and female reproductive capacity.

According to Becker (1991), spermatogenesis is reduced during peak temperature periods of the year. Therefore, if the effect of heat on reproduction acts early in spermatogenesis then it is likely that the peak in temperature will correspond with a trough in births 10 to 11 months later rather than nine months after the peak months for heat. That is, couples wishing to conceive during August will not be successful until perhaps October or November when temperatures cool down. If we apply this principle to the United States, the trough in births should be in June-July as opposed to April-May.

Since this is not the observed trough period, one is left wondering whether Becker's view on this sequencing is correct. If so, then the heat explanation for the United States is ineffective. Perhaps, the causal mechanism explaining the birth deficit in April is the influence of heat on the frequency of sexual intercourse. Extreme heat and humidity make any physical activity (e.g. sexual intercourse) uncomfortable.

Lam and Miron's (1991a, 1991b) macro level results do not provide much support for a weather effect on the seasonality of births. According to the simplest possible model of the relations between weather and behaviour or biology, countries in the northern hemisphere should display similar seasonal patterns, and these patterns should be reversed six months from the patterns displayed in the southern hemisphere. In fact, there is little consistency to the patterns across countries or hemispheres. For example, they point to the significant differences in the seasonality of births between the United States (peak in September) and Europe (peak in the spring), and to the striking similarities of the American and New Zealand patterns as a clear challenge to any explanation of birth seasonality based only on seasonal weather patterns.

Photoperiod has been implicated as an additional possible source of the phenomenon in question. Roennenberg and Aschoff (1990a, 1990b) claim that on average, seasons in which the average amount of daylight is 12 hours are more optimal for human conception. They also propose that photoperiod operates through female fecundity, while temperature effects on conception seasonality act through variation in male sperm production and quality. This thesis assumes that there is an innate periodicity linked to seasonality in conception through changing conditions of light (Kevan, 1979; Becker, 1991). Some association between degree of daylight during the seasons and the sexual cycles of various animals has been recorded by scientists (Tromp, 1963; Reinberg, 1964; Pengelley, 1964). Light conditions the functioning of the pineal gland, which has been shown to exert some control over the sexual cycle of certain animal species. In general, the seasons with less daylight are associated with relatively few conceptions. Becker (1991) proposed that latitude can be used as a proxy to test for the possible effect on human reproduction: The farther away is a country from the equator, the fewer the proportion of conceptions during the winter months when the days are shorter, and the higher the conception rate during summer months when the days are longer. Indeed, in Canada, the peak in conceptions is during the summer with fewer conceptions in November to March (the exception is December, attributed to the Christmas effect discussed earlier). However, as demonstrated previously, the pattern in the U.S. of seasonality of conceptions contradicts the photoperiod thesis since there is a decline in pregnancies during the summer, and conceptions peak in the winter months.

The photic explanation can be tested more directly in nordic populations such as Eskimos and Inuit in the Canadian Arctic where there is constant night for four months of the year, followed by a period of part day and night, and then four months of constant day. According to the photic theory, the prolonged absence of the sun should inhibit pregnancy, while the period of constant daylight should promote conception. Ehrenkranz (1983) studied the seasonal birth records of the Labrador Eskimo from 1778 to 1940 recorded by the Moravian Missionaries. The records demonstrate an annual cycle in births characterized by a peak in March and a trough in June, which correspond to a peak in conceptions during spring and early summer (period of longer daylight).

Ehrenkranz (1983) contends that a cultural explanation for this pattern in births is unlikely due to the regularity of the pattern over 200 years, and that there is no evidence of prolonged periods of physical or sexual separations over the year in the Eskimo population studied. Condon (1982), however, claims that among the Inuit in the central Canadian Arctic, the seasonal pattern of births (a rise in the first half of the year) can be explained by behavioural and biological responses to extreme seasonality in the amount of daylight as well as in susceptibility to infection and illness. For example, in the long dark winters, it is customary for people to engage in a great deal of social visiting. This constant visiting between households probably limits the number of opportunities that adults have for private and sexual encounters. Condon (1982) also maintains that activity rhythms during this period of time become desynchronized with people staying up most of the night and sleeping through most of the day. Such desynchronization has been implicated in an increased susceptibility to infectious diseases during mid-winter, which may in turn affect conception rates (Condon, 1982).

Considering the weight of the evidence on photoperiod and its influence on seasonality of conception, the results of many investigations are inconclusive but suggest that there are natural circannual rhythms in humans (Reinberg, 1964; Pengelley, 1964); but it is also clear that photoperiod may be independent of circannual rhythms. It is also likely that photoperiod effects, as studied in isolated populations of the arctic, may influence the seasonality of conception indirectly rather than directly through social behaviours as described by Condon (1982). This point is reinforced by his observation that among the study population, adult women share a strong preference for giving birth during the first half of the year (January to June), thus, many conceptions now occur in a planned manner during the period of April to September by relying on the judicious use and discontinuation of contraception. The fact that both planned and unplanned births tend to be concentrated in the first half of the year suggest both biological (direct) and behavioural (indirect) responses to photoperiod.

Seiver (1985) proposed that circannual fluctuations in male hormones correlate moderately with the observed seasonal pattern of conceptions in the North Eastern United States. He reviews the work of Reinberg (1974, 1978) which shows that the production of the hormone urinary 17-ketosteroids peaks in November and bottoms out in May (see also Spira, 1991 and Levine, 1991). Thus, if the production of sex hormones influences either coital behaviour or fecundity, we could explain much of the seasonality of conceptions in the United States. Indeed, the August-September peak in births is about nine months after the hormone peak; and the trough in births coincides with the trough in hormones nine months earlier (Seiver, 1985).

The circannual hormone level explanation must be viewed, at best, tentative. Seiver's (1985) argument is based on a sample of one case followed over 15 years. Other studies tend to be based on small samples as well (see Spira, 1991; Zargniotti, 1991; Tjoa et al., 1982). Seiver (1985: 98), in fact remarks "I do not believe we can venture just yet beyond the realm of speculation about hormone-conception links." If seasonal fluctuations in hormone levels is a key factor, the question arises, why is the Canadian pattern of birth seasonality so much at variance with that of the United States?

We must agree with the conclusions of Lam and Miron (1991a) that no single explanation of the seasonality phenomenon suffices. Each of the explanatory causes reviewed have serious weaknesses. There are too many similarities in the pattern of seasonality of birth in both northern and southern hemispheres, in hot and cool climates, and within countries (by subgroup or region). It would appear, therefore, that social and biological factors are both important, and that they probably interact in complex ways, making a straight forward explanation of birth seasonality virtually impossible.

Towards an Integrated Explanation of the Seasonality of Births Phenomenon

We have seen that the most frequent types of explanations for the phenomenon in question are all of the "exogenous" type. That is, the factors implicated are only the start of a more complex sequence of causal mechanisms that serve to produce any observed seasonal pattern in births. In this section, we provide a synthetic, theoretical model of the way in which "exogenous" factors translate into the phenomenon of the seasonality of births through a number of intervening and proximate variables of fertility. We are cautious to point out that the model is a starting point and probably omits some relevant variables (e.g., seasonality of first coitus -- Rodgers, Harris and Vickers, 1992). However, it is felt that it does reflect to a large extent a reasonable synthesis of the social biological literature on this topic. Further extensions are possible.

The basic framework of our proposed model can be thought of as an adaptation of the formulation first conceived by Davis and Blake (1956), and later revised by Bongaarts (1978). Both these formulations assume that environment and social structure (culture, organization, etc.) affect reproduction through a series of intervening variables (or intermediate variables) such as marriage, coital frequency, voluntary abortion, involuntary abortion, contraception, sterility, post partum amenorrhea, and many others.

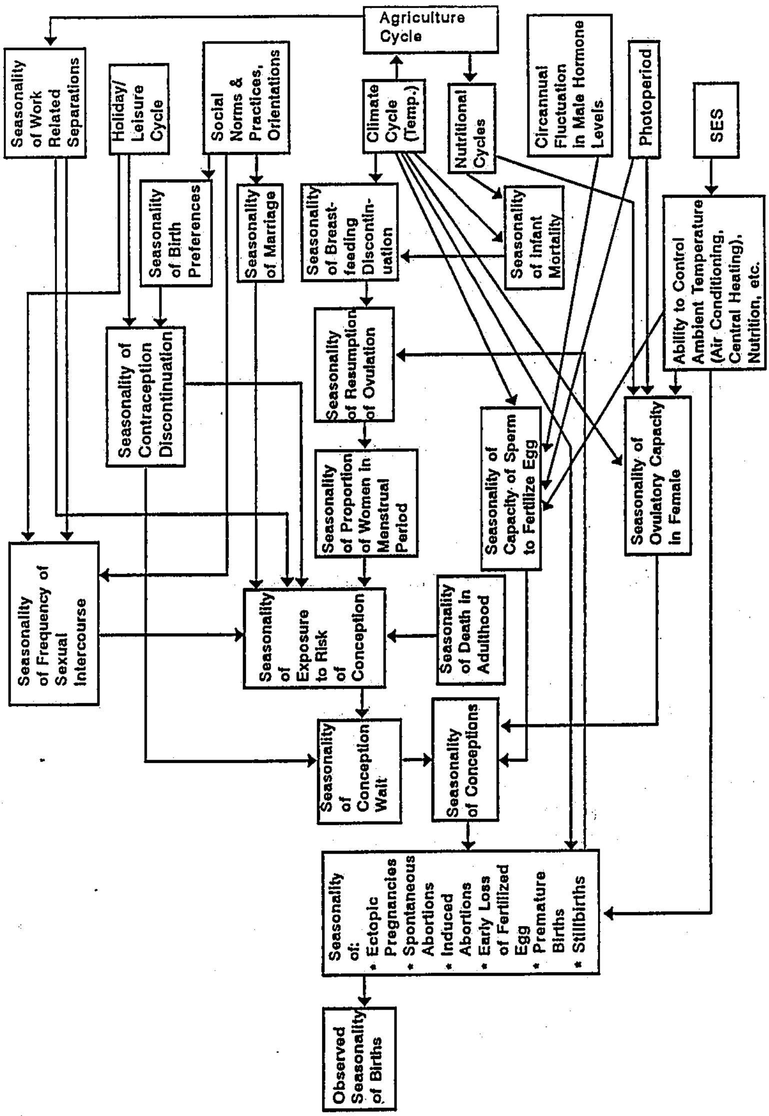


Figure 1: Theoretical Model of Seasonality of Conceptions and Births in Human Populations

As can be ascertained from Figure 1, the exogenous variables of birth seasonality include cultural, social, environmental and biological variables leading to other endogenous ones. Space restrictions preclude a detailed explanation of all causal linkages in the model and therefore, we will focus our attention on those thought to be most important. In fact, much of the discussion in the first section of this paper can be relied upon to explain some of the main causal linkages.

Since climate (temperature) has received much attention in the literature, we will explain this effect first. Seasonal fluctuations in temperature can affect agricultural outputs in developing nations (this was also the case in historical populations), which in turn causes seasonal fluctuation in nutritional intake. Cyclic deficits in agricultural output are often correlated with unfavourable weather. Infant mortality has been shown to increase during periods of nutritional deficits (Becker, Chowdhury and Leridon, 1986). If infant mortality rises during certain parts of the year (i.e., the rainy season—winter), mothers in such societies (developing countries) will time the discontinuation of breastfeeding accordingly. In fact, Underwood (1991) documents that in Guam, mothers tend to discontinue breastfeeding only during the dry season to minimize the potential deleterious effects of cold temperature on infant health through increased risk of infection. Eastman (1945) also showed that respiratory diseases in infants occur most frequently in winter and early spring. Thus, breastfeeding discontinuation is both a behavioural response to climate change over the seasons and to the seasonality of infant deaths.

If lactational discontinuation follows a seasonal pattern, there should be a corresponding seasonal pattern of the numbers of women exposed to the risk of conception, and the intervening effects on births through resumption of ovulation and proportion of women in the menstrual period.

This process will result in a seasonality of conception, directly and indirectly through seasonality of conception wait. Conception wait can range anywhere from one to three or more months (Bongaarts, 1978; Becker, Chowdhury and Leridon, 1986; Becker, 1991; Leridon, 1977; Bongaarts and Potter, 1983). Seasonality in conception waiting time will result if there is a seasonal pattern of the number of women exposed to the risk of conception (assuming conception wait is more or less uniform for those women exposed).

Seasonality of exposure to risk of conceiving is partly a function of seasonality of adult death (especially among women in the childbearing ages), temporary separations of couples, the frequency of sexual intercourse among couples, the seasonality of marriage, seasonality of contraceptive discontinuation (where contraception is practiced on a large scale), and as indicated earlier, holiday/leisure cycles. Thus, exposure to risk of conception is a key intervening variable (Kallen and Udry, 1989).

The seasonality of contraception discontinuation has received particular attention by researchers. While there is seasonality in conceptions in all countries, the distribution of conceptions and corresponding births can occur at different times of the year. In the United States, Rodgers and Udry (1988) have shown that the monthly preference of births and the actual monthly distribution of births are exactly the opposite. The discrepancy is due to what they call a "misinformed-reproducer effect." That is, couples who plan on conceiving at a given time of the year (the spring and early summer are preferred by most) are misinformed about the relation between timing of contraception discontinuation and the amount of time it takes to actually conceive. The majority of couples are probably off target by two to three months in terms of their desired month of giving birth because they fail to take into account the waiting time to conception. Their analysis suggests that the observed pattern of the seasonality of birth is partly a reflection of a "misinformed reproducer effect."

The seasonal distribution of conceptions in human populations is also a function of seasonal fluctuation in biological factors, which are themselves affected to some degree by environmental and social economic determinants. The lower part of Figure 1 indicates that climate (heat) affects the capacity of sperm to fertilize. Earlier we reviewed the literature which implicates the deleterious role of heat on spermatogenesis. We also discussed the possible link between photoperiod and reproductive capability, and the possible role (yet uncertain) of photoperiod and hormone fluctuations on male reproduction. To the extent that such causal linkages are indeed important, the ultimate result would be an emergence of a pattern of seasonality of conceptions.

Nutrition, photoperiod, temperature and ability to control ambient temperature (a social class variable) are linked to seasonality of ovulatory capacity in the female. By and large, the literature has tended to focus on the negative effects of heat and poor nutrition on the reduced ability to ovulate (Pasamanik, Dinitz, and Knoblock, 1959, 1960; Becker, Chowdhury and Leridon, 1986; Becker, 1991).

The proximate variables in Figure 1 include seasonality of ectopic pregnancy, spontaneous abortions, induced abortions, early loss of fertilized egg, and premature births. A number of studies suggest that seasonal patterns of births can be best understood once seasonality in pregnancy outcomes are discerned (Warren, Gwinn and Rubin, 1986; Kallen and Udry, 1989; Cohen and Bracken, 1977; Kallen and Enneking, 1992; Warren et al., 1980; McDonald, 1971; Wilcox, et al., 1988; Slatis and DeCloux, 1967; Becker, 1991; Becker, Chowdhury and Leridon, 1986).

Warren and colleagues (1986, 1980) have shown that seasonality in ectopic pregnancy, induced and spontaneous abortions, disappear once conception month is statistically controlled. This may explain why others have documented that there is seasonality in the incidence of spontaneous abortions. The reason is the failure to control for month of conception (MacDonald, 1971; Slatis and DeCloux, 1967).

Leridon (1977) shows that about 15% of all recognized pregnancies end in spontaneous abortions (see also Sheps, 1965). Wilcox and associates (1988) executed a controlled case study of women who were attempting to conceive, and were able to derive an estimate of early loss of pregnancy by monitoring change in human chorionic gonadotropin (HCG) hormone, which, once it reaches a certain level, is an early indicator of pregnancy. Out of 198 pregnancies identified, 22% ended before pregnancy was detected clinically. The total rate of early loss after implantation including clinically recognized spontaneous abortions was 31%.

According to Kallen and Enneking (1992) the etiologies of seasonality in such pregnancy outcomes is likely a combination of fluctuation in temperature (heat) and cold weather in the winter, which predisposes the mother to an increased risk of infections possibly causing spontaneous abortion. Seasonality in the incidence of premature births and stillbirths could also lead to an observed pattern of seasonality in births. More research is needed on this topic.

Lam and Miron (1991a, 1991b) have reasoned that in the case of spontaneous abortions, too few are accountable for the observed pattern of birth distribution over the seasons. However, if we consider the possibility of a combined effect of all pregnancy outcomes in Figure 1, sufficient basis might be assumed to significally account for the seasonality phenomenon in question.

Clearly, our model is incomplete and can only provide a starting point towards a comprehensive theory of birth seasonality in human populations. We can only provide a sketch of some of the causal linkages due to uncertainty in the causal mechanisms involved (e.g., photoperiod, circannual rhythms, etc.). Other factors can be described with more confidence, however, due to having more empirical knowledge about their causal mechanisms (e.g, marriage patterns, frequency of intercourse). It is virtually impossible to test this proposed model directly: The data are unavailable. A survey approach consisting of a large number of cases such as that executed by Becker and colleagues (1986) would be best suited for such a task. Our model can be applied to both contemporary and historical western nations and to developing countries. What should vary in such applications is the relative importance of the variables in the model. For example, in a developing country nutrition, agricultural cycles, and breastfeeding discontinuation would be more important than in a highly modern society. In industrial nations, personal preference for giving birth during certain times of the year, and the timing of contraception discontinuation would probably have greater weight in accounting for seasonality in the distribution of births.

The Study

In this study we are in a position to examine Census and Vital Statistics data over a longer period of time than previously investigated for Canada and the provinces (1881 and 1926-1989). To the best of our knowledge no other study in Canada has examined such a long series of births for the purpose of explaining their seasonal distribution over time. We examine the following questions: (1) what is in the pattern of seasonality for Canada and its provinces; (2) is there change in the pattern over time; (3) how do the Canadian and American patterns compare; (4) how can the observed patterns be explained? The first three questions can be answered by a straight forward examination of our data. The fourth question requires that we assess the evidence against a number of exogenous hypotheses.

Hypotheses

The Socioeconomic Explanation

In accordance with earlier works on this topic (Pasamanik, Dinitz and Knoblock, 1959) and recent research (Kestenbaum, 1987), the expectation is that seasonality is more pronounced in economically deprived populations. Given the relative regional economic inequality across Canadian provinces, we expect that the poorer the region, the more pronounced will be the seasonality of births. Therefore, an analysis of data for a recent period should reveal that relatively wealthy provinces such as Ontario, Alberta and British Columbia will have a less marked pattern of seasonality of births in comparison to poorer regions like Newfoundland and the other maritime provinces.

Marriage

Typically, it is assumed that high months for marriages will result in a corresponding peak in births nine months later (Kevan, 1979). But there is probably conception wait between the month of marriage (and hence initiation of coitus on a regular basis) by one to three months on average; therefore, the corresponding peak in births should be not nine months later, but approximately eleven months later (Becker, 1991). Our test will be limited by the fact that we do not have data on first births. The effects of the seasonal pattern in marriage should be more pronounced in connection with first births. In contemporary Canada, the most preferred months for marrying are July and August. Therefore, the corresponding contemporary peak in births should be June and July. However, in 1881 and 1926 Canada showed a bimodal distribution of marriages with peaks in June and September, and a trough in July-August. Therefore, in the early period there should be corresponding peaks in births in May and in August (contemporary and historical data available on request).

Holidays

The frequently observed September peak in births across European populations, North America, and in the Christian and non-Christian world has been attributed to increased coital frequency during Christmas holidays (with the added assumption of less diligent use of contraception during this time). This effect is assumed to be spontaneous (Kevan, 1979), arising from the relaxed atmosphere that this part of the year affords couples. We anticipate therefore, that there will be a peak in births in September. We are not certain whether this effect will be evident across time, as most of the evidence in support of this effect has been based on "contemporary" populations.

It is also assumed that summer holidays engender a similar effect, with the exception that it is largely a planned behaviour. Couples wish to conceive in the summer months and to give birth in the spring and summer. The literature indicates that there is a strong preference for giving birth within the months of March to June (Rodgers and Udry, 1988). Our hypothesis is that in contemporary society this effect is facilitated by the widespread availability of contraception and its judicious use by couples. In the past, when contraception was not readily available, couples were less capable in planning the timing of births. Therefore, the hypothesized effect should be noticed only after the turn of the century, when the idea of family limitation began to spread throughout the society; and this effect should intensify in more recent decades (due to the availability of effective conception).

Agricultural/Economic Cycles

In agricultural societies the harvest months should be associated with reduced conception rates due to increased work loads, temporary spousal separations, and cyclical fluctuations in agricultural (food) output. Assuming that the harvest months in early Canada were August and September, there should be a corresponding trough in births during May and June. However, we anticipate that with the passage of time, this effect will disappear as a consequence of urbanization and its concomitant effects (e.g., availability of family limitation means and the decline of agriculture as a dominant mode of production in society).

Temperature

The literature indicates that spermatogenesis is adversely affected by extreme heat or prolonged exposure to heat (Kandell and Swerdloff, 1988; Lam and Miron, 1991b; Becker, 1991). Following the postulates of this thesis, our prediction is that conception probabilities decline in the hottest months of the year, July and August, producing a corresponding trough in births during April and May. This effect should persist through time.

Photoperiod

This explanation assumes that both humans and animals are affected by the amount of exposure to daylight. Analysts have documented that in human populations situated at latitudes far from the equator, conception probabilities are reduced during the winter months, which have shorter days, while conception rates rise during the late spring and summer months (Condon, 1982; Ehrenkranz, 1983; Mathers and Harris, 1983; Lam and Miron, 1991a; Becker, 1991). Therefore, we anticipate that conceptions will peak in the summer and decline in the winter, which would produce a peak in births during springtime (March - June) and a trough from August to December. We expect that this effect should be constant across time periods since there is hardly any variation in the amount of daylight over the seasons from year to year.

Birth Month Preference

Most couples in contemporary societies indicate a strong preference for giving birth during the spring (Rodgers and Udry, 1988) and early summer. If this is assumed to be true, most couples wanting to conceive will discontinue contraception in June - November in order to give birth between March and August. But according to Rodgers and Udry (1988), typically, most couples are two to three months off target because they fail to take into account waiting time to conception. Allowing for an average three-month conception wait, the corresponding rise in births should be between June-November. We expect that this effect should be most pronounced during more recent periods than during early decades in Canadian history.

Methods of Analysis

Births by month of occurrence, province, and year were examined for 1881 and for 1921 - 1989 (adjusted for differences in the number of days in the month and for leap years). It was not possible to include the continuous years from 1881 to 1921 because some provinces did not exist in those days. Moreover, it was not until 1921 that Canada developed its national Vital Statistics registration system. In fact, complete continuous data for all the provinces could not be found until 1926 (see Appendix). Thus, our main data set includes the 63 years from 1926 to 1989. We examine 1881 data (from the 1881 Census) in order to determine how the seasonal distribution of births during this early period may have differed from later decades. One can safely assume that in 1881 Canada was characterized by a natural fertility regime (i.e., couples did not practice conscious family limitation). Fertility during that period in history was regulated by factors other than contraception, whereas in subsequent periods (especially after the turn of the century) society began to evolve into a controlled fertility regime (Bongaarts, 1978; Knodel, 1977).

We apply a time-varying parameter model appropriate for the analysis of time series used by Seiver (1985) in his study of the seasonality of births in the United States from 1947-1978. The method allows for the detection of an overall seasonal pattern of births and how it may have changed over time. We take the dependent variable as a 12-month moving average of births in order to minimize the trend in the continuous series of births, and express it as a function of month:

$$MAB_j = b_t X_t + \mu_t, \qquad t = 1, 2, \ldots, n \tag{1}$$

where,

$$MAB_j = \frac{B_j}{\sum_{i=j-6}^{i=j+5} B_i} \times 100, \tag{2}$$

MAB_j = moving average of births, in percent, for month j,
B_j = births in month j,
b_t = an OLS regression coefficient for month,
X_t = a set of monthly variables (coded as 1, 0, [-1 for December]).

The parameter b_t is time subscripted to denote that it may vary across time. Following Maddala's (1977: 390-392) exposition, we assume that b_t is a function of another variable, Z_t (continuous time):

$$b_t = \lambda + \gamma Z_t \tag{3}$$

Substituting this relationship in equation (1), we obtain the operational model:

$$MAB_t = \lambda X_t + \gamma Z_t X_t + \mu_t, \tag{4}$$

with restrictions $\sum \lambda = \sum \gamma = 0$.

The sign, size and statistical significance of γ gives an indication whether b_t in fact varies over time, while λ gives the initial effect of month on MAB_t.

The above equation can be used to arrive at the expected seasonality pattern for any given period within the time interval studied. For example, when $Z_t = 1$, $MAB_t = \lambda$ when $X_t = 1$. As time passes by one unit (t), MAB_t will increase by $\lambda + \gamma(t)$ when $X_t = 1$. Thus the initial degree of seasonality in any month (X_t) is measured by λ; its rate of change is measured by γ.

Results

Table 1 shows the regression results for Canada and the provinces. As an example of interpretation, the results for Canada show a March coefficient of $\lambda = 4.857$, which indicates that in 1926 March births were 4.833%

(99.976 + 4.857 = 104.833) above a centred 12-month moving average of births. The corresponding γ term for March is -.0044, which means that the seasonal coefficient for March reduces in magnitude over time. Thus, in 10 years time (in 120 months), the March effect would become 4.305 (4.833 + (-.0044 · 120)). By 1989, the March effect would become 1.480. Since both λ and γ terms are statistically significant (two-tailed test), we can conclude that March has a positive effect on the 12-month moving average of births, but it reduces in magnitude over time. The remaining coefficients in Table 1 can be interpreted in this fashion.

The Canadian Pattern

Figure 2 displays the changing pattern of seasonality of births for Canada as a whole. The most obvious conclusion is that the pattern has changed little since 1926. The months between January and February have all shown a reduction in their effects over time, while the September to December seasonals have increased their relative effects. August has not changed; it represents a pivotal point in the graph. From 1926 to 1961 the peak in births occurred between March and July, with a secondary rise in September. After the 1970s, September takes over as the global maxima, but the spring-early summer pattern is still pronounced, accounting for the majority of births in any given year.

Figure 3 shows the distribution of births by month and province in 1881 (data unavailable for Newfoundland, Alberta and Saskatchewan). The 1881 pattern is strikingly different than that observed for the mid-1920s to the present. In the early period, births peaked in March and declined significantly in May and June. In fact, the months of April through September, as well as November, represented below average levels of fertility, while October and December through March, were above average months.

What might explain this early pattern of seasonality in births for Canada? We tried to ascertain whether the trough in May and June would be accounted for by a predominance of stillbirths during these months. Unfortunately, such data are unavailable for 1881. The earliest data published are for 1926. The distribution of stillbirths (available on request) indicate that in 1926 the risk was highest in March and lowest in July. May was not a particularly high month for the incidence of stillbirths. Assuming this situation prevailed in 1881, the seasonality of still births cannot account for the birth trough in May and June observed in 1881.

Figure 2: Seasonality of Births in Canada
1926-1989 (Selected Years)

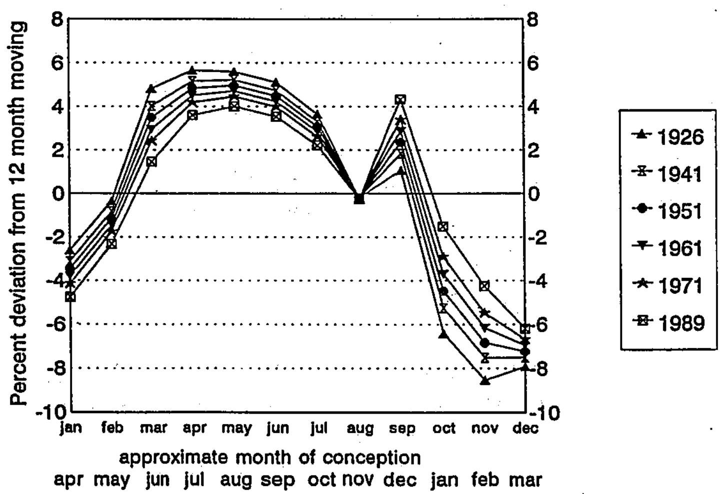
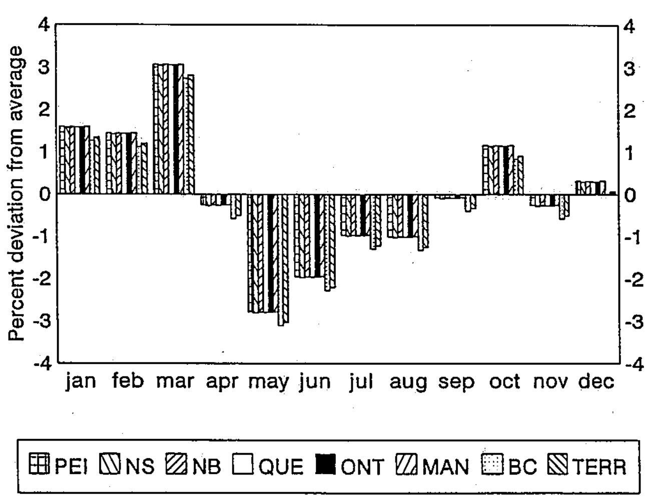


Figure 3: Seasonality of Births in 1881
Provinces and Territories



Marriage seasonality may be a possible explanation for the May trough in 1881, as relatively few people married in the months of July and August (data available on request). Most marriages occurred in June and September. Therefore, conceptions from marriages contracted in June could have resulted nine months later in the observed March peak in births. Unfortunately for this thesis, nine months from the September peak in marriages is associated with a relatively low (but rising) period for births in June. It would seem, therefore, that marriage timing may be at best a partial factor in providing an explanation of the early pattern of seasonality of births.

This interpretation assumes an immediate timing of conception with the timing of marriage. If a three-month conception wait is assumed, the correlations established above would not materialize. The June peak in marriage would coincide with the June low in births; and the September rise in marriages would result in the observed small rise in September births. Thus, we conclude that marriage may be an important factor, but we cannot be definite about this due to our uncertainty in the mean length of conception wait between marriage and pregnancy in pre-industrial Canada. Also, the lack of data on first order births further limits a more stringent test of the marriage effect thesis.

Concerning the more "contemporary" pattern of birth seasonality, most Canadian marriages since the early fifties tend to be concentrated in the months of May to August (data available on request). Again, assuming an average of a three-month conception wait between marriage and pregnancy, the majority of births should occur in the months of May-August. The graph for births (Figure 2) provides only tentative support for this expectation, as there is an above average number births during this period (however, August is an average month). The relatively low propensity to marry during October through April coincides somewhat, but not perfectly, with a low period in births during these same months if we allow for an average three-month conception wait between marriage and pregnancy. Clearly, marriage patterns are at best a limited explanation for the observed birth distributions over the "early" and more "contemporary" patterns.

The major shift in the seasonal pattern of births between 1881 and the early part of this century can be accounted by the rapid urbanization Canada underwent during this period (see Stone, 1967) and the assumed concomitant rise in the practice of family limitation. With increasing modernization, couples could plan the timing of births such that most babies would be born in the spring and early summer months. A major advantage of such timing in earlier decades was that this would ensure a greater survival probability for newborns, due to the avoidance of extreme cold and exposure to potentially fatal infections during the winter months (Underwood, 1991; Eastman, 1945). With the passage of time, infant mortality fell, but this preference for timing births in the spring and early summer remained. However, the main difference between the earlier and later preference system is that the latter is based on matters of convenience for parents and no longer as a strategy for avoiding undue risk to the infant.

Unfortunately, this pattern of the monthly distribution of births is also consistent with other explanations that cannot be readily separated with our data. For example, summer holidays could also account for the increased distribution of births during the spring and early summer in the "contemporary" pattern. But, due to data limitations we cannot separate the "preference" effect from the holidays influence. Notwithstanding this problem, the consistent peak in births in September strongly suggests a Christmas holiday effect on conception rates. The September seasonal in Canada was relatively low in 1926 (λ = 1.046), but increased considerably over time (γ = .0043) such that by 1989, it accounted for over four percentage points above the average number of births—more than any other month.

For the "contemporary" pattern of the seasonal distribution of births (1926 - 1989), the temperature (heat) thesis can be rejected since it predicts a trough in births in April-May. Even if we allow for a two-month delay in conception due to spermatogenesis decline in the hot summer months of July and August (Becker, 1991), the birth trough should be in June-July. Our data indicate that both versions of this prediction do not hold well, as the months of May to July are associated with above average fertility in Canada. It may be that at our latitude, maximum temperature is insufficient to cause the expected effect.

However, the thesis is not inconsistent with the 1881 pattern of seasonality of births, as the May trough in birth does, indeed, correspond to August conceptions. However, a rival explanation to the heat thesis is that in pre-industrial Canada, August heralded the beginning of the harvest season, and workloads increased for men and women, possibly reducing fecundability.

Photoperiod thesis predicts a decline in conception during winter and a rise during spring and summer. For the most part, the "contemporary" evidence seems to be consistent with this theory, as conceptions in Canada are below average in October-February, and reach a high during June-September. However, the December peak in conception rates (September peak in births) casts doubt on the explanatory power of this hypothesis. Moreover, the

August low in conceptions observed in 1881 introduces a further challenge to the photoperiod thesis.

Concerning the preference for birth month thesis, we have seen that since 1926, the distribution of births in Canada as a whole is consistent with the notion that parents prefer to have babies during the months of March to August. The data for Canada corresponding to the "contemporary" situation seems to fit this hypothesis. However, in connection with the "misinformed reproducer" thesis proposed by Rodgers and Udry (1988), if one assumes that there is an average three-month waiting time to conception between the timing of contraceptive discontinuation and pregnancy, the corresponding peak in births nine months later will be shifted to the right by three months. That is, assuming that couples want to see the birth of their babies during the spring and summer months, there should be a corresponding rise in conceptions between the months of September to February. As it turns out, for Canada as a whole, these are not especially high months for conceptions (except for the December rise mentioned earlier). It may be that in general, couples have not been as "misinformed" about conception wait as suggested by Rodgers and Udry (1988) and are effective in timing their conceptions such that most births occur in the spring and summer. In fact, if we set aside the "misinformed reproducer effect" thesis, the observed distribution of births in Canada and corresponding approximate conception times provide a good fit to the "preference" thesis elaborated earlier.

Provincial Analysis

The equations in Table 1 were used to generate the graphs displayed in Figures 4, 5 and 6. All provinces exemplify, to a varying degree, the overall pattern shown earlier for Canada as a whole: there is a rise in births in September; March to July generally represent above average fertility months; October to February are typically low months. Notwithstanding these similarities, some differences are worthy of mention.

For example, in all provinces, the first six months of the year have tended to reduce their relative contribution to seasonality, while the latter part of the year have become more pronounced over time. In Newfoundland, we see the opposite pattern. Since 1949 (the initial time point for which data become available), February to July have increasingly been contributing more births, while August through January have been producing relatively fewer births over time. In Newfoundland, April is now the peak month, with a secondary peak in September. In all other provinces, the most current situation denotes, for Quebec, Manitoba and Saskatchewan, that September has become the peak month for births. The predominance of the current peak is particularly striking in New Brunswick, Ontario and in the Territories.

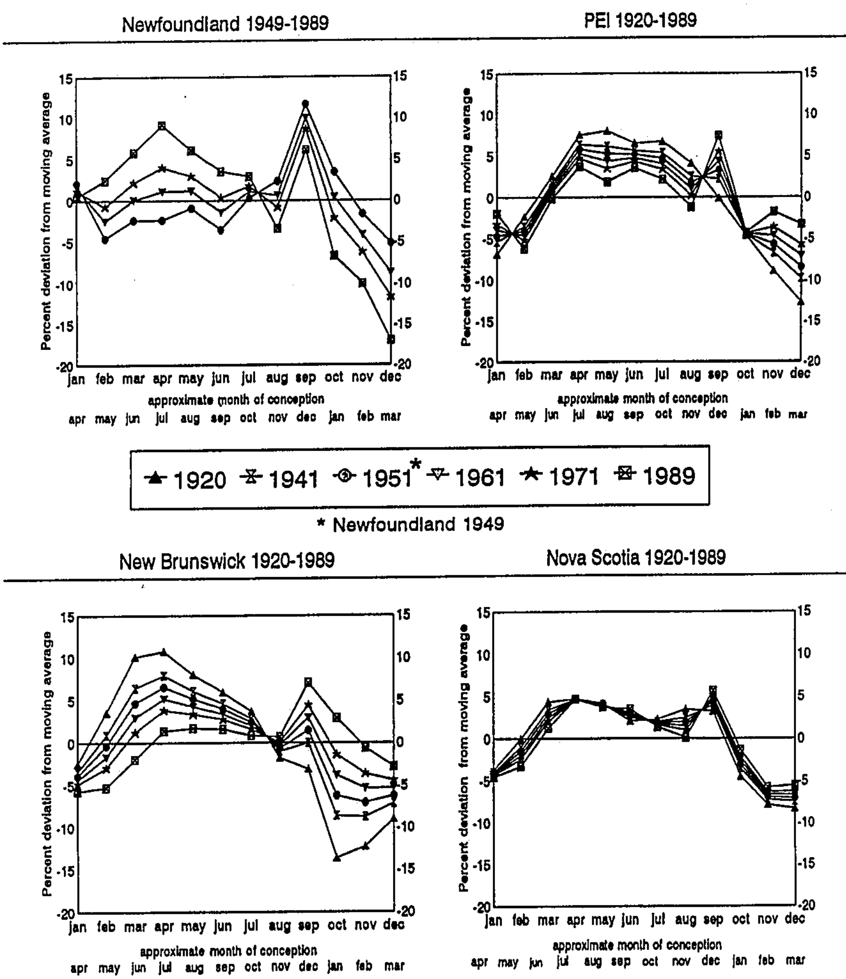


Figure 4: Seasonality of Births by Time Period
Atlantic Provinces of Canada

Table 1. Seasonal Regressions For the Monthly Distribution of Births, Early 1920s - 1989, Canada and the Provinces

λ Terms	Canada	Nfld	PEI	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Sask	Alberta	BC	Yukon/ NWT
January	-2.596**	2.087	-6.833**	-3.691**	-2.435**	-2.358**	-2.345**	-2.483**	-4.079**	-1.417*	1.990**	27.489**
February	-0.325	-4.580**	-2.031	-0.019	3.617**	-0.670	1.333*	-0.115	-1.628	0.640	1.833*	34.043**
March	4.857**	-2.397	2.524	4.381**	10.207**	4.932**	6.107**	5.103**	5.392**	4.853**	4.090**	28.066**
April	5.689**	-2.420	7.555**	4.740**	10.881**	7.918**	4.174**	4.164*	5.071**	5.188**	1.793*	3.394
May	5.635**	-0.952	8.071**	4.206**	8.115**	8.598**	4.973**	0.977	1.634	3.923**	2.638**	-15.289**
June	5.148**	-3.599*	6.550**	2.067*	6.035**	6.876**	5.531**	2.246**	0.934	2.588**	2.799**	-4.377
July	3.684**	0.284	6.790**	2.284**	3.773**	3.427**	4.111**	3.493**	2.114*	1.757*	1.741*	0.466
August.	-0.170	2.431	4.178	3.521**	-1.759	-2.776**	0.749	2.244**	4.102**	-0.491	1.868**	-18.121**
September	1.046*	11.760	-0.165	3.242**	-3.171**	0.267	0.564	3.549**	3.244**	-0.174	1.817*	-14.479**
October	-6.467**	3.632*	-4.632*	-4.506**	-13.814**	-8.853**	-6.328**	-3.916**	-2.574**	-3.934**	-4.520**	-14.164**
November	-8.579**	-1.416	-8.944**	-7.891**	-12.393**	-10.078**	-9.861**	-6.911**	-5.691**	-5.485**	-7.095**	-13.777**
December												
γ Terms												
January	-0.0028**	-0.0034	0.0059	-0.0010	-0.0039*	-0.0025	-0.0041**	-0.0027	0.0004	-0.0033*	-0.0090**	-0.6391**
February	-0.0026*	0.0145	-0.0046	-0.0039*	-0.0107**	-0.0017	-0.0052**	-0.0025	.0000	-0.0033*	-0.0058**	-0.6458**
March	-0.0044**	0.0170	-0.0032	-0.0038*	-0.0146**	-0.0014	-0.0076**	-0.0043**	-0.0050**	-0.0039**	-0.0038**	-0.2601*
April	-0.0027**	0.0239**	-0.0046	.0000	-0.0114**	-0.0012	-0.0029**	-0.0013	-0.0009	-0.0024	0.0013**	0.0525
May	-0.0021*	0.0145**	-0.0075	-0.0006	-0.0076*	-0.0038*	-0.0031**	0.0052**	0.0038*	0.0010	0.0032*	0.3489*
June	-0.0021*	0.0146**	-0.0036	0.0018	-0.0053**	-0.0026	-0.0034**	0.0021	0.0050**	0.0018	0.0006	0.0846
July	-0.0019	0.0054	-0.0056	-0.0011	-0.0035	-0.0016	-0.0019	.0000	0.0007	0.0014	0.0015	0.0025
August	-0.0001	-0.0118*	-0.0064	-0.0040*	0.0030	0.0034*	-0.0013	-0.0035	-0.0057	0.0007	-0.0034*	0.3639**
September	0.0043**	-0.0115*	0.0091*	0.0029	0.0123**	0.0038*	0.0057**	-0.0003	-0.0006**	0.0050**	0.0035	0.3439**
October	0.0065**	-0.0210**	0.0005	0.0038*	0.0200**	0.0083**	0.0076**	0.0015	-0.0014	0.0004	0.0027	0.1975
November	0.0057	-0.0175**	0.0086*	0.0025	0.0141**	0.0047**	0.0095**	0.0033*	0.0002	-0.0002	0.0029*	0.1862
December												
Constant	99.976	99.978	99.975	99.971	99.956	99.968	99.971	99.963	99.970	99.968	99.968	99.926
R^2	0.839	0.507	0.277	0.580	0.615	0.801	0.748	0.573	0.532	0.598	0.586	0.224
F	174.788	21.62477	14.150	50.884	59.009	135.121	109.234	49.515	41.878	54.738	542.283	9.881
n	762	486	834	834	834	762	834	834	834	834	834	774

* Significant at $P \leq .05$ (two-tailed t test).

** Significant at $P \leq .01$ (two-tailed t test).

NOTE: n varies due to provinces not having the same starting point in the births series (e.g., Canada starts in 1926; Newfoundland in 1949; PEI in 1921, etc). December is the reference month in the equation.

In general, there is much uniformity in the patterns of seasonality of birth across provinces. In most cases, the graphs for each period are closely concentrated and produce considerable overlap (e.g., Nova Scotia, Quebec, Saskatchewan, Manitoba, Alberta and British Columbia).

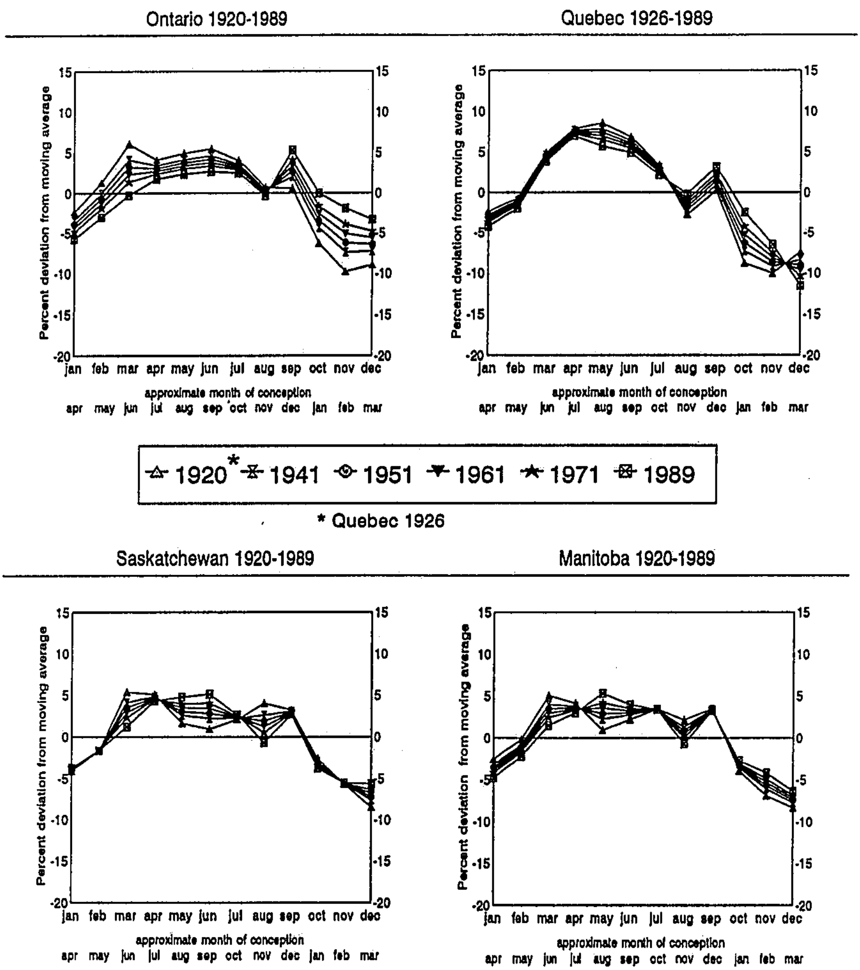


Figure 5: Seasonality of Births by Time Period Ontario, Quebec, Manitoba and Saskatchewan

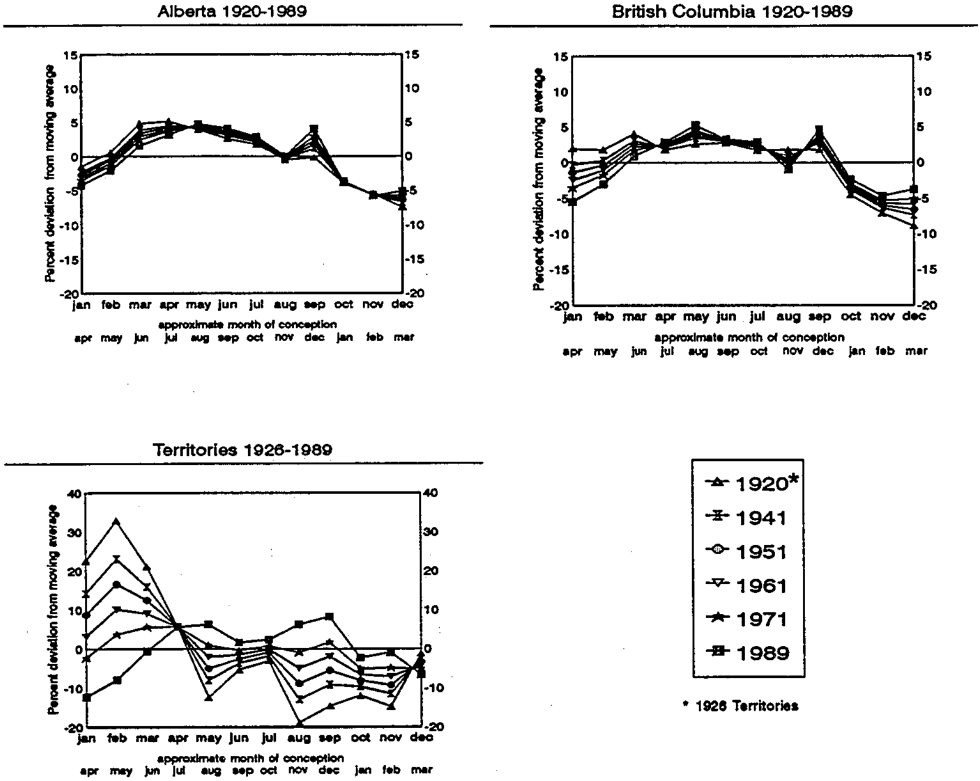


FIGURE 6: SEASONALITY OF BIRTHS BY TIME PERIOD-ALBERTA, BRITISH COLUMBIA AND THE TERRITORIES

The Territories display a rather interesting shift in their pattern of seasonality of births over time. During the mid-twenties, most births occurred between January and April peaking in May with notable troughs in May and August. By 1971, this pattern was transformed such that it became considerably "flatter," and began to approximate the typical pattern observed for Canada as a whole, and by 1989, this region of Canada experienced a monthly fertility pattern that is not very distinct from other areas of this country: a September peak, and an April-May rise in births, with relatively few births between the months of October to February.

This change in the fertility pattern for the Territories is perhaps the most convincing indirect evidence for a modernization effect on the pattern of seasonality of births. In the 1920s, this region's distribution was not too dissimilar to the 1881 configuration observed for Canada as a whole. Of course, the reasons for the similarity may differ, but what is clear from the evidence presented is that this region has followed a similar general shift in its monthly fertility distribution over the decades spanning the period of 1926 to 1989.

What are we to conclude from this general uniformity in pattern and shift across the regions over time? The most obvious implication is that modernization has had a similar transformation within the regions of this nation. We argued earlier that the decline of rurality and agricultural life and the rise of the family limitation idea, followed with the widespread use of fertility regulation, has culminated in the observed contemporary pattern of seasonality of births. In other words, modernization has allowed parents to plan effectively the timing of conception and births, such that most women bear children during the preferred months of March-July.

The increasing importance of September in the annual distribution of births, we argued earlier, is due to a Christmas/New Year effect. We believe this is a spontaneous effect as opposed to a planned process. This implies that even in a fully contracepting society, the timing of conceptions may not be totally determined by rational deterministic models of decision making. This represents an interesting avenue for further research.

With reference to the socioeconomic thesis developed earlier, we anticipated that "poor" regions would demonstrate a more pronounced level of seasonality than relatively wealthy ones. The graphical evidence in Figures 4 to 6 lead us to reject this thesis as the amplitudes across regions in both historical and contemporary periods do not appear to differ significantly. Of course, we recognize that this is a rather imperfect test of the hypothesis and therefore cannot give strong claim to its refutation.

With regard to the remaining hypotheses, there is little basis from the empirical evidence displayed, to assume that our earlier conclusions in connection with the overall Canadian pattern do not apply to the provincial evidence.

Conclusion

There is a definite pattern of birth seasonality in Canada. Since 1926 it has virtually remained constant. There is a concentration of births in March-July, and a trough in October-February. September is a peak month, and has become more pronounced over time, while the spring-summer levels have reduced over time. August has generally been an average month. This general pattern is strikingly different from that observed for the earliest point for which there are published statistics. In 1881, births peaked in March and fell dramatically thereafter, bottoming out in May, rising gradually thereafter, producing a minor maxima in October. The 1881 pattern of seasonality has strong similarities with the current seasonal pattern of births in the United States. It would be interesting to pursue this point in subsequent analysis.

Based on the literature review, we proposed eight "exogenous" type hypotheses for the phenomenon of seasonality in births. We found it difficult to uniquely separate them due to data limitations. Notwithstanding this problem, our observations suggest that there is a Christmas holiday effect on conception rates. As well, there is indirect indication that the "contemporary" pattern is partly a function of parental preference for having babies during the spring and early summer. In the early period, the observed pattern of birth seasonality was probably determined by natural fertility factors, or parity independent conditions, such as the timing of marriage, the agricultural cycle, and spontaneous abortions.

We reasoned that the seasonal distribution of marriage may have some limited bearing on the monthly birth distributions. We reject the photic and temperature (heat) effects, as the observed patterns deviate radically from the postulated ones under the assumptions of these theses. Finally, we feel that the shift from the 1881 pattern to the "contemporary" one is largely a consequence of rapid urbanization beginning at the turn of the century and the concomitant spread of family limitation ideals and means.

We could not test our proposed theoretical model due to data unavailability. It is hoped that future research will benefit from our synthesis. Further analysis with micro data is perhaps the best way to proceed, as a full explanation of the phenomenon requires information on a wide range of biological, social and economic variables not easily accessible from published Vital Statistics data.

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Appendix: Data Sources

The source used for the 1881 monthly data on births was the 1880-81 Census of Canada. The number of births per month are reported for the twelve months preceding April 4, 1881 (Census of Canada, 1881: iv)*. Data are published for the provinces of Prince Edward Island, New Brunswick, Nova Scotia, Quebec, Ontario, Manitoba, British Columbia and the Territories. The Territories of 1881 encompass the areas of Alberta, Saskatchewan, Northwest Territories, Yukon and Labrador. The 1881 data have the limitation in that within the provinces of Manitoba, British Columbia and the Territories, the Indian population by admission were not adequately covered by the Census (Census of Canada, 1881: iv).

Data for monthly births in the subsequent years used in the analysis, 1920 to 1989, are obtained from yearly Vital Statistics publications. Not all provinces and territories in Canada began reporting data in 1920 with the exceptions of Quebec (1926), Northwest Territories and Yukon Territory (1925) and Newfoundland (1949). Cautionary notes for the Yukon and Northwest Territories are provided in the earlier years by the Chief Statistician of the Dominion Bureau of Statistics regarding the completeness of data from the Territories.

The number of births for the provinces and territories by month were aggregated and the yearly sum of births for each area checked against published yearly totals, also available from Vital Statistics. For the most part, the summed monthly totals match the yearly published totals. Exceptions to an exact match of published yearly totals for each area in Canada with the monthly generated totals include Newfoundland where adjustment for undercount is done, and in Quebec where duplication is cited to occur in various years. It is assumed in this paper that the number of births stated as "unknown" are evenly distributed among the months.

* Census of Canada, 1880-1881, Vol. II, Ottawa: Maclean, Roger and Company 1884.

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