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Imperfect Institutions and the Seasonality of Birth Rates in Agricultural Iceland

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Abstract

The seasonal pattern of birth rates in agricultural Iceland, peaking in late summer and early autumn, gradually disappeared when the population migrated to fishing villages in the last decades of the 19th century and the first three decades of the 20th century. We interpret this evidence as supporting the theory that fertility depends positively on women's net energy intake. Women took active part in Iceland's sheep farming, with a peak workload in the summer months and a much lighter load in October to December. The lighter workload coincided with an increase in the number of conceptions. In this way, nature helped the population to survive for centuries plagued by low productivity, the absence of capital, and a foreign monopoly on trade with other countries.

Keywords: Fertility, agricultural society, institutions.

JEL: J13, D02

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1. Introduction

We explore the causes of the seasonality of births in an agricultural society taking advantage of the rapid urbanization of Iceland in the late 19th century and early 20th centuries. When agriculture was the dominant industry in Iceland, births peaked in late summer and early autumn, with the highest number of births in August. We are interested in whether this seasonal pattern resulted from cultural traditions or biological factors and whether it helped the nation survive centuries of deprivation and hardship.

The population of Iceland did not grow from the Age of Settlement (A.D 874-1000) and the end of the 19th century.[1] The nation lived close to its subsistence level. Laws that made land ownership a requirement for marriage acted to curb population growth and reduce the threat of famines. Icelanders did not share in the rise in living standards enjoyed by many European countries in the 18th and early 19th centuries. Investment in modern fishing vessels was prevented by institutional barriers such as the absence of investment capital and the Danish trade monopoly hindered economic development by keeping the price of Iceland's fish exports artificially low and preventing Icelanders from trading with other countries such as Britain. The late 19th century brought free trade, foreign capital and foreign technologies that raised the marginal productivity of labour in the fishing sector. As a result, workers migrated from rural farms to fishing villages situated close to fertile fishing grounds. Between 1890 and 1940, the share of the population living in farming areas (farms) fell from 88.2% to 35.6%. We explore the effect of this transition on the seasonality of fertility taking into account different hypotheses on the causes of the cyclicality of fertility.

We are not the first to explore seasonality of births in agricultural societies. Knodel and Wilson (1981) find strong seasonal patterns in births in 18th and 19th century German villages, which suggest reduced rates of conception during the harvest period from August through November. Levy (1986) studies birth seasonality in rural Egypt and finds evidence consistent with attempts to avoid births during the period of peak labour demand, with a maximum in December and minima in June and September. The authors interpret the evidence as showing that people avoid births in months when the opportunity cost of time is high. Mosher (1979) studies farming communities in Taiwan

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[1] The population was around 40,000 between A.D. 900 and 1100; 55,000 from 1000-1300; 60,000 from 1300-1500; and 55,000 from 1500-1900. It started to grow in the 1890s, reaching 77,967 in 1900; 84,528 in 1910; 120,264 in 1940; 173,855 in 1960; 226,948 in 1980; and 279,049 in 2000. As of 2016, it is 332,529. Source: Gunnarsson (2000) and Statistics Iceland (www.statice.is).

and finds that the annual cycle of production influences birth seasonality through the intervening variable of diet. Massey and Mulan (1984) study Mexican data where husbands spend part of the year in the United States, with predictable results. Spencer *et al*. (1976) study seasonal patterns in the birth rate in Belgium in the 17th and 18th centuries. They find that in both rural areas and in the cities (Liege and Ghent) there is a peak in February and March, with a secondary cluster around August and September, the latter indicating conception after the harvest. Interestingly, the agricultural areas have a much more pronounced August-September peak, a pattern similar to what we detect in the Icelandic data. There is no cyclical pattern in the urban parish in Ghent.

2. On the seasonality of births

A selective pressure to maximize the survival of offspring explains the well-known seasonal pattern of births in the animal kingdom. Turek *et al*. (1976) find that the administration of melatonin, which tends to increase with the length of the photoperiod – that is the length of the day – resulted in reduced testicular weight and suppressed spermatogenesis in golden hamsters and grasshoppers but had no such effect on mice and rats. This they interpreted as suggesting that the level of melatonin plays a role in species that have seasonal fluctuations in births. Gerlach and Aurich (2000) study the interplay of the photoperiod, the production of melatonin and prolactin, and fertility in the stallion, ram and hamster. They show that this interplay creates differing seasonality patterns in the species, depending on whether they are long-day or short-day breeders.

The seasonality of births among humans is a widely observed phenomenon. Lam and Miron (1994) find that the pattern of seasonal variations differs dramatically between countries and time periods. They describe two main patterns. The first is the European pattern, which is characterized by a global peak in the spring and a local peak in September, followed by a trough in the fall and early winter. The American pattern is markedly different, as it is characterized by a spring trough from April to May. However, the two patterns are not complete polar opposites, as they do share a September peak and a similar trough in the fall and winter. These patterns have also been found in other parts of the world, and the September peak that is common to both patterns is found in many countries (Doblhammer, Rodgers, and Rau, 1999). Christmas holidays in modern societies may explain this September peak.

We start by reviewing some of the possible biological causes and then mention one possible economic reason for the seasonality. The biological causes include the effect of net energy intake on ovarian activity; the effect of a high outdoor temperature on semen quality in hot climates; and the effect of the length of the day on the level of melatonin in the brain, which may affect fertility.[2] Economics could also help explain the pattern if people take into account the opportunity cost of childbirth when deciding when to have children.

Ellison, Valeggia, and Sherry (2005) note that human reproduction is a highly energy-intensive process for females, which makes a positive net energy intake increase ovarian activity. The net energy intake could therefore be a possible predictor of the timing of conceptions. In subsistence agricultural economies, such as in agricultural Iceland, there is large variation in both workload and the amount of available resources over the course of the year. The workload is high during the harvest season, and the food is less nutritious in spring and early summer.[3] Once the harvesting is over, the workload falls and the food becomes more nutritious. Therefore, it is possible that conceptions occur more frequently in the weeks after the harvest. Bailey *et al.* (1992) find supporting evidence for this thesis. They find that rainfall is positively linked with food production in many countries and increases ovarian function and fertility. They find that reduced food availability has a negative effect on conception and find support for the hypothesis by comparing two groups of subsistence farmers, only one of which displays seasonality in food production.

Lam and Miron (1996) propose an alternative biological explanation. They find that high temperature has a depressing effect on conception. Since the temperature peak occurs in the summer months, this suggests a trough in births in the early spring, which is the American pattern. Furthermore, they find that this effect increases with the average level of temperature: it is mild in Sweden, where the mean summer temperature barely exceeds 16°C but exerts a stronger effect in the southern part of the United States, where the mean summer temperature is 27°C. Thus Lam and Miron (1994) find a stronger cyclical pattern in the state of Georgia than in either California or New York, and a strong pattern in India and Israel. Although the heat effect is found in many parts of the

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[2] For surveys of the literature, see Lam and Miron (1991).

[3] In Iceland, the volume of milk produced by each cow reached a minimum in the spring, milk being the main provider of vitamin C and many nutrients. The vitamin C content of the milk was greatest when the cows were in the pastures in the summer. The lack of sunlight in the winter also created a vitamin D deficiency in people.

world, Lam and Miron (1996) find no evidence that extremely low temperatures affect conception. Levine (1999) has suggested a reduction in semen quality during hot summer months as a potential cause. Lam and Miron find that the magnitude of the cyclicality has decreased in the southern U.S. states in recent decades, something that might be explained by the introduction of air conditioning.

Manfredini (2009) finds that the length of the photoperiod in Italy from 1993-2005 is positively associated with conception, with the longer days in summer months having a positive impact and the shorter winter months a depressing effect. According to Reiter (1998), the seasonal level of melatonin could be one reason. Therefore, if long summer days reduce the level of melatonin and lower melatonin levels increase the rate of conception, the effect may be to stimulate conception. Reiter shows how melatonin plays a role in the seasonal patterns of mammals, and because the secretion of melatonin is photosensitive in humans, the timing of births might be affected. However, a functional link between melatonin and reproduction has not been firmly established, as clinical trials have given inconclusive results.

One can also explain the seasonality using economics. Pitt and Siegel (1998) attribute the seasonality of births in Senegal to seasonality in the opportunity cost of childbirth. If the opportunity cost of birth varies over the year, parents might shift births to those months where the opportunity cost is low. In agricultural societies, this generally occurs after harvesting.

Holidays may play a role in modern societies. Summer holidays may be responsible for the spring peak in births in many European countries, and the Christmas holidays may be responsible for the September peak in the U.S. and the local September peak in Europe. However, we do not have to be concerned with the role of holidays when studying agricultural Iceland, where holidays were unheard of. There is also the possibility that seasonality of marriage rates caused the seasonality in birth rates. However, researchers have rejected this hypothesis for many other countries.[4] Gardarsdottir (2000) documents the high illegitimacy rates in agricultural Iceland, which makes it unlikely that the seasonality of weddings causes seasonality of births.

Iceland's transition from rural agriculture to urban fishing and services in the last decades of the 19th century and the first decades of the 20th century provides a testing

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[4] Mathers and Harris (1983) find that marriage seasonality has little effect on birth seasonality in Australia.

group for these explanations of birth seasonality. We briefly describe the evolution of the Icelandic economy in the 19th and the 20th centuries before exploring the data on the seasonality of births.

3. Urbanization

The level of technology in Iceland's 19th century agriculture was very primitive, as is described by Vasey (1996). Eggertsson (2009) notes that agricultural practices made agriculture very sensitive to cold spells and diseases. In particular, farmers were discouraged from stocking up on fodder by an A.D. 1096 law that taxed fodder if it was more than one year old. Moreover, a 1281 piece of legislation forced farmers to give excess hay away to other farmers at a fixed price if requested. Although this law was repealed in 1806, the norm of hay sharing was long-lived. It created a moral hazard problem by reducing the incentive to stock hay, and as a result, livestock starved to death during the cold spell from 1880 to 1883. The main exceptions were communities that coordinated livestock planning (Bjarnason, 1913).

Jonsson (1993) notes that Icelandic agriculture enjoyed no significant technological improvements until the beginning of the 20th century. The farmers were restricted to owning small hayfields, which could only be used to grow vegetables and fodder (hay) for the winter. Poor farmers dominated farming, although fishing was an important secondary activity. While the milking of cows required a constant effort throughout the years, the workload in sheep farming is very seasonal and continues to be so to this day. The sheep breed around Christmas, and lambing takes place in the spring and farmers then send the sheep the mountains to graze over the summer months. In September, the farmers gather the sheep and bring them to collection points before slaughtering them. This occurs only once a year. Thereafter, the surviving sheep are kept in pastures and then indoors until the following summer. This cycle has repeated itself for centuries. During the harvest season, farmers required more labour, and extra workers came from the coastal areas in early July for 8-10 weeks. In the winter, around February and March, labour – mainly male workers – transitioned to the coastal areas for fishing and returned to farm work in May. Permanent migration from agriculture to the fisheries was discouraged through labour bondage. Anyone who did not own land had to work as a labourer for a landowner and could not marry and have a family.[5] This was society's method of population control.

Jonsson (2009) describes the tug-of-war between Denmark, Britain, and the Hanseatic League in the 15th and 16th centuries. Throughout this period, Denmark managed to retain control of Iceland, at one point by forming an alliance with the latter against Britain. The Danish king maintained a monopoly in trade with Iceland from 1602 until 1855, which made the price of fish artificially low and artificially raised the price of agricultural products. The Danish authorities prevented Icelanders from trading with Britain, where the price of fish was higher. Instead, Denmark bought the fish caught from Iceland at below world market prices. Although the trade monopoly ended in 1787, Icelanders could not trade freely with other countries until 1855. Following trade liberalization, there was a substantial increase in fish exports to Britain, which led to an increase in the number of sailing ships, introduced for the first time in 1780. The growth of the fishing industry then created demand for capital, and in 1885 Parliament created the first State bank (Landsbanki). However, this bank could not satisfy the fishing industry's demand for capital, which led to the establishment of a private bank in 1904 (Islandsbanki) (see Thorsteinsson *et al.*, 1991). Snævarr (1993) notes that the bank was foreign with capital of roughly 7.5% of Iceland's gross national product, which enabled it to fund the mechanization of the fishing fleet. In 1905 came the first motorized fishing vessel, which marked an important step in the development of a specialized fishing industry in Iceland. Iceland exported fresh fish to Britain and salted cod to southern Europe, with Portugal an important export market. Fishing replaced agriculture as the country's main industry.

The growth in the fishing industry was the main driver of urbanization, and favourable conditions for growth didn't emerge until after 1880, with the opening up of trade at world market prices. Accompanying this growth was a rapid expansion of the service sector around the beginning of the 20th century, which then created further conditions for growth in the fishing industry. The growth of the fishing industry created many jobs that attracted people from the countryside to the new fishing villages. At the end of the 19th century, the majority of Icelanders lived in rural areas, with only 16.6%

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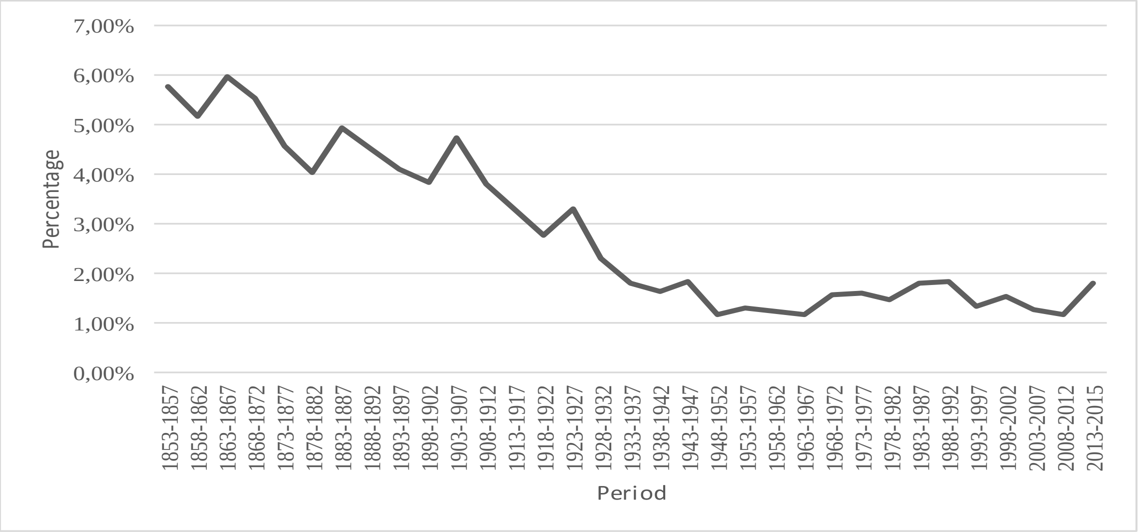
[5] The population was 71,981 in 1880. There were about seven sheep for every person alive; that is, 515,364 sheep on the island, 23,337 cows, and 41,342 horses. By 1990 the population had increased to 253,784, with around two sheep per person (548,707 sheep), while the number of cows had increased in proportion to the population, to 74,903 cows.

living in villages in 1899 (Jonsson and Magnusson, 1997). The relaxation of labour bondage in 1894 preceded extremely rapid urbanization in Iceland, with only around 30% of the population living in villages in 1910, as opposed to 75% by 1950. This transition coincided with a drastically reduced ratio of people employed in agriculture. In 1880, 77% of the population worked in agriculture, but by 1930 that ratio was only 36% (Jonsson and Magnusson, 1997).

4. Empirical analysis

We start by exploring directly the seasonality of births in selected periods in Iceland.[6] Figure 1 shows the difference between the month of highest and lowest fertility by year since 1853. The figure shows a reduction in seasonality over the period. The percentage difference between the highest and lowest values falls from 5.69% in 1853-1900 to 3.57% from 1901 to 1948, 2.05% from 1949 to 1996, and only 2.01% in the modern era from 1997 to 2015. The standard deviation falls from 1.87% for the period 1853-1900 to around 0.6% for 1949-2015.

Figure 1. Difference (%) between month with highest and lowest frequency of births



Source: *Statistics Iceland* (www.statice.is).

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[6] Our main data source is *Statistics Iceland* (www.statice.is). In 1990 the agency published *Icelandic Historical Statistics*, which includes annual data on the proportion of the Icelandic population living in urban nuclei from 1889 to 2014, the number of births by month from 1853 to 2015, and data on the share of labor employed in agriculture in the period 1801-1990.

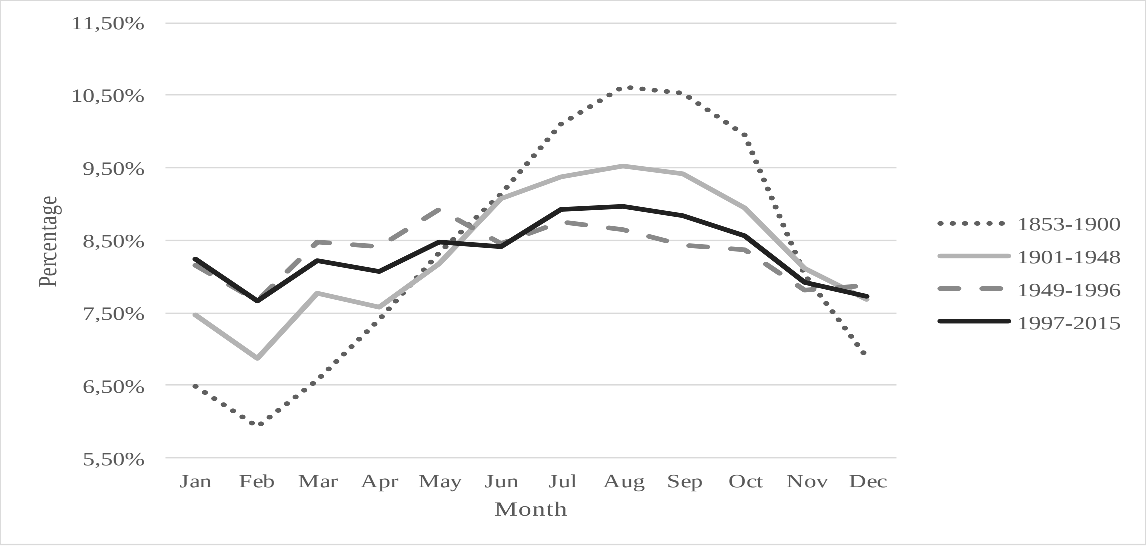
There were changes not only in the magnitude of seasonality over the period but also in the patterns. In the 19th century, a global peak characterized the pattern in August, followed by a trough in the fall and winter and a global minimum in February. The global February minimum was consistently observed throughout the period from 1853 to 2015. At the beginning of the 20th century, there is a dramatic reduction in seasonality and a change in pattern. In 1901-1948, the August global peak was still present but less pronounced, as was the winter trough. Additionally, a local peak in March emerged and remained present in all later periods.

We then remove the time trend in the number of monthly births by taking the number of births each month in a particular year and dividing by the total number of births in the same year:

$$b_{i,t} = \frac{B_{i,t}}{\sum_{i=1}^{12} B_{i,t}}$$

where $B_{i,t}$ is the number of births in month i of year t. Figure 2 shows monthly values for $b_{i,t}$, with each series representing a five-year average for each month. It is clear that there was a dramatic decrease in the seasonality of births over the period from 1853 to 2015.[7]

Figure 2. Five-year average monthly values of $b_{i,t}$, Iceland, 1853-2015.



Source: *Statistics Iceland* (www.statice.is).

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[7] A more detailed look at each period can be found in the Appendix.

A change occurred in the period from 1949 to 1996, when the frequency of births in winter and spring increased relative to births in summer and autumn. The result was that May was now a global peak month in births, while October was a mild local peak. This is broadly consistent with the widely observed European pattern of births. Thus the seasonality of births changed from having a peak in late summer and early autumn in agricultural Iceland to a less a pronounced peak in the spring, as is observed in Europe.

In the period from 1997 to 2015, there was a noticeable increase births from July to October and a decrease in births from March to June. This resulted in a pattern again resembling that in 1901-1948, although much less pronounced, with the main difference being the presence of a local peak in May in 1997-2015. It is not clear what caused this change.

Thus the data show a peak in August in the earliest period, 1853-1900, with high values also in July, September, and October. A similar pattern emerges in 1901-1948, but it is much less pronounced. There is much less seasonality thereafter: the period 1949-1996 has a small spring peak, and 1997-2015 has a small peak from July to September.

4.1 Principal component analysis

Graphical analysis takes us only so far in observing the change in seasonal patterns of births in Iceland. Any further analysis becomes difficult because of the high dimensionality of the data. Principal component (PC) analysis allows us to reduce this dimensionality. Table 1 shows the eigenvalues for the matrix of $b_{i,t}$ for twelve months per year from 1853 to 2015.

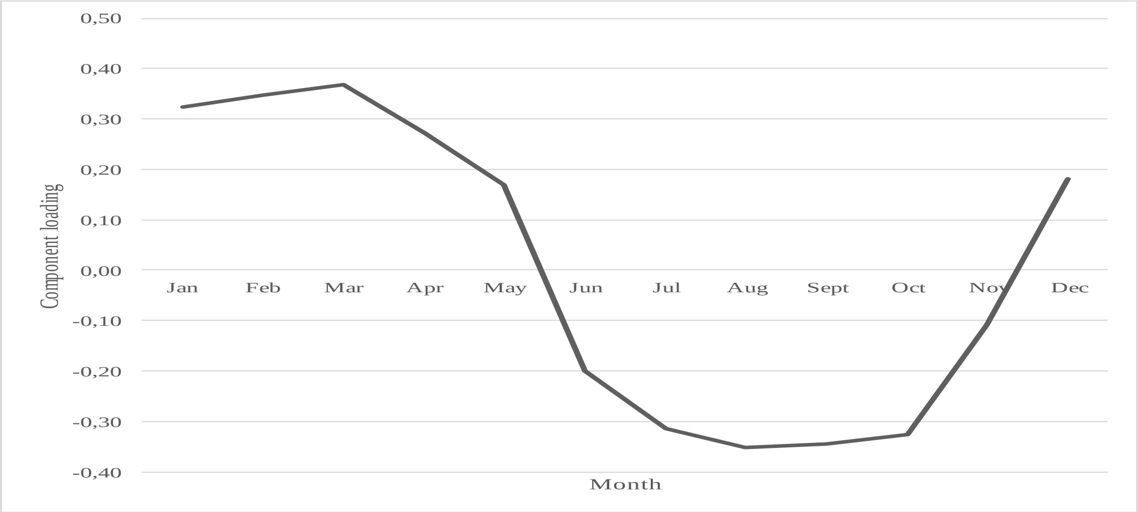
Table 1. Principal component analysis of $\boldsymbol{b_{i,t}}$, Iceland, 1853-2015.

Principal Component	Eigenvalue	Proportion of variance	Cumulative variance
1	5.80	48.32%	48.32%
2	1.59	13.27%	61.59%
3	1.05	8.75%	70.33%
4	0.80	6.69%	77.02%
5	0.71	5.96%	82.98%
6	0.52	4.32%	87.30%
7	0.42	3.47%	90.77%

Source: *Statistics Iceland* (www.statice.is).

The first principal component explains more than 48% of the cumulative variation in $b_{i,t}$. The values in the eigenvector of this PC capture the seasonality of births in agricultural Iceland, as is shown in Figure 3 below. The figure shows the component loadings for the first principal component.

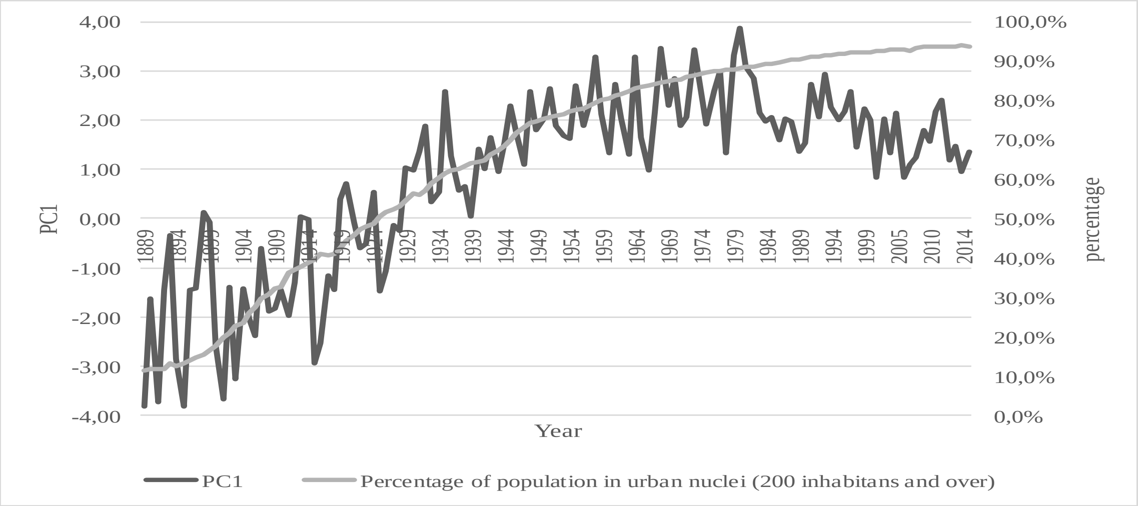
Figure 3. Component loadings for the first principal component.



Source: *Statistics Iceland* (www.statice.is).

Figure 4 shows the value of the first PC juxtaposed with the share of the population living in urban villages. A negative sign of the first PC indicates a peak in summer and early autumn and a trough in winter and spring. The positive relationship between the two series indicates that increased urbanization goes together with a higher value of the PC. The PC starts out negative in the 19th century. Because the summer and early fall months have a negative value in the eigenvector of the PC, this shows that the birth rate was high in this period. The PC then approaches zero and becomes positive around 1920. A positive value of the PC indicates that the birth rate is relatively low in the summer and early autumn months. This is broadly similar to the European pattern of births that would characterize the seasonal pattern in Iceland from the second half of the 20th century. The Icelandic pattern gave way to the European pattern from 1853 to 1948, although there were a number of years with significant deviations from the trend. As is noted above, during this period Iceland’s economy transitioned very rapidly from agriculture to other industries, and with this went the dramatic seasonality of workload in that sector.

Figure 4. The first PC and the share of the urban population 1889-2014.

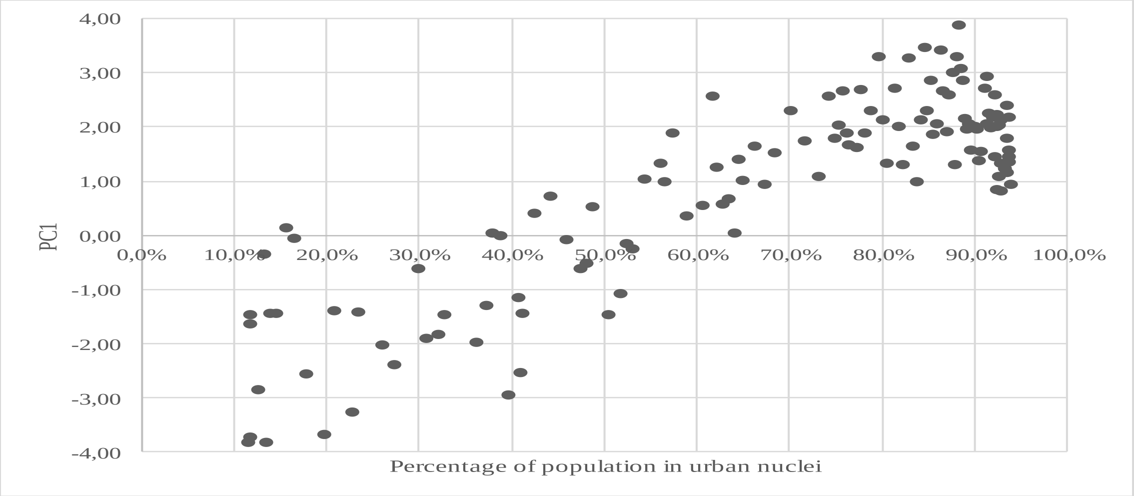


Sources: *Statistics Iceland* (www.statice.is) and the book *Icelandic Historical Statistics*.

4.2 A linear regression model

We now move on to estimate the relationship between the first PC, which captures the seasonality of births, and the share of the population living in urban areas. Figure 5 shows the relationship between the two variables in a scatter plot. The vertical axis has the value of the first PC and the horizontal axis the share of the population living in non-farm villages. A clear positive relationship appears so that more urbanization goes together with a higher value of the PC, indicating that births are less frequent in the late summer and early autumn months.

Figure 5. Scatter plot of the PC and the share of the population in villages 1889-2014.

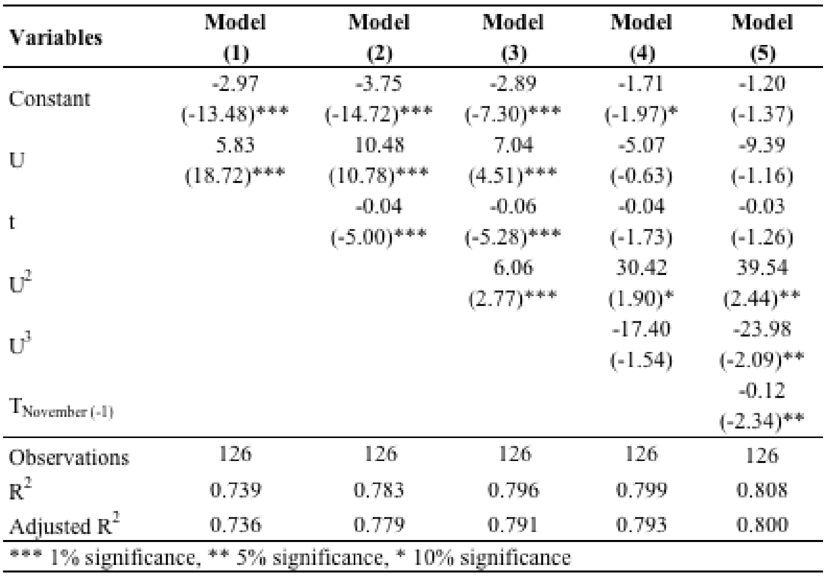


Sources: *Statistics Iceland* (www.statice.is) and the book *Icelandic Historical Statistics*.

To test for the effect of urbanization, a series of multiple regression models for the period 1889-2014 were estimated. In the first model shown in column (1) of Table 2, the PC is regressed on the share of the population living in urban nuclei. A time trend is added in the second model, shown in column (2). The square of the urbanization variable is added in the third model, reported in column (3). The results show that urbanization consistently has a positive and significant coefficient. Furthermore, the coefficient for U^2 is positive, suggesting that the relationship between urbanization and the first principal component is nonlinear, so that the effect of urbanization on the seasonality of births increases with the level of urbanization. We add the cubed value of U in column (4), which is not significant at the 10% level but has a negative coefficient, suggesting that the relationship changes from being convex to becoming concave in U with increased urbanization.

The results suggest that urbanization decreased the distinctive late summer peak and August global peak – that is, autumn conceptions – that characterized the seasonal pattern of births in the agricultural society of 19th-century Iceland.

Table 2. Least square regression models, Iceland, 1889-2014.



Variables	**Model (1)**	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**
Constant	-2.97 (-13.48)***	-3.75 (-14.72)***	-2.89 (-7.30)***	-1.71 (-1.97)*	-1.20 (-1.37)
U	5.83 (18.72)***	10.48 (10.78)***	7.04 (4.51)***	-5.07 (-0.63)	-9.39 (-1.16)
t		-0.04 (-5.00)***	-0.06 (-5.28)***	-0.04 (-1.73)	-0.03 (-1.26)
U^2			6.06 (2.77)***	30.42 (1.90)*	39.54 (2.44)**
U^3				-17.40 (-1.54)	-23.98 (-2.09)**
$T_{November\ (-1)}$					-0.12 (-2.34)**
Observations	126	126	126	126	126
R^2	0.739	0.783	0.796	0.799	0.808
Adjusted R^2	0.736	0.779	0.791	0.793	0.800

*** 1% significance, ** 5% significance, * 10% significance

Source: the book *Icelandic Historical Statistics* and the *Icelandic Meteorological Office* (www.vedur.is).

Having established the importance of the autumn months for conception, we next explore the effect of the average autumn temperature. In the final column, we add the mean monthly temperature in a town on the west coast, Stykkishólmur, where temperature records go furthest back, lagged by 9 months.[8] The coefficient of the temperature variable is statistically significant at the 5% level of significance and negative. Note that the value of the dependent variable, the PC, is negative in the first decades of the sample that cover the agricultural period. Hence the negative coefficient of the November temperature implies that the warmer the month of November is, the higher the number of conceptions in that month and the number of births in August of the following year.[9]

5. Interpreting the results

A peak in late summer and early autumn characterized the seasonal pattern in the agricultural society of the 19th century, with the highest number of births in the month of August and the trough in births in winter and fall. The pattern therefore highlights the importance of the autumn months for conception. This pattern disappeared when the population had migrated from the rural agricultural areas to coastal villages.

These results are consistent with the thesis of Ellison *et al.* (2005), that positive net energy intake increases ovarian activity in women and is therefore a possible predictor of conception. In particular, the net energy intake is greater in the autumn, once the harvest (hay) is in and farmers have herded the sheep from the pastures in late summer and early autumn. The work effort made by both men and women falls at this point. Moreover, a warm November would also increase the net energy intake in that month.

The results go against Pitt and Sieger's (1998) hypothesis that in agricultural societies there is an incentive to shift births to months with low opportunity cost. The peak in births in late summer occurs at a time of maximum demand for labour in the agricultural society of Iceland. During this time, farmers and their workers had to mow the fields, bring the hay into the barn, and take the sheep to slaughterhouses in September after searching vast mountain areas. Farmers had completed these tasks by the beginning of October, and the labour effort required on the farm was lower until the lambing season in the spring. Thus conceptions were more frequent during the autumn months in

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[8] The Icelandic Meteorological Office has monthly temperature data for the town Stykkishólmur on the west coast of the island from 1830 to 1999. Statistics Iceland has monthly temperature data for Stykkishólmur from 1949 to 2014. Although the average annual temperature varied over the period 1853-2015, the seasonal temperature pattern remained the same. See figures in the Appendix.

[9] When the average temperature for all months was included, only the November temperature had a statistically significant coefficient (at the 5% level). Interacting the urban variable U with the temperature in November did not yield a significant coefficient.

agricultural Iceland, and births were more frequent in late summer at the peak of the harvest season. If longer days decrease the level of melatonin, we would also see increased rates of conception in summer, especially from May to July, with births peaking in February, March, and April; however, this pattern only emerged in the 20th century, when the population was predominantly urban. Because Iceland's climate is moderate and the summer cold, we also cannot take seriously Levine's (1999) explanation that semen quality is adversely affected in the summer months.

This leaves us with one biological explanation: that the net energy intake affects the ovarian function of women, with a higher net intake increasing the probability of conception. Clearly, women working in the fields in the summer months used up more energy, and in September, once the harvest was in, the net energy intake rose, possibly increasing the probability of conception. The period between the slaughtering of the sheep (in September) and Christmas was a time for resting in Iceland's agricultural society. People read books and spent time together. The availability of light during long and dark days was limited, making work difficult. Furthermore, in the spring there was a decline in the supply of milk. The fact that the seasonality of births fell and changed when people moved from rural agricultural areas to more urban fishing villages provides further support for this explanation.

One more factor deserves mention. In the spring, from about February to May, most men moved temporarily to the seaside to fish, which was a source of some income for the farmers. It is very likely that this factor also contributed to the cyclicality of births, in particular the February low in Figure 2, but it cannot explain fully the late summer peak, as the number of conceptions did not rise in June and July, when the men were back on the farms.

6. Conclusions

We have found that births peaked in late summer and early spring in agricultural Iceland, a pattern that gradually disappeared when the population moved to coastal fishing villages in the last decades of the 19th century and the first decades of the 20th century. We use our results to test some of the explanations proposed for the seasonality of birth rates in other countries. The evidence does not support the hypothesis that the long summer days increase fertility by reducing the level of melatonin, as conceptions peaked in November. Neither does it support the hypothesis that hot weather reduced fertility in the summer, because the climate is moderate. Moreover, the evidence does not support the hypothesis that couples planned ahead in order to have children at the optimal time, for August and September were the months of peak work, when fields were mowed, hay collected and put in barns, and sheep shepherded in the mountains.

The evidence is consistent with the hypothesis that it is easier for women to become pregnant when their net energy intake is large; i.e., when they have nutritious food and the work effort is limited. By timing conceptions in the autumn months, nature increased the probability of a successful pregnancy. The seasonality may in this way have been helpful in sustaining the population of Iceland through centuries of near-subsistence living and significant seasonality of work effort.

Compliance with Ethical Standards: The authors declare that they have no conflict of interest.

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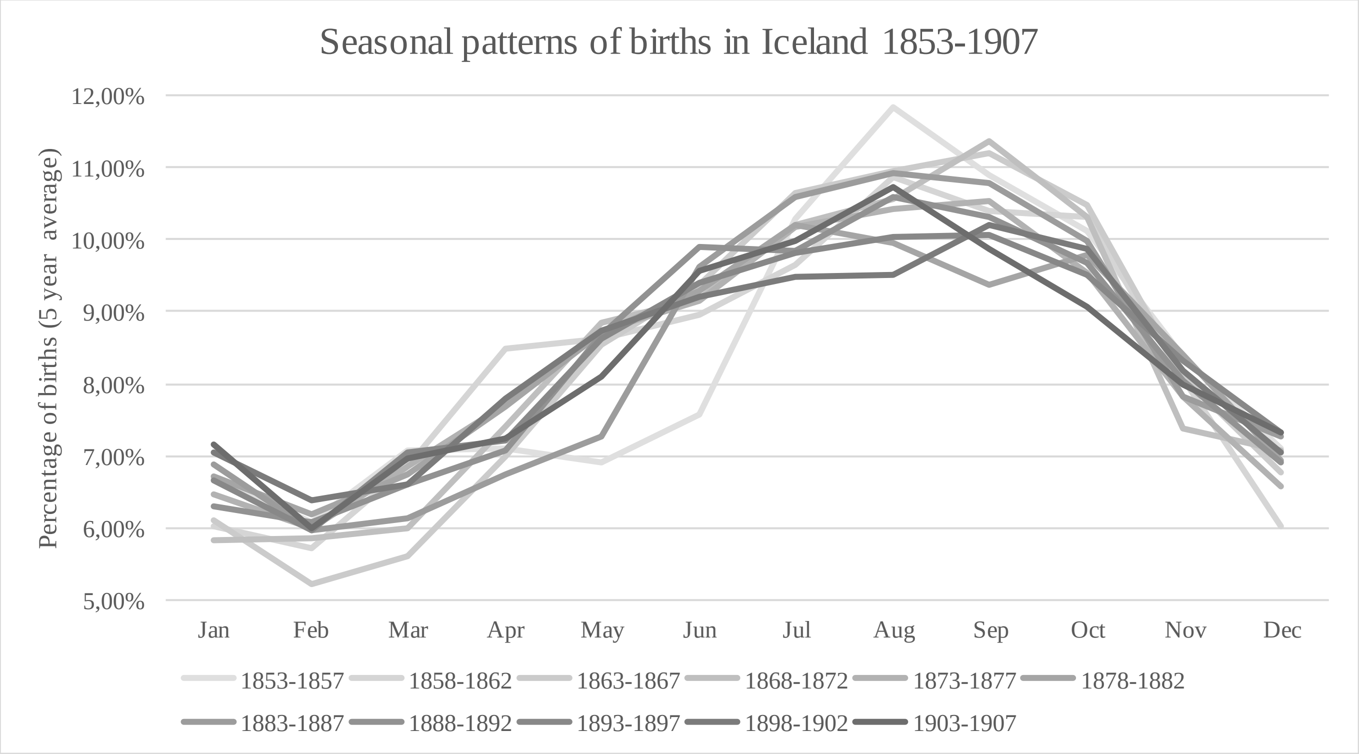
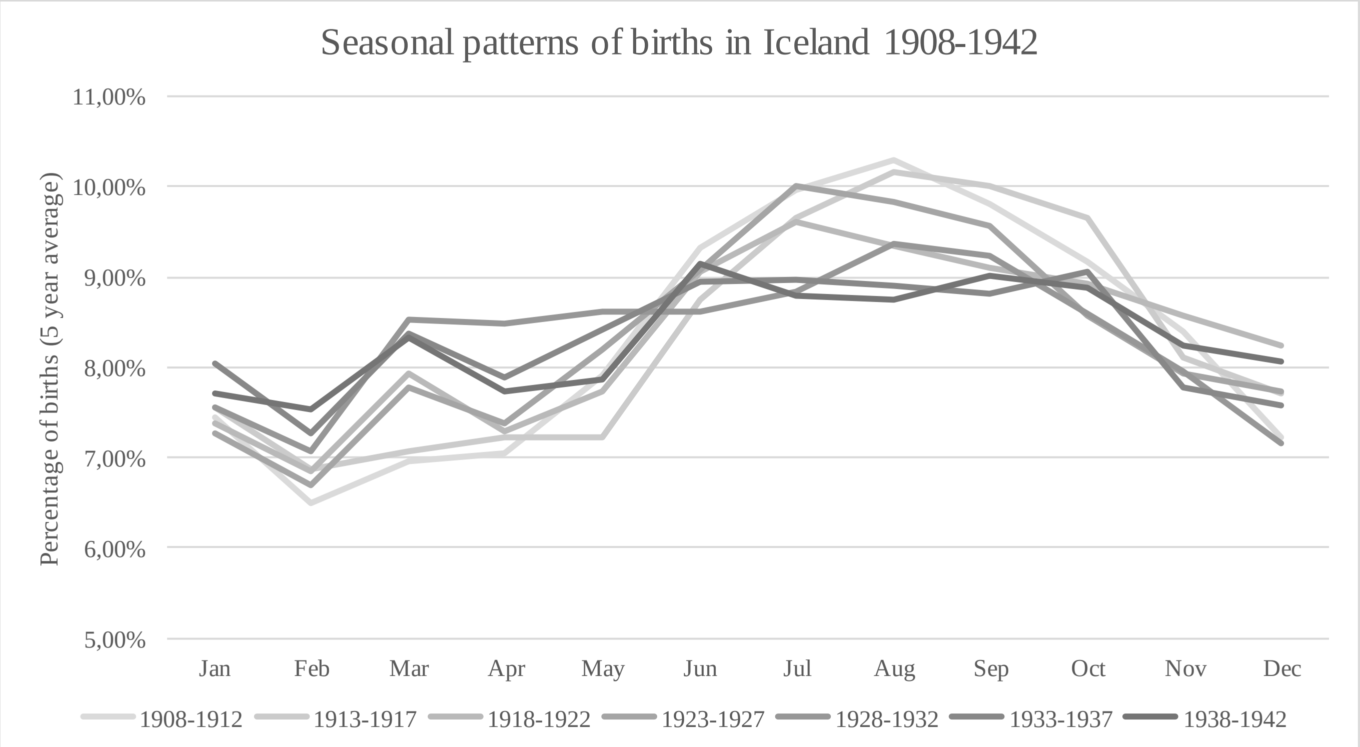
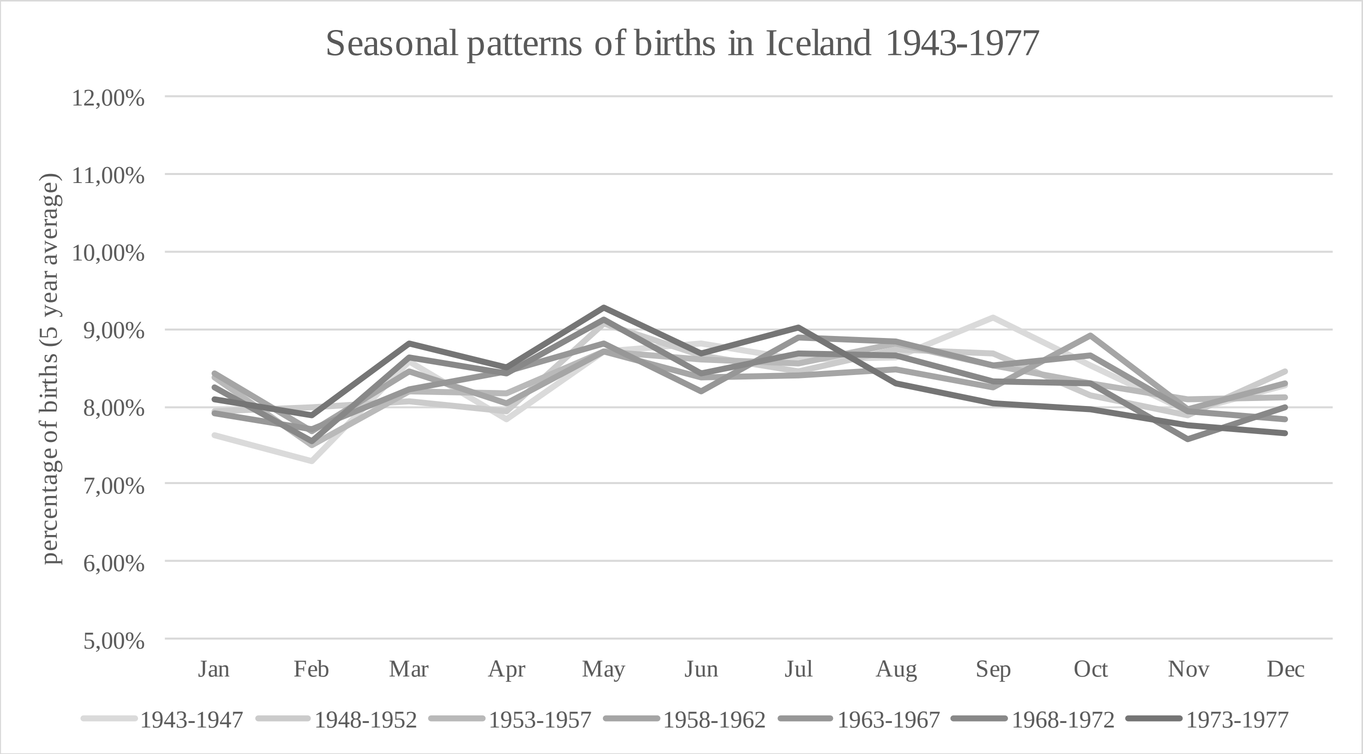
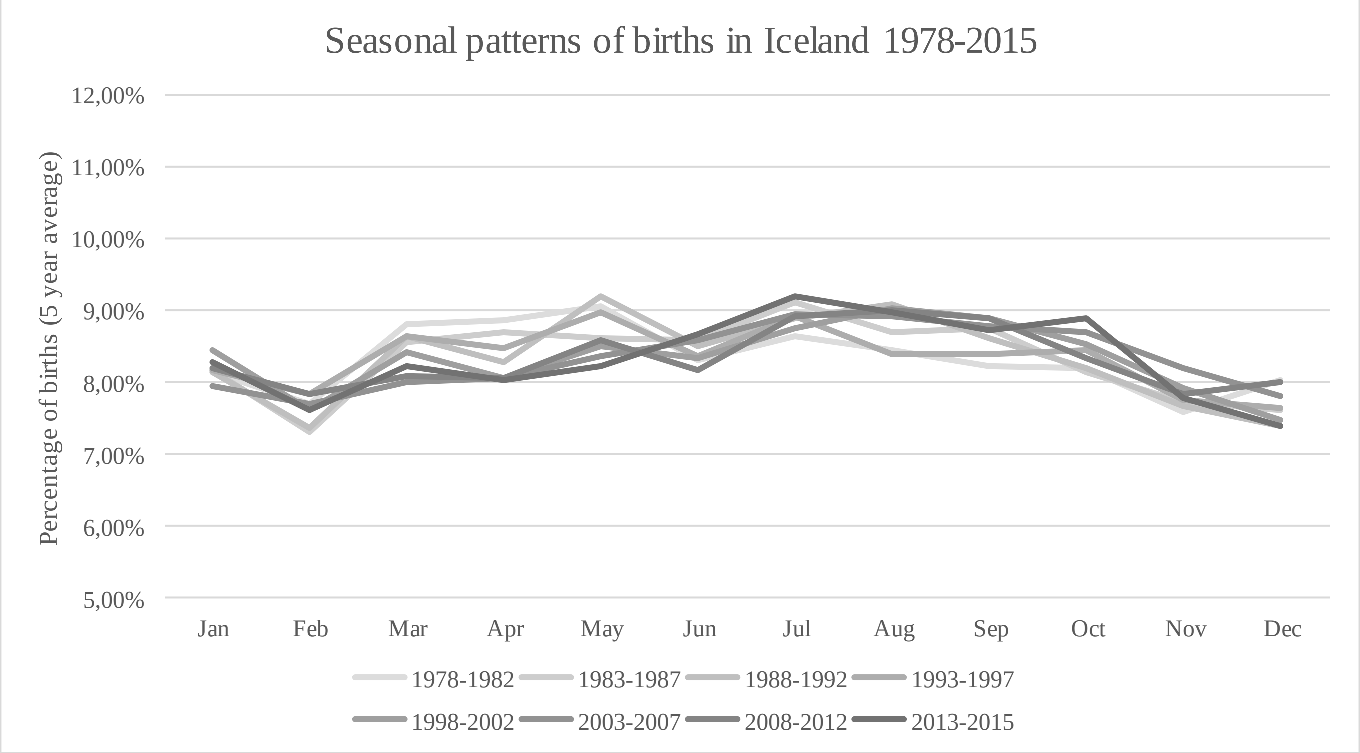
Appendix

Seasonal patterns of births in Iceland, 1853-2015



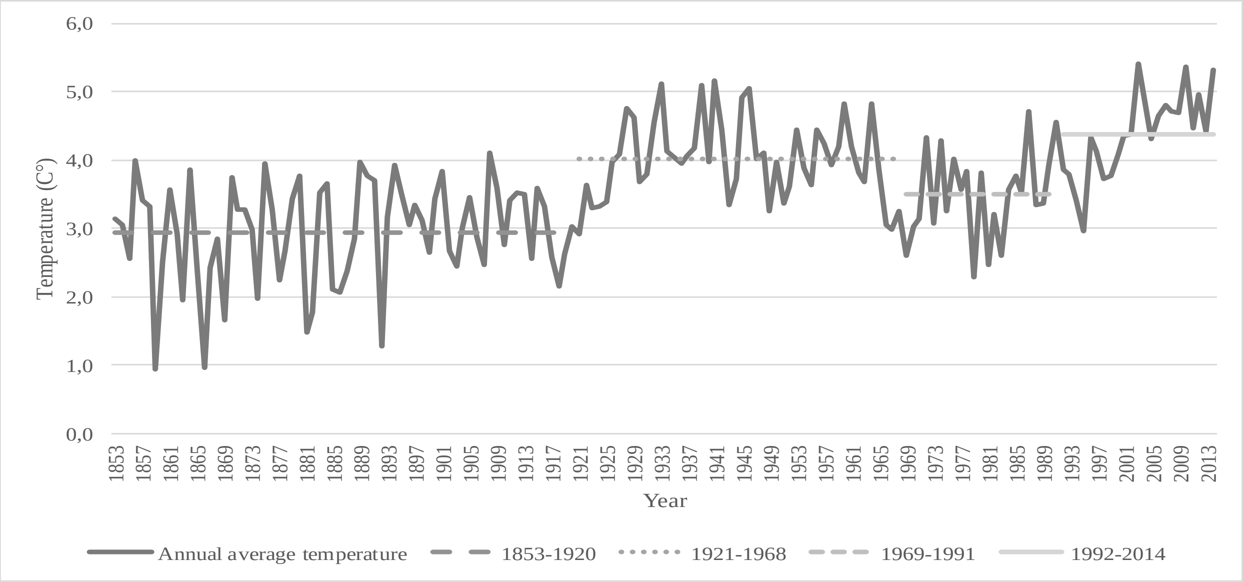



Seasonal patterns of births in Iceland 1943-1977
percentage of births (5 year average)
12,00%
11,00%
10,00%
9,00%
8,00%
7,00%
6,00%
5,00%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1943-1947
1948-1952
1953-1957
1958-1962
1963-1967
1968-1972
1973-1977


Seasonal patterns of births in Iceland 1978-2015
Percentage of births (5 year average)
12,00%
11,00%
10,00%
9,00%
8,00%
7,00%
6,00%
5,00%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1978-1982
1983-1987
1988-1992
1993-1997
1998-2002
2003-2007
2008-2012
2013-2015

Temperature in Stykkisholmur, 1853-2014

Annual averages



Seasonal cycle