Environment Before and After Birth and Mortality in Old Age

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One of the more puzzling discoveries in biodemography is the persistent relationship between season of birth and mortality at later ages. Gabriele Doblhammer (2004) has shown that persons born in the spring tend to live longer than those born in the fall. Since seasonality is reversed in the northern and southern hemispheres, the most favorable months of birth are October to December in Austria and April to June in Australia (Doblhammer 2004). Moreover, the effect of season of birth increases with distance from the equator as seasonal variations become more pronounced. Doblhammer also demonstrates that the legacy of season of birth cannot be explained by other individual characteristics, like socio-economic status, or by secular changes in the level of mortality.

While Doblhammer provides convincing evidence that month of birth has a long lasting association with mortality, she is unable to pinpoint a specific explanation for this pattern. The two factors in early life most likely to explain this association are nutrition and disease. David Barker's "fetal programming" hypothesis emphasizes the long-run consequences of maternal nutrition during pregnancy (Barker, Osmond, Golding, Kuh, and Wadsworth 1989; Barker 1994). Barker argues that poor maternal nutrition affects fetal development in ways that appear many years later.

Links between diseases in early childhood and late life mortality have been invoked by a number of researchers. For example, cohort effects in mortality are often attributed to differences in exposure to disease in infancy and childhood(Elo and Preston 1992; Forsdahl 1977; Preston and van de Walle 1978). Bengtsson and Lindström (2000) found that individuals who were infants during years of very high mortality had higher risks of dying above age 55 than those born when infant mortality was low. Finch and

Crimmins (2004) argue that diseases in early life pre-dispose the immune system to inflammatory responses, which increase the likelihood of degenerative diseases later in life.

We argue here that differences in longevity by season of birth are due to exposure to disease in childhood, not pre-natal maternal nutrition. Specifically, we find that differences in old-age mortality by season of birth parallel seasonal differences in infant mortality during the first month of life. Relative risks of dying were higher for those born in winter (January, February, and March) in our study population, which suggests that respiratory diseases played a leading role in establishing this pattern.

Three kinds of evidence will be offered to support this conclusion. First, we show that differentials in old age mortality by season of birth are similar to the seasonality of mortality in the first month of life. In contrast, mortality in the remainder of the first year of life follows a different pattern, which does not resemble the effect of season of birth at later ages.

Second, we show that the season of birth effect is related to the level of mortality in the year of birth. When mortality in the year of birth was low, individuals born in the winter had higher old-age mortality than those born in the summer, but the disadvantage of persons with winter birthdays disappeared in years of high mortality. Thus, epidemic diseases, which change the seasonality of morbidity and mortality, tend to mask rather than enhance the season of birth effect. In contrast, we find no interactions between mortality differentials due to season of birth and either pre-natal food prices or the socio-economic status of the household of origin, which suggests that the season of birth effect was not related to nutrition.

Third, the long-run disadvantage of those born in winter months was much greater among males than among females, which consistent with greater susceptibility of males to respiratory diseases in the first month of life. In the absence of preferential treatment, males usually have higher infant mortality than females, and males may be born with less mature respiratory systems than females (Friedrich, Stein, Pitrez, Corso, and Jones 2006; Lum, Hoo, Dezateux, Goetz, Wade, DeRooy, Costeloe, and Stocks 2001; Waldron 1983). Risks of dying during infancy were about thirty percent higher for males than for females in our study population, which corresponds to the greater importance of season of birth among elderly males than females.

Setting, Sources and Methods

This study is based upon life histories from the late nineteenth century in three municipalities in eastern Belgium: Verviers, Sart, and Limbourg. These locations were chosen primarily because each had registers of population covering most of the nineteenth century, but they also yield interesting contrasts. Despite their geographic proximity, our three study sites had distinctive economic and demographic histories during the nineteenth century.

In the nineteenth century Verviers became an important center of woolen textile production. Manufacturers in Verviers persuaded an English mechanic, William Cockerill, to settle in Verviers and build them the first mechanical spinning machines on the continent. Verviers grew from about 10,000 inhabitants in 1800 to around 25,000 in 1850 and 52,000 in 1900 (Alter 1988; Desama 1985).

Sart covers a large geographic area, which was and still is sparsely populated. The land is poorly suited to agriculture, and much of the population of Sart was impoverished in the early nineteenth century. The average population in Sart was about

2,000 inhabitants, but they lived in half a dozen hamlets, rather than a single settlement. Conditions improved after 1850 as out-migration (principally to Verviers) reduced population pressure and new agricultural techniques were introduced (Alter, Neven, and Oris 2004).

The average population of Limbourg was also about 2,000, but it had a distinctly urban aspect during the nineteenth century. Most of the population lived in a single settlement, and many were employed in textile production. Limbourg lost population in the early nineteenth century, as machines in its larger neighbor replaced spinning wheels and handlooms, but the development of factories in Limbourg itself resulted in population growth after 1850 (Capron 1996; Capron 1998).

Verviers, Sart, and Limbourg were very different epidemiologically as well as economically. Verviers suffered from all of the ills of urban growth in a period before modern health measures. Expectation of life at birth was little more than 30 years around 1850, and cholera was epidemic in 1833, 1834, 1849, and 1866. Sart, in contrast, benefited from its isolation. Life expectancy at mid-century was around 45 years, and the 1849 cholera epidemic by-passed Sart entirely. Mortality in Limbourg was somewhat higher than in Sart, but its small size and geographic location spared it from the high levels of mortality observed in Verviers.

Data for this study are drawn principally from registers of population, births, and deaths. Population registers are particularly useful for demographic analysis, because they recorded demographic events (births, deaths, marriages, and migration) as well as household structure and occupations. We have information on all inhabitants of Sart and Limbourg. Our sample for Verviers consists of people whose names begin with the letter

"B." We focus on the period from 1850 to 1899, except for Limbourg where our data end in 1890. Only persons born in Sart, Limbourg, or Verviers are examined here.

Methods

We use the Cox partial-likelihood method to estimate the effects of individual attributes on the likelihood of dying. The Cox model implicitly controls for the effect of age, which is used as the baseline hazard. The following covariates are included in our models:

1. Sex
2. Season of birth
3. Year of birth grouped into ten-year birth cohorts
4. Birthplace (Limbourg, Sart, or Verviers)
5. Residence (Limbourg, Sart, or Verviers)
6. Economic status in childhood is derived from the occupations of the heads of households in the population. Individuals living in households headed by a professional, manager, or business proprietor are classified as "high" economic status. All others, including those not observed during childhood, are classified as "low" economic status.
7. Prices 0-2 months before birth have been derived from "*Mercuriales,*" which are official prices collected monthly in the Verviers market from 1801 to 1874. We use the price of rye for Limbourg and Verviers, because most workers ate bread made in whole or part from rye, rather than wheat bread which was preferred but more expensive. Oats prices are used for Sart, because previous research indicates that this population relied on oats in times of crisis. Prices have been detrended by using the Hodrick-Prescott filter to identify the trend, which is then subtracted from

the observed series. We compute the level of rye prices for each month of birth by averaging the differences from trend in the month of birth and the two preceding months.   Months of birth are classified as months of "high" prices if prices were above the 75th percentile of the distribution of detrended prices.

8. Annual death rates have been estimated from the number of deaths in each year in each municipality. To allow for changes in population we compute the trend in deaths by using the Hodrick-Prescott filter, and then compute the ratio between the observed number of deaths and the trend. This procedure allows us to estimate annual death rates beginning in 1797 in Verviers, 1799 in Sart, and 1700 in Limbourg. This procedure is necessary, because estimates of population are not available for every municipality before 1831. The result is a very good approximation of the crude death rate, however. Correlation coefficients between this measure and available crude death rates vary from 0.88 to 0.92. We divide years into high and low death rates by whether they were above or below the trend. Since the trend is specific to each municipality, each place has a different level of mortality. Between 1831 and 1869, the average crude death rates were 23 in Sart, 24 in Limbourg, and 35 in Verviers.

Season of Birth and Mortality in Infancy and Old Age

In this section we compare the season of birth effect in old age to season of birth effects in infancy. If infections during infancy had life-long consequences, these seasonal patterns should be the same. We examine mortality in the first month of life separately from mortality in later infancy (months 2 to 12), because different environmental influences were likely to be at work at different ages. All newborns were breastfed during the nineteenth century, which protected them from exposure to some kinds of diseases. We expect that diseases in the first month of life were primarily due to air-born diseases, as well as infections caused by conditions at delivery (which should not vary seasonally). Older infants began to receive supplementary foods which had a higher risk of contamination by water-born infections. These differences between early and later infancy should be reflected in seasonal patterns of mortality. During the nineteenth century air-born diseases were more prevalent during the winter months, while water-born diseases usually struck in the summer. We also expect to see much stronger evidence of water-born diseases among infants in Verviers, which was much more vulnerable to diseases like cholera than the two smaller communities.

Table 1 and Figure 1 present estimates of the effect of season of birth on mortality above age 50 in Sart, Limbourg, and Verviers. The model controls for sex, year of birth, and high prices in the month of birth. The latter can be construed as a test of the “fetal programming” hypothesis, which we discuss below. It is included here to remove the effect of seasonal variations in prices, but it does not have consistent or statistically significant effects in these models. Only subjects born in years of below average death rates are included in Table 1 and Figure 1, because we show below that high mortality changes the pattern of season of birth effects. Persons born in winter (January, February, and March) are used as the reference group.

There are pronounced mortality differentials by season of birth in Limbourg and Verviers and much smaller effects in Sart. Individuals born in winter faced higher risks of dying than those born during the spring or summer in the town and city. The risk of dying for individuals born in the spring was only half the risk faced by those born in the winter, and the relative risks of summer births were 40 percent lower than those of winter births. In Limbourg the risk of death remained low for those born in the fall, but in Verviers fall births had no advantage over winter births.

In Tables 2 and Figure 2 we use similar models to estimate the seasonality of mortality during the first month of life, specifically from the fourth to the thirtieth days of life. The first three days of life are excluded for both theoretical and practical reasons. On one hand, deaths in the first day of life are more likely to be due to congenital conditions and accidents during delivery, which should be less relevant for old age mortality. On the other hand, the records often do not distinguish between stillbirths and live births that died in the first day or two of life. Our population register data for Sart and Limbourg have been supplemented with infant deaths recorded in death registers to capture these *"enfants sans vie,"* but they have not yet been added to the Verviers data. We circumvent these problems by excluding the first three days of life from the analysis, but the results would be the same if we started the analysis at birth.

The seasonal pattern of mortality in the first month of life resembles the season of birth effect in old age. In both cases the risks were highest for those born in the winter/fall and lowest for those born in the spring/summer. Breschi and Livi Bacci (1997) show that this pattern was typical for neo-natal mortality in Belgium, but they find other patterns in other parts of Europe.

The seasonality of mortality in the remainder of the first year of life differs from the pattern that we observe in the first month. Table 3 and Figures 3 and 4 show relative risks of dying during the second through twelfth months of life for both the season of birth and the current season (season at risk).   Children born during the winter continued to have relatively high mortality in later infancy, but the disadvantage of winter births was much less after the first month of life (Figure 3). We also find that fall births had the lowest risk of dying in later infancy.

When we look at the effect of current season on mortality in later infancy, we find a strong contrast between Verviers and the two smaller communities. While winter was the most deadly season in Sart and Limbourg, infants in Verviers were at much higher risk in the summer months. A summer peak in infant and child mortality is usually a sign of water-born diseases, and mortality in Verviers remained very high until water from a new reservoir was piped into the city in the 1870s.

We conclude that the season of birth effect in old age bears a much stronger resemblance to seasonal differences in mortality during the first month of life than during later infancy. In both early infancy and old age we observe relatively higher risks for those born in the fall and winter than for those born in the summer and spring. While winter births were still at a disadvantage in later infancy, fall births tended to have the lowest mortality. Mortality by current season followed different paths in our three study sites. Infants older than one month faced very high risks of dying during the summer in Verviers, but this pattern was absent in Sart and Limbourg.

The patterns described here differ from those observed by Doblhammer in more recent data, which tend to show the lowest old age mortality among individuals born in the spring. The difference may be due to changes in the distribution of mortality during the first year of life. Doblhammer's (2004) analysis of Danish infants born between 1911 and 1915 shows higher mortality for spring and summer birthdays, but higher current month mortality in winter. Infant mortality was lower in 1911 than in the period examined here, and breastfeeding had probably decreased as well.

Season of birth and pre-natal nutrition

Table 4 provides two ways of testing the "fetal programming" hypothesis, which emphasizes maternal nutrition. This analysis is limited to data from Limbourg and Verviers, because season of birth had much less effect on old age mortality in Sart (see Table 1). We expect that individuals born in years of high prices and/or in relatively poor households were most likely to experience poor nutrition *in utero*. The estimated relative risk for being born in a period of high prices is 1.16 in Model 1, which is consistent with the "fetal programming" hypothesis, but we cannot be confident that this value did not occur by chance. Model 1 does not imply that individuals born in high economic status household lived longer in old age.

Models 2 and 3 test the "fetal programming" hypothesis in a different way. In these models we ask whether high prices or high economic status at birth help to explain the season of birth effect. These models include interactions between season of birth and high prices or high household economic status at birth. If season of birth represented nutrition *in utero*, the interactions should change the effects of seasons of birth on old age mortality. For example, we would expect mortality differences between high and low seasons of birth to be greater in times of high prices or among individuals from poor households. Neither of these patterns is present in Table 4. These results imply that the link between season of birth and old age mortality is not related to maternal nutrition.

Season of birth and level of mortality

Model 1 (Table 4) and Model 4 (Table 5) offer the same tests for the hypothesis that season of birth represents differences in exposure to disease in infancy. The simple test of this hypothesis in Model 1 is negative. Individuals born in years of high death rates did not experience higher mortality above age 50. The estimated relative risk for birth in a year of high mortality is 0.92, and it lacks statistical significance. On the other hand, the model changes significantly when we introduce an interaction between season of birth and the death rate in the year of birth in Model 4. In the interaction model the season of birth effect is stronger in low mortality years and weaker in high mortality. This is easier to see in Figure 5, which plots the net effects of season of birth for low and high mortality years. The figure shows that the pattern of high mortality among winter births and low mortality among spring and summer births occurs in low mortality years. The disadvantage of winter births disappears in high mortality years, resulting in almost no difference in the risk of dying by season of births.

The way in which the season of birth effect changes in high mortality birth years is somewhat puzzling. We might have expected that high mortality would shift the seasonal pattern by increasing the risks of those born in the summer or some other season. Instead, we find that the relative risks of those born in winter were lower if they were born in high mortality years. In other words, high mortality in the year of birth erased differences due to season of birth by eliminating the disadvantage of winter births not by adding a disadvantage to any other season of birth. This shift could be a consequence of the selective operation of mortality. Mortality among winter births in high mortality years may have been so high that only the relatively robust among them survived to age 50. We hope to find a way to test this hypothesis.

<u>Season of birth and sex</u>

Males had higher risks of dying in all of the models examined here. The excess mortality of males was 22 to 74 percent in the first month of life (Table 2), 8 to 64 percent in later infancy (Table 3), and 22 to 55 percent above age 50 (Table 1 and Model 1 in Table 4). These are the extreme ends of the life course, and the middle years were more likely to be characterized by excess female mortality(Alter, Manfredini, and Nystedt 2004).

Model 5 (Table 5 and Figure 6) tells us that season of death had very different effects on the old age mortality of males and females. The pattern that we observed in Figure 1 (high risks for those born in the fall/winter, low risks for spring/summer births) characterizes males but not females in Figure 6. Model 5 suggests that season of birth mattered a great deal for old men but not at all for old women.

Conclusion

The results presented here suggest to us that sickness in the first weeks of life had a profound influence on health at later ages. We have seen that the pattern of differential mortality by season of birth in nineteenth-century eastern Belgium was very similar in early infancy and in old age. Risks of dying were highest for those born in the winter and fall, and risks were lowest for those born in the spring and summer. We find a different pattern when we look at mortality later in infancy, however. Season of birth was much less important for the mortality of older infants, and differences associated with current season (season at risk) varied by community.

We also found that old age mortality was affected by interactions between season of birth and the level of mortality in the year of birth and sex. Differential mortality by season of birth was greater when death rates in the year of birth were low. Paradoxically, we found that high mortality in the year of birth erased the effect of season of birth by removing the disadvantage due to a winter birthday. We suspect that this pattern may be due to the selective effect of mortality. Mortality in Verviers was certainly high enough to produce large selection effects, but we have not yet determined how important of selection was.

Finally, we found that season of birth had a much greater effect on the old age mortality of men than of women. This too points back to a mortality differential established early in infancy. Males are born with lower respiratory flows than female infants, which seems to make them more vulnerable to infections (Waldron 1983). Our analysis of infant mortality also found excess male mortality, especially in the first month of life, and mortality in the first month of life was higher in winter, when respiratory diseases are more prevalent.

Table 1. Models of the Relative Risks of Dying for Ages 50 and Older in Three Belgian Communities in Low Mortality Years, 1850-1899

	Combined		Sart		Limbourg		Verviers	
Covariate	Relative risk	p-value	Relative risk	p-value	Relative risk	p-value	Relative risk	p-value
Season of birth								
Jan.-Mar.	1.00	ref.	1.00	ref.	1.00	ref.	1.00	ref.
Apr.-Jun.	0.67	0.00	0.93	0.69	0.37	0.01	0.53	0.02
Jul.-Sep.	0.81	0.13	0.98	0.90	0.60	0.09	0.62	0.12
Oct.-Dec.	0.91	0.50	1.13	0.48	0.51	0.05	0.90	0.70
Prices 0-2 months before birth								
Normal	1.00	ref.	1.00	ref.	1.00	ref.	1.00	ref.
High	1.04	0.75	0.94	0.70	0.78	0.38	1.37	0.19
Year of birth								
1800-09	1.03	0.81	1.10	0.63	1.44	0.28	0.54	0.22
1810-19	0.97	0.79	1.40	0.06	0.68	0.28	0.44	0.02
1820-29	1.00	ref.	1.00	ref.	1.00	ref.	1.00	ref.
1830-39	1.07	0.71	1.11	0.72	0.89	0.88	0.98	0.95
1840-49	0.65	0.28	0.19	0.10			1.19	0.73
Sex								
Female	1.00	ref.	1.00	ref.	1.00	ref.	1.00	ref.
Male	1.22	0.04	1.19	0.19	0.89	0.64	1.55	0.03
Birthplace								
Sart	1.41	0.53						
Limbourg	1.00	ref.						
Verviers	0.83	0.67						
Residence								
Sart	1.70	0.32						
Limbourg	1.00	ref.						
Verviers	1.90	0.28						
Subjects	996		456		191		316	
Deaths	429		241		77		103	
Time at risk	12747.58		6710.5		2309.9		3400.6	
Degrees of freedom	13)		(9)		(9)		(9)	
Chi-squared	18.53		14.96		14.32		21.83	
p-value	0.1382		0.09		0.11		0.01	

Table 2. Models of Relative Risk of Dying from Three to Thirty Days of Life for Three Belgian Communities, 1806-1899

	Combined		Sart		Limbourg		Verviers	
Season of birth	Relative risk	p-value	Relative risk	p-value	Relative risk	p-value	Relative risk	p-value
Jan.-Mar.	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Apr.-Jun.	0.67	0.03	0.54	0.02	1.14	0.77	0.70	0.33
Jul.-Sep.	0.59	0.01	0.53	0.02	0.37	0.14	0.80	0.54
Oct.-Nov.	1.02	0.90	1.08	0.74	1.49	0.37	0.62	0.24
Sex								
Female	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Male	1.55	0.00	1.64	0.01	1.74	0.12	1.22	0.47
Year of birth								
1800-19	1.24	0.52	1.13	0.74				
1820-29	1.35	0.32	1.23	0.53				
1830-39	0.60	0.18	0.55	0.15				
1840-49	0.92	0.79	1.05	0.89	1.04	0.96	0.00	1.00
1850-59	1.00	ref	1.00	ref	1.00	ref	1.00	ref
1860-69	1.09	0.72	0.83	0.62	1.05	0.92	1.45	0.35
1870-79	1.19	0.44	0.86	0.70	1.19	0.69	1.57	0.26
1880-99	1.13	0.65	1.13	0.71				
Commune								
Sart	1.32	0.20						
Limbourg	1.00	ref						
Verviers	1.61	0.03						
Subjects	9513		5561		2037		1915	
Deaths	211		123		35		53	
Time at risk (years)	73.95		43.13		15.80		15.02	
Degrees of Freedom	13		11		8		7	
Chi-squared	33.03		26.29		12.38		11.17	
p-value	0.00		0.01		0.13		0.13	

Table 3. Models of Relative Risk of Dying in the Second to Twelfth Months of Life for Three Belgian Communities, 1806-1899

	Combined		Sart		Limbourg		Verviers	
Covariate	Relative risk	p-value	Relative risk	p-value	Relative risk	p-value	Relative risk	p-value
Season of birth								
Jan.-Mar.	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Apr.-Jun.	0.96	0.61	0.93	0.54	0.96	0.84	1.02	0.90
Jul.-Sep.	0.86	0.12	0.82	0.13	1.01	0.97	0.86	0.39
Oct.-Nov.	0.74	0.00	0.66	0.00	0.84	0.42	0.85	0.40
Current season								
Jan.-Mar.	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Apr.-Jun.	0.87	0.13	0.69	0.01	0.88	0.54	1.37	0.10
Jul.-Sep.	0.94	0.54	0.72	0.01	0.84	0.39	1.71	0.00
Oct.-Nov.	0.78	0.01	0.75	0.03	0.78	0.25	0.82	0.34
Sex								
Female	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Male	1.31	0.00	1.33	0.00	1.64	0.00	1.08	0.54
Year of birth								
1800-19	1.33	0.12	1.51	0.06				
1820-29	1.08	0.67	1.22	0.35				
1830-39	1.57	0.00	1.79	0.00				
1840-49	1.00	ref	1.00	ref	1.00	ref	1.00	ref
1850-59	1.43	0.00	1.76	0.01	1.36	0.12	1.25	0.22
1860-69	1.32	0.02	1.43	0.09	1.24	0.28	1.24	0.23
1870-79	1.17	0.27	1.32	0.15	1.24	0.54		
1880-99	1.31	0.00	1.33	0.00	1.64	0.00	1.08	0.54
Commune								
Sart	0.82	0.06						
Limbourg	1.00	ref						
Verviers	1.35	0.00						
Subjects	9159		5374		1975		1810	
Deaths	891		448		196		247	
Time at risk (years)	7770.7		4619.9		1644.3		1506.5	
Degrees of Freedom	16		14		11		10	
Chi-squared	92.66		41.04		17.15		25.88	
p-value	0.00		0.00		0.10		0.00	

Table 4. Models of the Relative Risk of Dying at Ages 50 and Older
in Limbourg and Verviers, 1850-1899

	Model 1		Model 2		Model 3	
Covariate	Relative risk	p-value	Relative risk	p-value	Relative risk	p-value
Season of birth						
Jan.-Mar.	1.00	ref.	1.00	ref.	1.00	ref.
Apr.-Jun.	0.69	0.02	0.70	0.06	0.69	0.05
Jul.-Sep.	0.85	0.35	0.86	0.46	0.79	0.23
Oct.-Dec.	0.95	0.74	0.92	0.65	0.99	0.97
Death Rate						
Low	1.00	ref.	1.00	ref.	1.00	ref.
High	0.92	0.49	0.91	0.48	0.93	0.58
Sex						
Female	1.00	ref.	1.00	ref.	1.00	ref.
Male	1.26	0.05	1.26	0.05	1.28	0.04
Prices 0-2 months before birth						
Normal	1.00	ref.	1.00	ref.	1.00	ref.
High	1.16	0.28	1.15	0.55	1.16	0.29
Season x Prices						
Jan.-Mar.			1.00	ref.		
Apr.-Jun.			0.92	0.83		
Jul.-Sep.			0.97	0.94		
Oct.-Dec.			1.15	0.70		
Economic status in childhood						
Low	1.00	ref.	1.00	ref.	1.00	ref.
High	1.02	0.88	1.02	0.89	1.00	0.98
Season x Economic status						
Jan.-Mar.					1.00	ref.
Apr.-Jun.					1.01	0.99
Jul.-Sep.					1.36	0.41
Oct.-Dec.					0.83	0.62
Year of birth						
1800-09	0.85	0.39	0.85	0.40	0.82	0.31
1810-19	0.69	0.03	0.69	0.03	0.69	0.03
1820-29	1.00	ref.	1.00	ref.	1.00	ref.
1830-39	1.38	0.09	1.37	0.10	1.37	0.10
1840-49	1.41	0.26	1.42	0.25	1.40	0.27
Birthplace						
Limbourg	1.00	ref.	1.00	ref.	1.00	ref.
Verviers	0.88	0.74	0.89	0.77	0.87	0.73
Residence						
Limbourg	1.00	ref.	1.00	ref.	1.00	ref.
Verviers	0.93	0.84	0.91	0.80	0.92	0.84
Subjects	879		879		879	
Deaths	302		302		302	

Time at risk	9635.3	9635.3	9635.3
Degrees of freedom	13	16	16
Chi-squared	24.74	25.07	26.37
p-value	0.03	0.07	0.05

Table 5. Models of the Relative Risk of Dying at Ages 50 and Older in Limbourg and Verviers, 1850-1899

	Model 4		Model 5	
Covariate	Relative risk	p-value	Relative risk	p-value
Season of birth				
Jan.-Mar.	1.00	ref.	1.00	ref.
Apr.-Jun.	0.52	0.00	0.71	0.14
Jul.-Sep.	0.74	0.15	1.28	0.28
Oct.-Dec.	0.78	0.24	0.94	0.81
Death rate				
Low	1.00	ref.	1.00	ref.
High	0.60	0.04	0.92	0.51
Season x High death rate				
Jan.-Mar.	1.00	ref.		
Apr.-Jun.	2.20	0.02		
Jul.-Sep.	1.49	0.26		
Oct.-Dec.	1.65	0.14		
Sex				
Female	1.00	ref.	1.00	ref.
Male	1.28	0.04	1.53	0.06
Season x Male				
Jan.-Mar.			1.00	ref.
Apr.-Jun.			0.96	0.90
Jul.-Sep.			0.43	0.01
Oct.-Dec.			0.99	0.98
Prices 0-2 months before birth				
Normal	1.00	ref.	1.00	ref.
High	1.15	0.30	1.15	0.30
Economic status in childhood				
Low	1.00	ref.	1.00	ref.
High	1.04	0.76	1.01	0.96
Year of birth				
1800-09	0.86	0.43	0.83	0.34
1810-19	0.69	0.04	0.67	0.02
1820-29	1.00	ref.	1.00	ref.
1830-39	1.40	0.08	1.35	0.12
1840-49	1.42	0.25	1.34	0.34
Birthplace				
Limbourg	1.00	ref.	1.00	ref.
Verviers	0.87	0.73	0.86	0.69
Residence				
Limbourg	1.00	ref.	1.00	ref.
Verviers	0.94	0.88	0.95	0.90
Subjects	879		879	

Deaths	302	302
Time at risk	9635.3	9635.3
Degrees of freedom	16	16
Chi-squared	30.50	33.07
p-value	0.02	0.01

Figure 1

Relative Risk of Dying by Season of Birth at Ages 50+ in Three Belgian Communities, 1850-1899

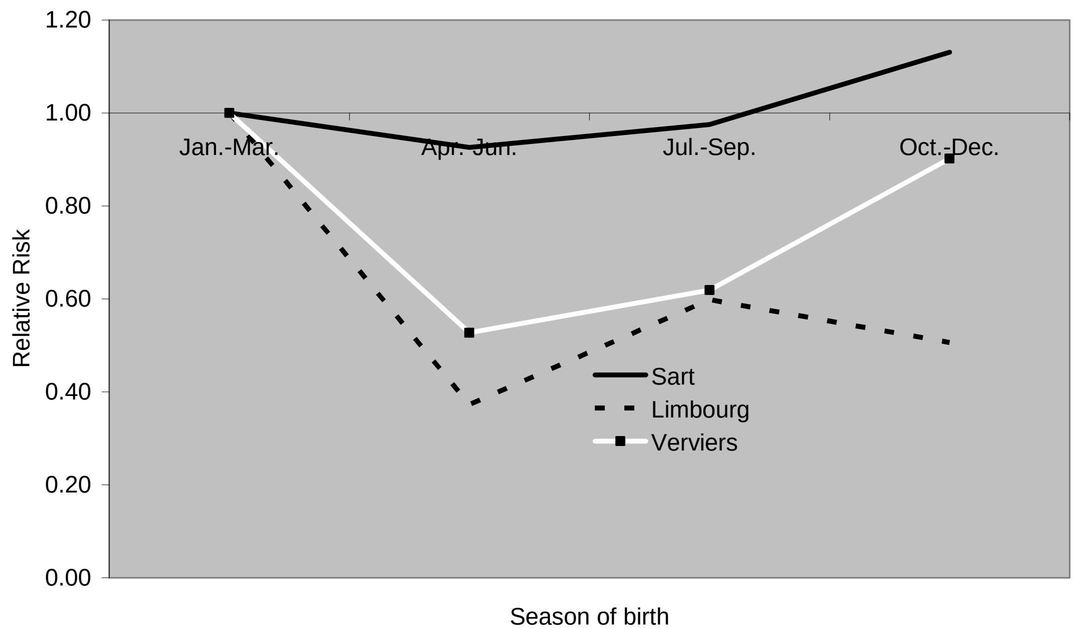

Figure 2.

Relative Risk of Dying by Season in the First Month of Life in Three Belgian Communities, 1806-1899

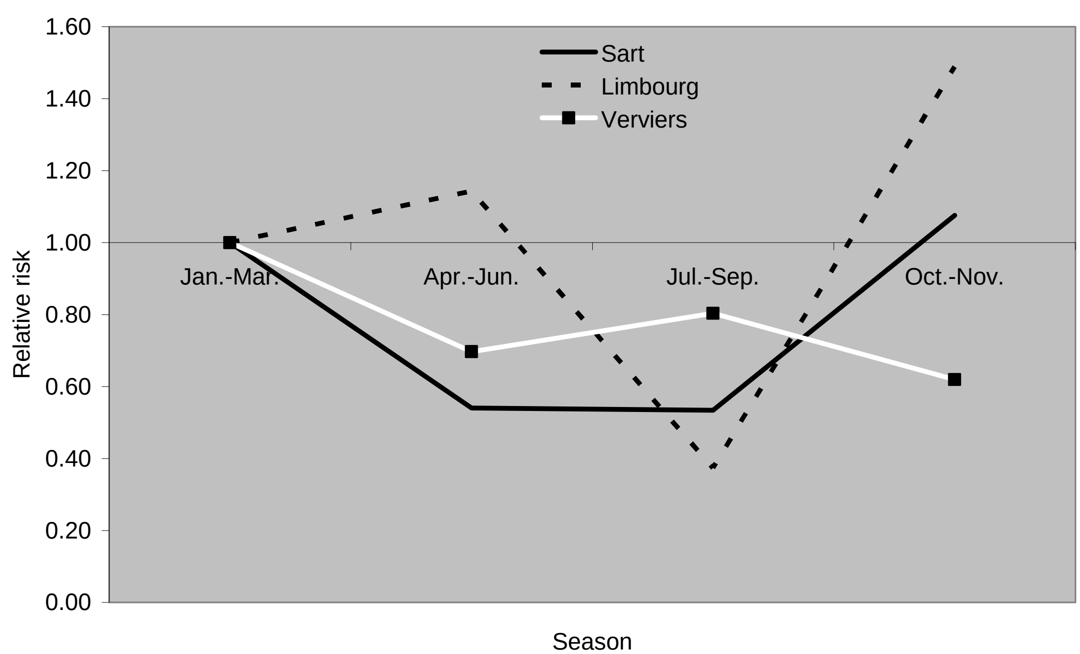

Figure 3.

Relative Risk of Dying by Season of Birth from the Third to Thirtieth Days of Life in Three Belgian Communities, 1806-1899

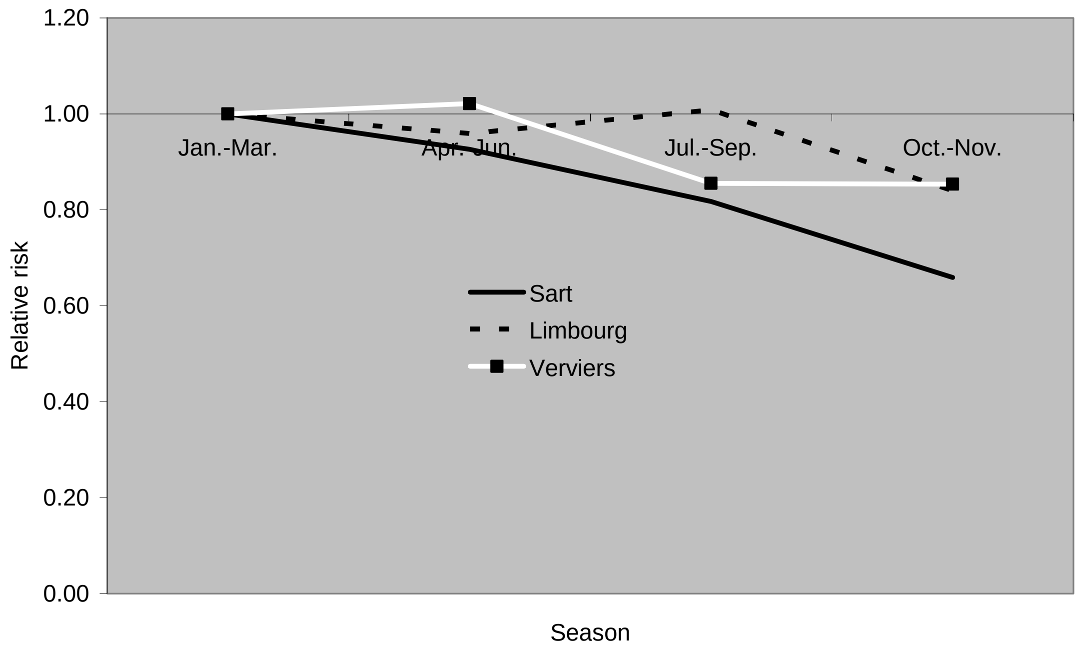

Figure 4.

Relative Risk of Dying by Season at Risk in the Second to Twelfth Months of Life in Three Belgian Communities, 1806-1899

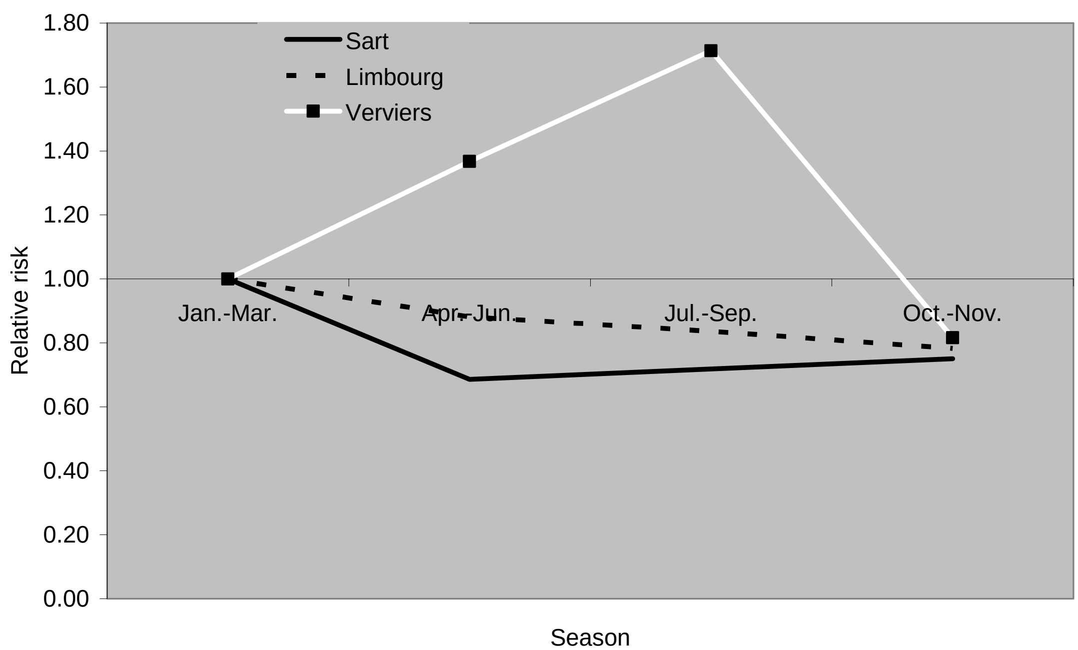

Figure 5.

Relative Risk of Dying by Season of Birth and Death Rate at Ages 50+ in Limbourg and Verviers, 1850-1899

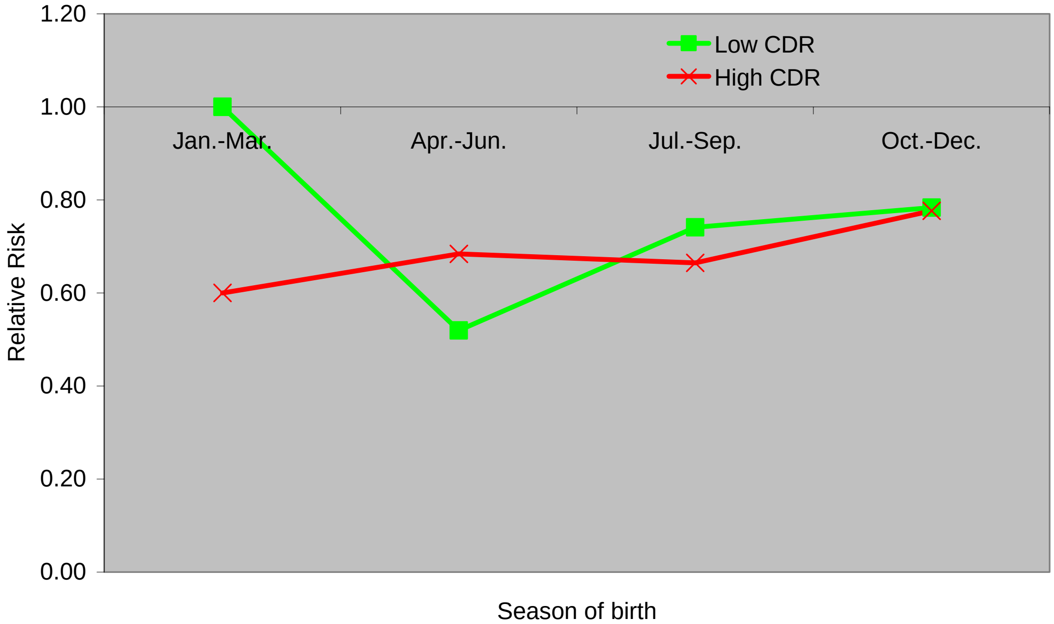

Figure 6.

Relative Risk of Dying by Season of Birth and Sex at Ages 50+ in Limbourg and Verviers, 1850-1899

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