The Shape of a Fertility Transition: An Analysis of Birth Intervals in Eastern Belgium

George Alter, Indiana University
Michel Oris, University of Geneva
Konstantin Tyurin, Indiana University
10 March 2007

Paper prepared for Population Association of America, New York City, March 29-31, 2007.

Abstract
We propose here a new way to look for evidence of fertility control. Most previous studies have relied on age-specific patterns of marital fertility, which do not provide sensitive measures of the timing of "stopping" behavior and do not consider "spacing" at all. We show that both stopping and spacing can be identified in birth interval survival curves. Analysis of data from nineteenth-century Belgium finds that changes in both stopping and spacing were at work. The fertility transition was characterized by an increase in stopping, but there was also a decrease in spacing, which began earlier and continued while stopping was spreading. We also introduce a statistical technique, known as the "cure model," which allows us to estimate the effects of covariates on stopping and spacing separately.

Contact information:
George Alter
Population Institute
Indiana University
408 North Indiana Ave.
Bloomington, IN 47408
alter@indiana.edu

Introduction

This paper describes a new way of looking for evidence of fertility transitions. We begin with a brief description of the controversies that have characterized the debate about historical fertility transitions for the past two decades. In our view, this debate has reached a theoretical and empirical impasse, and new approaches are needed to move forward. We introduce here a new empirical approach based on survival curves for birth intervals, and we show that both stopping and spacing can be detected in these curves. Next, we show that our interpretation of the curves is not an artifact of other factors affecting birth intervals, such as age, marital status, and breastfeeding. Then, we examine results from a statistical procedure that models both stopping and spacing as we observed them in birth interval survival curves. This procedure, which is known in biostatistics as the "cure model," was introduced to fertility analysis by Yamaguchi (1995) and Li and Choe (1997), but it has received surprisingly little attention. We use this model to evaluate alternative explanations for the rise in fertility that often precedes the fertility transition (Dyson and Murphy 1985), which some have taken as evidence of pre-transition fertility control.

The Impasse in Historical Studies of Fertility Transtions

It is now twenty years since the publication of the summary volume of the European Fertility Project (Coale and Watkins 1986). While the project still stands as a major turning point in understanding the nature of historical fertility transitions, controversies that grew out of the European Fertility Project have not been resolved (Friedlander, Okun and Segal 1999; VandeKaa 1996). Although the European Fertility Project highlighted the diffusion of ideas within culturally homogeneous areas, it was not designed to identify the content of those ideas. Two conflicting schools of thought quickly emerged. A number of the participants in the European Fertility Project argued that the diffusion process consisted of information and attitudes about birth control (Knodel and van de Walle 1979). Since evidence from nineteenth- and early twentieth-century Europe points to the importance of *coitus interruptus*, most researchers did not argue that the means to control fertility were unavailable (Fisher and Szreter 2003; Santow 1995). Rather, they argued that fertility control was "unthinkable" (Aries 1980) or outside the "calculus of conscious choice" (Coale 1973). In this view, opposition to birth control by the Catholic Church and other institutions was only overcome as the spread of secular and scientific ideas developed during the Enlightenment spread through the population.

An alternative interpretation emphasizes not birth control but attitudes about children. The 18th century is considered a turning point leading to increasingly sentimental views about childhood, which spread more broadly through European society during the Victorian era (Hutton 1998; Plumb 1975). In addition, parents' aspirations for their children rose during the 19th century as changes in the economy increased the value of education and created new opportunities for social mobility and less reliance on inherited wealth. Caldwell (1976; 1982) characterized this as a shift in the "intergenerational flow of wealth," which resulted in more parental investment in "child quality" and less reliance on economic transfers from children to parents. This approach has some things in common with economic theories of fertility emphasizing the importance of "child quality" (Becker and Lewis 1973). The quality/quantity tradeoff implies that increasing income results in changing preferences about investing in children (Robinson 1997; Sanderson 1976), but Caldwell argues that preferences can change before income rises. Recently, there has been a new form of this argument. Lucas (2002) argues that couples begin investing more in child quality than in quantity when they see that returns to human capital are rising. According to Galor and Weill (1999), this model differs from Becker's formulation, because investments in child quality do not depend upon the level of income.

A division has also emerged between those who view the demographic transition as a unified process and those who see a multiplicity of unique local transitions (Mason 1997). Cleland and Wilson (1987) emphasize how rapidly fertility decline spread across Europe. Others argue that adoption of family limitation depended upon social, economic, and political contexts that varied within and between communities. Szreter (1996) argues that attitudes favoring family limitation in the English working class were not simply borrowed from the middle classes. Rather, workers constructed their own world view in which small families became associated with emerging concepts of "respectability" and citizenship, a process that varied from community to community depending upon economic conditions, community structure, and the availability of female employment (See also Seccombe 1990; Szreter and Garrett 2000). Schneider and Schneider (1996) trace three separate transitions in a Sicilian town. Fertility among the gentry fell during the 1890s, among artisans in the 1920s and 1930s, and only after 1945 among farm laborers. In their view each transition was separate and determined primarily by changes in the circumstances of a particular group.

In addition to their theoretical dimensions, these debates raise questions about methods for measuring the prevalence of birth control and the timing of fertility transition. Since European Fertility Project relied on data aggregated to the province level, the methods used to date fertility transitions were arbitrary and not reliable. Brown and Guinnane (2003) point out that calculations based on geographic units, like provinces, tend to underestimate differences between urban and rural areas, because cities were usually surrounded by much more populous rural districts. Guinnane, Okun, and Trussell (1994) argue that neither I_g nor the Coale-Trussell Mm model are good indicators of turning points in fertility control, especially if spacing was present before the transition. The Coale-Trussell (1974) model is based on a strong form of the natural fertility hypothesis, which assumes that fertility control follows a fixed pattern of age-specific deviations from the natural fertility pattern. Okun (1994) used simulations to show that

Mm does not capture early stages of the fertility transition, when only a small sub-population is practicing fertility control. Age at last birth, which is used as a criterion of family limitation in family reconstitution studies, cannot be calculated when fertility histories are censored by migration or death. This makes it very difficult to apply to mobile urban populations. Moreover, all of these approaches measure changes in fertility by age, when we really want to know how fertility responds to changes in the number of surviving children.

The "natural fertility" hypothesis is central to the debate about identifying fertility transitions. Henry (1961) observed that decreases in age-specific marital fertility rates tended to be concentrated at older ages in the early stages of fertility decline. Some historical demographers interpret this to mean that: (a) fertility transitions were due to "stopping" rather than "spacing;" and (b) pre-transition populations did not use either stopping or spacing to limit family sizes (Knodel 1987; Knodel and Vandewalle 1979). This view has been challenged by studies arguing that intentional spacing was used either during the transition or earlier (Anderton and Bean 1985; Mineau, Bean and Anderton 1989; Szreter and Garrett 2000; Van Bavel 2004; Van Bavel and Kok 2004), and some researchers reject the "natural fertility" model completely (Bledsoe 1996; Skinner 1997).

One of the problems impeding this debate has been lack of agreement about a way to measure birth spacing. By assuming the prevalence of natural fertility, the Coale-Trussell Mm model effectively assumes that intentional birth spacing did not exist. Methods intended to demonstrate the existence of birth spacing have not been generally accepted. We believe that the approach described here offers a way forward by conceptualizing stopping and spacing in a simple and intuitive way.

Visualizing stopping and spacing

We propose Figure 1 as a picture of a typical fertility transition. The figure is based on data from the nineteenth-century population registers of Sart, Belgium, a poor agricultural community on the frontier between Belgium and Germany. (For more information about fertility in Sart see Alter, Neven, and Oris (2005).) The lines in Figure 1 are "survival curves," which show the proportion of women who are still waiting for a birth by time since last birth. These curves were computed by the Kaplan-Meier method, which allows us to use information from incomplete (censored) life histories. Only women who have had at least one birth are included in these calculations, and women who had more than one birth are included once for each birth.

Each curve in Figure 1 remains at 100 percent during the nine months required for gestation, but falls quickly between nine months and four years. Since very few births occur after six years, the curves level off and become approximately horizontal. These two features of the curves correspond to spacing and stopping. The spacing between births is reflected in the slope of the declining survival curve in the first five years after the previous birth. If the curve decreases more steeply, births will be closer together. The height of the curve after ten years measures the proportion of intervals that will never be closed by another birth, i.e. stopping. When this proportion rises, family limitation is increasing.

Figure 2 examines the fertility transition in Sart in more detail by dividing the century into three periods: 1812 to 1846, 1847 to 1875, and 1876 to 1900. We see here that the increase in stopping only occurs in the last period. The percentage of unfinished intervals fell from 15.2 in 1812-1846 to 13.7 percent in 1847-1875 before rising to 19.4 percent after 1875. An increase of less than six percent does not seem large, but it has a compound effect. If a couple does not complete the birth interval after their third child, they are never at risk of having a fourth, fifth, or sixth birth. The six percent increase in incomplete intervals after 1875 corresponds to a decrease in the Total Fertility Rate for ages 20-49 of 0.6 children (Table 1).

In Figure 3 we remove differences in stopping to highlight changes in "spacing." We follow a suggestion in Yamaguchi and Ferguson (1995), who point out the similarity between this problem and Hajnal's (1953) construction of the Singulate Mean Age at Marriage. Hajnal treats age-specific proportions never married as a distribution of the survival curve for marriage, and he subtracts the proportion never married at age 50 to get the distribution of those who will eventually marry. In Figure 3 we focus on the speed of completing birth intervals by removing birth intervals that were incomplete ten years after the last birth. This shows that transition rates increased and birth intervals became shorter in each successive period.

The pattern in Figures 2 and 3 is a classic case of the "ski-jump," a brief increase in fertility before it begins a precipitous decline (Dyson and Murphy 1985; Van de Walle 1974). Decomposing the survival curve for birth intervals into spacing and stopping reveals that the rise in fertility was due to a trend toward shorter birth intervals, which continued even after fertility began to decrease because of family limitation. This pattern is only partially captured by the Coale-Trussell model, which is included in Table 1. The estimate of M, Coale and Trussell's index of the level of marital fertility, does increase between 1812-1846 and 1847-1875, but it does not capture the additional increase after 1875. The Coale-Trussell index of fertility control, m, is very close to zero in the first two periods but rises to 0.13 during 1875-1899. Since the interpretation of values of m below 0.2 has always been uncertain, it would not have been possible to conclude that a fertility transition was underway without other evidence (Okun 1994).

Disaggregating Birth Interval Survival Curves

Figure 2 includes all birth intervals regardless of age and parity, and it is reasonable to ask whether our interpretation is affected by changes in composition of the population. In this section we examine several possible confounding factors.

1. Age

Figure 4 presents birth interval survival curves by age to show that age has a powerful effect on both spacing and stopping. Older women had longer birth intervals and were less likely to complete birth intervals. While both factors are important, the proportion of incomplete intervals increases dramatically after age 40. Could the pattern observed in Figure 2 be due to changes in the age distribution of the population? This interpretation is invalidated by the age-specific birth interval survival curves shown in Figure 5. The proportion of incomplete intervals increased after 1875 in all four of the five-year age groups shown in Figure 5. The overall pattern in Figure 2 is clearly dominated by women in their thirties, whose birth interval survival curves show all of the features discussed above.

2. Duration of Marriage

Hillary Page (1977) pointed out that models of fertility can be improved by the inclusion of marital duration. Figure 6 shows that spacing and stopping can be detected in birth interval survival curves controlling for both age and marital duration. We present curves for women aged 30-34 who had been married 5-9 years and for women aged 35-39 who had been married 10-14 years. These curves are more irregular than the previous figures, because they are based on smaller sub-samples, but they tell the same story.

3. Infant Survival

Changes in infant survival can also influence fertility, because infant death terminates breastfeeding and reduces the duration of lactational amenorrhea. In Figure 7 we present birth interval survival curves separately by the survival of the previous infant.[1] The curves for birth intervals following a surviving infant (Figure 7a) are the same as the overall pattern. The curves following an infant death (Figure 7b) differ in an interesting way. As we would expect, birth intervals following an infant death are shorter than those in which the previous infant survived. We also see that the proportion of incomplete intervals (stopping) increased after 1875 regardless of the status of the previous. We cannot be certain about changes in birth spacing over time in Figure 7b, however. The curves after 1846 in Figure 7b do appear to decrease more quickly than

[1] The survival of the previous infant is a time-varying covariate, so a birth interval contribute to both Figures 7a and 7b. In this analysis we truncate intervals on the previous infant's date of death, but it would be more appropriate to add nine months for gestation to this date (Alter 1988). This will be done in future drafts of this paper.

the pre-1846 curve in the first two years after a birth, but the difference is much less than in Figure 7a. We return to this issue below.

The "Cure Model"

A number of researchers have applied survival analysis to birth intervals from historical sources (Alter 1988; David and Mroz 1989; Ewbank 1993; Gutmann and Watkins 1990; Mroz and Weir 1990; Van Bavel 2004; Van Bavel and Kok 2004). We believe that this is the correct approach, but previous analyses have foundered on a fundamental misspecification of the statistical model. Conventional survival analysis assumes that all individuals will eventually experience the event if they live long enough. In practice, all individuals are assumed to be at risk of the event, even if their life histories are censored (e.g. by death) before the event occurred. This assumption excludes the kind of behavior that interests us here. If a couple intends to stop childbearing after reaching a certain family size, their hazard rate falls to zero as soon as their last child is born. We want to know which attributes make a couple more likely to stop childbearing, and these attributes may have quite different effects on the hazard rates of those who are continuing to have children.[2]

A distinct class of models, known as "cure models" in biostatistics and sometimes called "split population" models in the social sciences, offers a solution to this problem (Farewell 1982; Kuk and Chen 1992; Li and Choe 1997; Yamaguchi 1998, 2003; Yamaguchi and Ferguson 1995). These models assume that a population consists of "movers" and "stayers," and they apply two linked sub-models to the data. One part of the model predicts being a stayer, who will never experience the event. The second part of the model is a survival analysis of the timing of transitions among movers. Each sub-model includes covariates, which affect the proportion of stayers and the rate at which movers make transitions respectively. The two parts of the cure

[2] We note also that the survival curves for Sart shown in Figure 2 violate the proportional hazards assumption that underlies some forms of event history analysis, such as the Cox partial-likelihood model. If hazard rates are proportional, survival curves will not cross, as they do in Figure 2.

model correspond to the behaviors of stopping ("cure fraction") and spacing in fertility analysis. As we show below, we expect some covariates to affect stopping and spacing in contrary directions, increasing stopping and reducing spacing.

In this paper we use an accelerated failure time version of the cure model. The proportion of the population surviving at time *t* is

$$S(t;x,z) = \pi(x) + (1-\pi(x))S_m(t;z),$$

where $\pi(x)$ is the proportion of stayers in the population (also called the "cure fraction" or "stoppers"). The proportion of stayers is modeled by the logistic link function

$$\pi(x) = 1/(1+\exp(-x'\beta)),$$

where *x* is a vector of explanatory variables. The survivor function of movers is modeled in the accelerated failure time (AFT) framework with a lognormal function

$$S_m(t;z) = 1 - \Phi\left(\frac{\ln\{t\} - z'\gamma - \mu}{\sigma}\right)$$

where Φ() is the cumulative distribution for the Gaussian (normal) distribution and *z* is a vector of explanatory variables. Thus, the model includes two vectors of covariates, *x* and *z*, which are used to explain stopping and spacing respectively.[3]

Spacing and Stopping in Sart

Table 3 presents the results of a cure model regression on birth intervals for Sart from 1812 to 1899. There are two sub-models, which we have labeled the "Stopping model" and the "Spacing model." We include mother's age, occupation of head of household, and year of observation in both sub-models. The Stopping model also includes the sex composition of surviving children, and the Spacing model includes measures of active breastfeeding and duration of marriage. Distributions of all covariates are found in Table 2.

[3] The statistical model used here does not address an important problem. Available software assumes that each spell, in this case a birth interval, is independent. This is not the case for fertility analysis, where each woman may have ten or more birth intervals. We are working on cure model software that will handle repeated events, but it is not available yet.

Interpretation of the estimated coefficients is easiest to see by examining the effects of mother's age. In the Stopping model a positive coefficient indicates that a larger proportion of birth intervals are never completed. The estimated coefficients in the Stopping model increase rapidly after age 35, which indicates that a rising number of women are no longer fertile. The Spacing model measures the probability of another birth, and covariates with positive coefficients in this model increase the likelihood of another birth, which shortens birth intervals. The negative coefficients for ages above 35 in the Spacing model mean that birth intervals became longer at older ages.

The coefficients for year of observation in Table 3 show that the cure model can capture the key aspects of the fertility transition in Sart, which we identified in the survival curves. In the Stopping model we find a decrease in the proportion of incomplete intervals in the middle period (1847-1875) and an increase in the third period (1875-1899) in comparison to the period before 1847, which is used as the reference group. Although the positive coefficient for the last period is not statistically significant when compared to 1812-1846, the coefficient for 1847-1875 is negative and statistically significant. This implies that the increase in stopping after 1875 would have been unlikely to occur by chance. The coefficients for year of observation in the Spacing model in Table 3 tell a different story. Since the probability of the next birth increased after 1847 and again after 1875, birth intervals became shorter in each successive period.

Thus, the cure model captures the conflicting trends in stopping and spacing that we identified in Figure 2. This is only possible in a compound model that describes stopping and spacing separately. The results from a standard event history model will be unreliable in this situation. Indeed, these data clearly violate the assumptions of proportional hazard models, like the Cox (1975) partial likelihood model, which assume that survival curves do not cross as they do in Figure 1.

Parity, Fecundity, and Selectivity

Even when individual life histories are available, it is difficult to devise a test for parity-specific fertility control in a historical population. Two kinds of unobserved heterogeneity tend to conceal the behavior that interests us. First, fecundity varies among couples for biological or behavioral reasons that cannot be measured. Second, fertility control is itself a kind of unobserved heterogeneity, because we can only infer the intention to stop from behavior. Selection effects due to these differences among couples create associations between fertility and parity in aggregate data that differ from the true relationship at the individual level.

Controlling for other factors, unobserved differences in fecundity create a positive correlation between fertility and parity, such that birth intervals become shorter (hazard rates increase) as the number of children ever born increases. This pattern results from the changing distribution of women by fecundity as parity increases. Women who tend to have long birth intervals are much less likely to reach higher parities than women who tend to have short birth intervals. A woman who has her first birth at age 20 and tends to have children five years apart can only expect six more births before reaching menopause, while a woman whose births tend to be two years apart can have fifteen births in the same time. Consequently, the proportion of women with long birth intervals decreases as parity increases.

During a fertility transition, we expect family limitation to have a similar effect. Couples who have a target family size will continue having children until they reach their target and then they will stop. This means that the proportion of couples who are practicing birth control goes up at the target family size, but it decreases at higher parities, because couples who reach higher parities do not intend to stop having children.

Table 4 and Figures 8 and 9 show that the cure model captures both of these selection effects. In Table 4 we estimate a cure model including covariates for children ever born (1, 2,…, 8 or more) in each time period in Sart. The estimated coefficients for children ever born are compared in Figure 8 for the spacing model and in Figure 9 for the stopping model. In Figure 8, we observe that the hazard rate increases (birth intervals become shorter) as parity increases. This pattern begins after the second birth, and it is very regular in the periods before 1847 and after 1875. No pattern is evident in the middle period.

Table 4 and Figure 9 show no relationship between parity and stopping in the first two periods, but women with more than four births were less likely to stop after 1875. This suggests that some couples were aiming for target family sizes between two and four children.

Thus, both kinds of selection effects appear in these results. There is a positive relationship between parity and short birth intervals in the spacing model, because of unmeasured differences in fecundity. In the post-1875 period, there is a negative association between parity and stopping, because couples using birth control do not reach higher parities.

In the future, we hope to add features to the model to capture differences due to fecundity. In conventional event history models, differences between women can be modeled by adding a random "frailty" effect. This specification is not yet available for cure models, however.

The "Ski Jump"

Table 4 also offers new insight into the fertility transition in Sart. Consider first the rising level of fertility and shorter birth intervals after 1846. Previous studies have suggested that fertility may have increased because of better nutrition or shorter duration of breastfeeding. Neither of these explanations finds strong support in Table 4.

If improvements in nutrition caused the rise in fertility after 1846, we would expect to find large differences in birth spacing among social strata in the pre-1846 period and smaller differences after 1846. In previous research we found large socio-economic differentials in heights of military recruits in Sart in the early nineteenth century (Alter, Neven and Oris 2004).

Men who were wealthy enough to be students at age 20 were nearly ten centimeters taller than day laborers of the same age. Differences in heights by occupation narrowed but did not disappear after 1850. We do find a positive (0.23) estimated coefficient for high status families in the 1812-1846 period indicating shorter spacing than in farmers' households. But laborers, who were under the most economic stress in the early nineteenth century, hardly differed from farmers before 1847. Paradoxically, differences in birth spacing emerged after 1846 when fertility was higher. Laborers had longer birth intervals than farmers in the middle and later periods, when improvements in nutrition should have produced more convergence between rich and poor. Birth intervals were shorter among higher status families between 1847 and 1875, but they had longer intervals after 1875.

Knodel (1988) has shown the important effect of breastfeeding on fertility, and he suggests that the rise in fertility in 19th-century German villages may have been due to earlier weaning later in the century. We investigate the influence of breastfeeding on fertility by constructing a time-varying covariate capturing the impact of infant deaths. We assume that breastfeeding only affected fertility during the first year of an infant's life. Most infants were partially or fully weaned by age one, and breastfeeding stopped when an infant died. Consequently, we create a binary variable that takes the value of one during the period from 9 to 21 (=12 months + 9 months gestation) months after the last birth if the previous child was alive. This variable is set to zero after 21 months for all infants and 9 months after an infant death.

Table 4 shows that breastfeeding had a large effect on birth spacing. The estimated coefficients for women with a surviving infant are -0.62, -0.59, and -0.44 for periods 1812-46, 1847-75, and 1875-99 respectively. These coefficients are large – about the same size as the effect of being over age 45. The stability of these coefficients in the first two time periods means that the effect of breastfeeding did not diminish after 1846 when fertility increased.

Breastfeeding did have less effect after 1875, but we expect this effect to be less pronounced when some women are using family limitation.

Thus, estimates of the cure model for Sart do not support the two most prominent physiological explanations for rising fertility: improved nutrition and shorter breastfeeding. This suggests that we must look more closely at behavioral explanations. It is possible that some forms of birth control (such as abstinence) were used to delay births in the early nineteenth century before the fertility transition began (Bengtsson and Dribe 2006; Perrenoud 1988).

The cure model also tells us who began stopping first. Only one of the occupation groups has a statistically significant coefficient in the stopping model: high status families in the middle time period. The estimated coefficient of .97 for high status families from 1846 to 1875 means that these women were more than twice as likely to stop with the most recent birth than farmers' wives. In other words, high status families led the way in family limitation in Sart, as they did in other places. The difference between high status families and farmers diminished after 1875, when farmers had begun to adopt family limitation too.

Conclusion

Our goal has been to provide a new way of looking at an old problem. We have argued that both stopping (i.e. family limitation) and birth spacing can be observed in birth interval survival curves. With the cure model we can translate this insight into a statistical analysis that considers factors affecting stopping and spacing separately.

The statistical analysis in this paper is only a first step, and it is intended primarily to illustrate the promise of this approach. We have shown that the cure model does capture the opposing movements in stopping and spacing that produced the ski jump of rising and falling fertility in Sart. We have also seen that the nineteenth century rise in fertility cannot be attributed to physiological processes associated with better nutrition or shorter breastfeeding.

Much remains to be done to develop this approach. The cure model can be parameterized in many different ways, and we need to carefully consider which covariates belong in the stopping and spacing sub-models. The model also needs to be expanded to incorporate repeated observations and other aspects of birth interval analysis.

Table 1.
Measures of Marital Fertility in Sart, Belgium

	Total Marital Fertility Rate Ages 15-49	Total Marital Fertility Rate Ages 20-49	Coale-Trussel Model of Marital Fertility	
			M	m
1812-1846	9.9	8.0	0.87	0.00
1847-1875	10.7	8.6	0.96	0.01
1875-1899	11.1	8.0	0.95	0.13

* Parameters of the Coale-Trussel model were estimated from age-specific marital fertility rates in five year age groups using the maximum likelihood procedure described by Brostrom (1985).

Table 2.
Summary Measures and Variable Distributions

	1812-1846	1847-1875	1876-1899	Total
Number of birth intervals	2521	2068	1565	5883
Number of births	1809	1477	1044	4330
Person years at risk	7550.3	5598.8	4447.6	17596.6
Age of mother				
15-24	8.0	6.4	6.8	7.2
25-29	20.1	17.5	19.3	19.1
30-34	26.6	26.2	23.4	25.7
35-39	23.7	25.8	25.6	24.9
40-44	16.1	16.9	17.6	16.8
45-49	5.5	7.2	7.4	6.5
Total	100.0	100.0	100.0	100.0
Occupation of head of household				
Farmer	44.5	62.7	59.7	54.1
High status	1.8	5.4	10.2	5.0
Industrial or artisan	5.5	11.5	18.0	10.5
Laborer	7.6	13.0	4.8	8.7
Other and n.a.	40.6	7.4	7.4	21.7
Total	100.0	100.0	100.0	100.0
Surviving children				
1+ son & 1+ dau	51.8	65.1	61.2	58.4
1+ dau, 0 son	18.8	15.2	18.2	17.5
1+ sons, 0 dau	24.3	16.7	17.8	20.2
No surviving children	5.1	3.1	2.9	3.9
Total	100.0	100.0	100.0	100.0
Breastfeeding				
Dead or 1+	57.0	56.0	56.8	56.6
Surviving infant	43.0	44.0	43.2	43.4
Total	100.0	100.0	100.0	100.0
Marital duration				
0-4 years	24.7	20.9	22.8	23.0
5-9 years	21.3	22.6	21.0	21.7
10+ years	54.0	56.6	56.2	55.4
Total	100.0	100.0	100.0	100.0

Table 3. Estimated Coefficients of a Cure Model Regression for the Probability of a Birth, Sart, Belgium, 1812-1899

	Stopping model		Spacing model	
Age of mother				
15-24	0.02		0.07	
25-29	0.01		0.07	**
30-34	0.00	ref.	0.00	ref.
35-39	0.97	**	-0.13	**
40-44	2.93	**	-0.29	**
45-49	4.75	**	-0.28	**
Occupation of head of household				
Farmer	0.00	ref.	0.00	ref.
High status	0.38		0.04	
Industrial or artisan	-0.11		-0.04	
Laborer	-0.06		-0.07	
Other and n.a.	-0.06		-0.03	
Year of observation				
1812-1846	0.00	ref.	0.00	ref.
1847-1875	-0.37	**	0.11	**
1876-1899	0.26		0.22	**
Breastfeeding				
Dead or 1+			0.00	ref.
Surviving infant			-0.56	**
Marital duration				
0-4 years			0.00	ref.
5-9 years			-0.20	**
10+ years			-0.23	**
Surviving children				
1+ son & 1+ dau	0.00	ref.		
1+ dau, 0 son	-0.02			
1+ sons, 0 dau	-0.17			
No surviving children	-0.01			
Constant	-3.48	**	-0.51	**
Shape constant			0.63	*

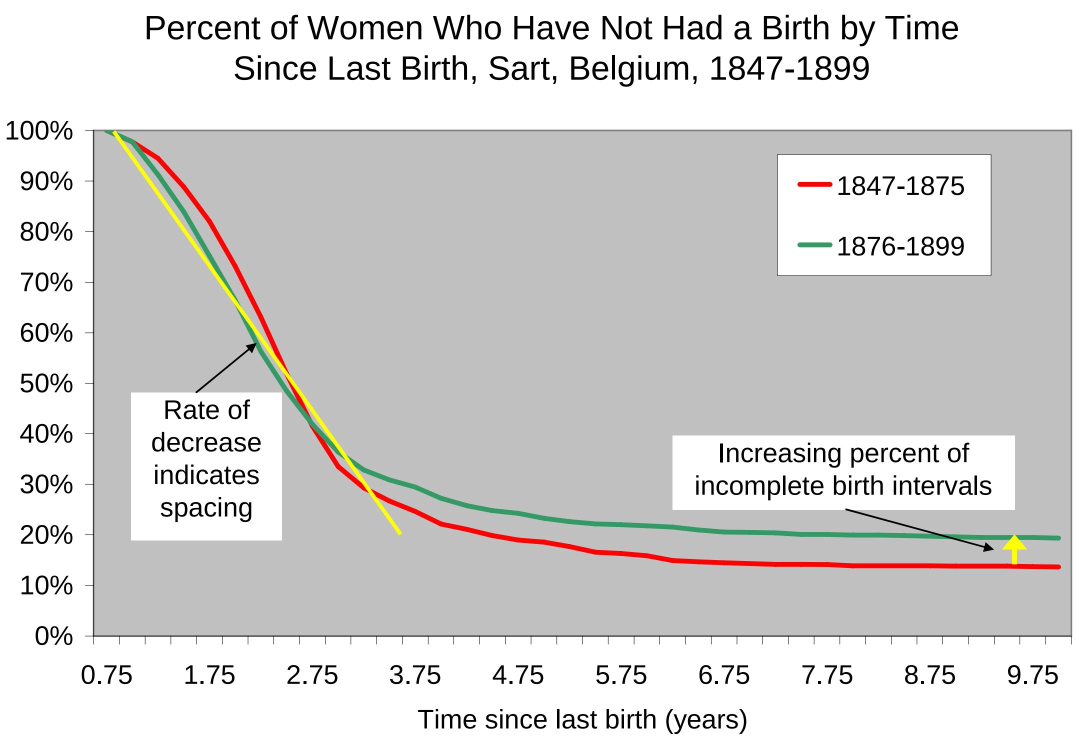
* p < .05
** p < .01

Table 4. Cure Regression Models for Birth Intervals by Time Period in Sart, Belgium

	1812-1846				1847-1875				1876-1899			
	Stopping model		Spacing model		Stopping model		Spacing model		Stopping model		Spacing model	
Covariate	Coefficient		Coefficient		Coefficient		Coefficient		Coefficient		Coefficient	
Age of mother												
15-24	-0.24		0.00		2.38	*	-0.12		-0.17		0.02	
25-29	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.
30-34	-0.69		-0.10	*	1.65	*	-0.13	**	0.12		-0.09	
35-39	0.71	*	-0.27	**	2.56	**	-0.32	**	1.05	**	-0.28	**
40-44	2.74	**	-0.47	**	4.79	**	-0.51	**	3.29	**	-0.57	**
45-49	4.18	**	-0.45	**	7.03	**	-0.58	**	5.61	**	-0.53	*
Occupation of head of household												
Farmer	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.
High status	0.47		0.23	*	0.97	*	0.17	*	0.24		-0.18	*
Industrial worker or artisan	-0.08		0.05		-0.24		0.00		-0.10		-0.13	*
Laborer	0.42		-0.01		-0.29		-0.09	*	-0.43		-0.07	
Other and not reported	-0.15		0.02		0.31		0.04		0.13		-0.16	
Children ever born												
1	-0.11		0.14	**	-1.20		0.24	**	-0.37		0.26	**
2	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.	0.00	ref.
3	0.34		-0.08		0.22		-0.07		-0.53		0.03	
4	0.21		-0.07		0.64		-0.02		-0.26		0.08	
5	0.05		0.07		0.32		-0.04		-0.80	*	0.13	
6	-0.10		0.13		-0.10		-0.12		-0.99	*	0.16	
7	0.03		0.07		0.45		-0.01		-0.82		0.21	*
8+	0.01		0.24	**	-0.11		0.06		-1.67	**	0.32	**
Previous child												
>12 months or Dead			0.00	ref.			0.00	ref.			0.00	ref.
Alive and <12 months			-0.62	**			-0.59	**			-0.44	**
Constant	-3.36	**	-0.60	**	-5.76	**	-0.43	**	-2.70	**	-0.50	**
Likelihood ratio chi-squared	853.31				856.58				433.62			
Degrees of freedom	33				33				33			
Time at risk	7550.3				5598.8				4447.6			
Births	1811				1477				1045			

* p<.05; ** p<.01

Figure 1



Percent of Women Who Have Not Had a Birth by Time Since Last Birth, Sart, Belgium, 1847-1899
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.75
1.75
2.75
3.75
4.75
5.75
6.75
7.75
8.75
9.75
Time since last birth (years)
1847-1875
1876-1899
Rate of decrease indicates spacing
Increasing percent of incomplete birth intervals

Figure 2

Kaplan-Meier Survival Estimates for Birth Intervals
by Time Period, Sart, Belgium

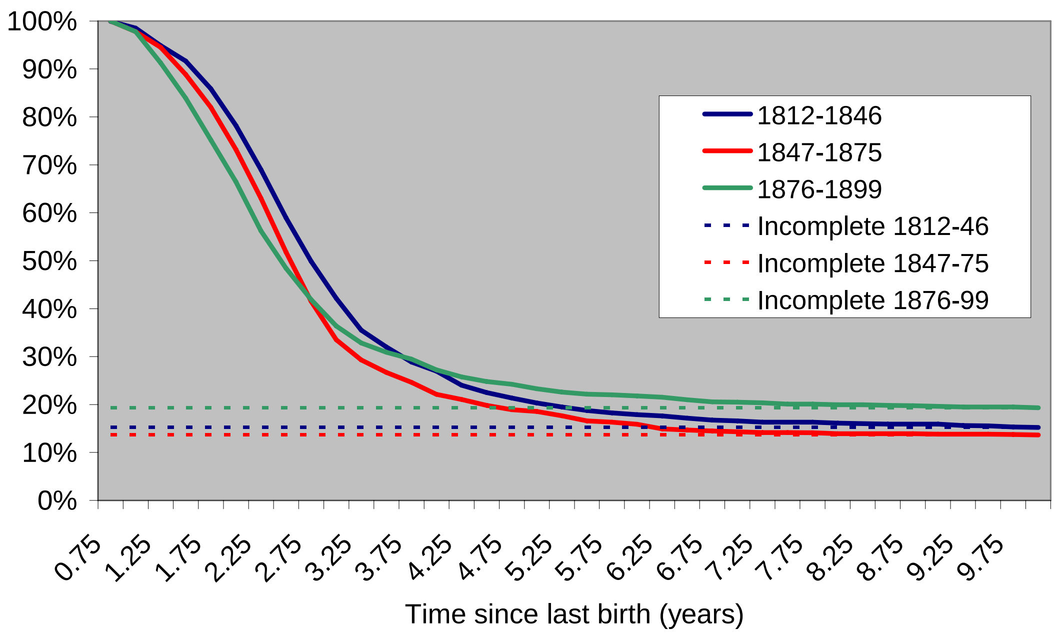


Figure 3

Kaplan-Meier Survival Estimates for Completed Birth Intervals
by Time Period, Sart, Belgium

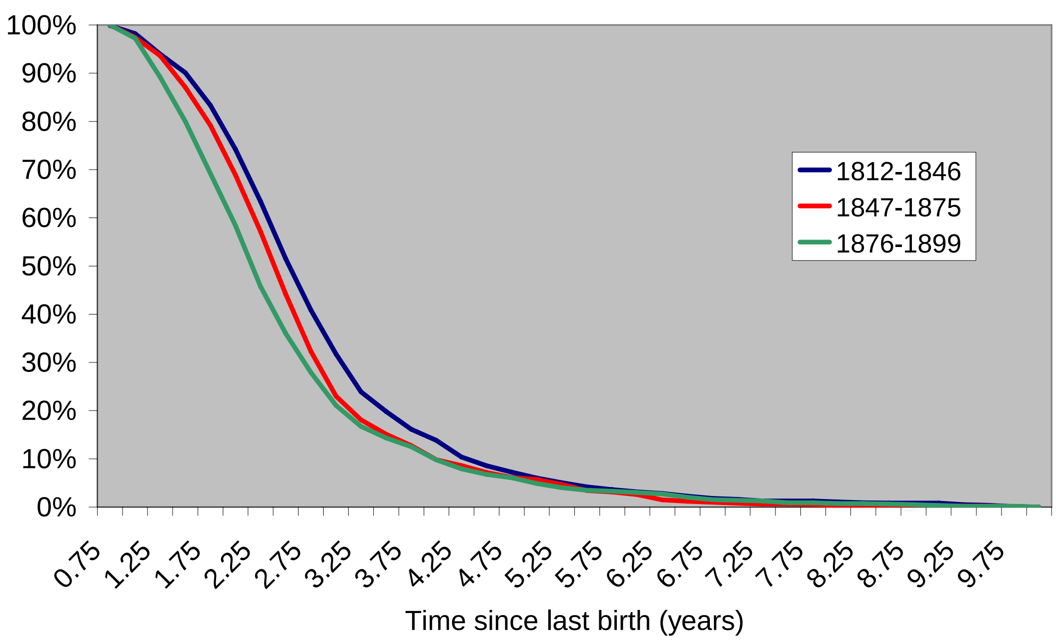
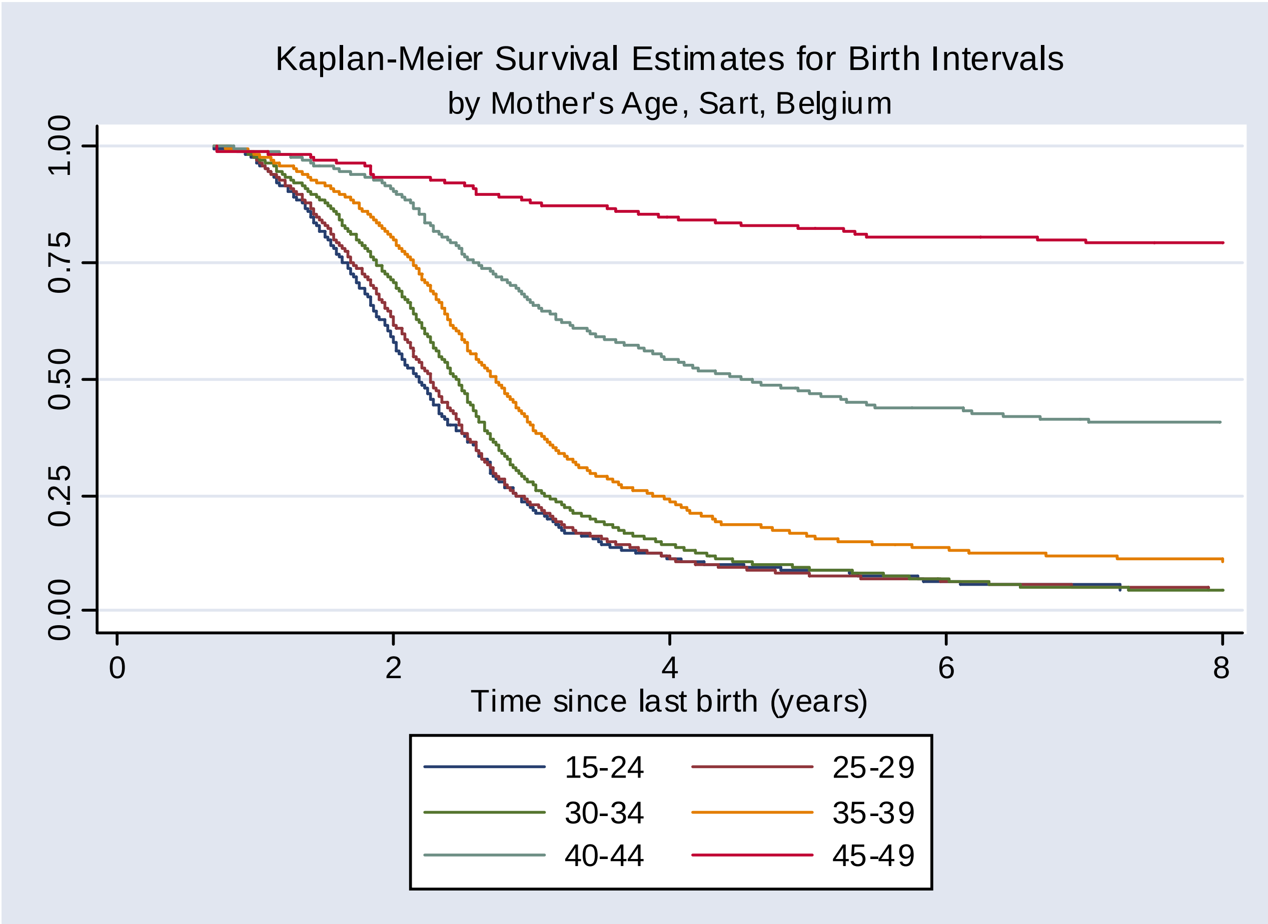


Figure 4



Kaplan-Meier Survival Estimates for Birth Intervals
by Mother's Age, Sart, Belgium
1.00
0.75
0.50
0.25
0.00
0
2
4
6
8
Time since last birth (years)
15-24
25-29
30-34
35-39
40-44
45-49

Figure 5

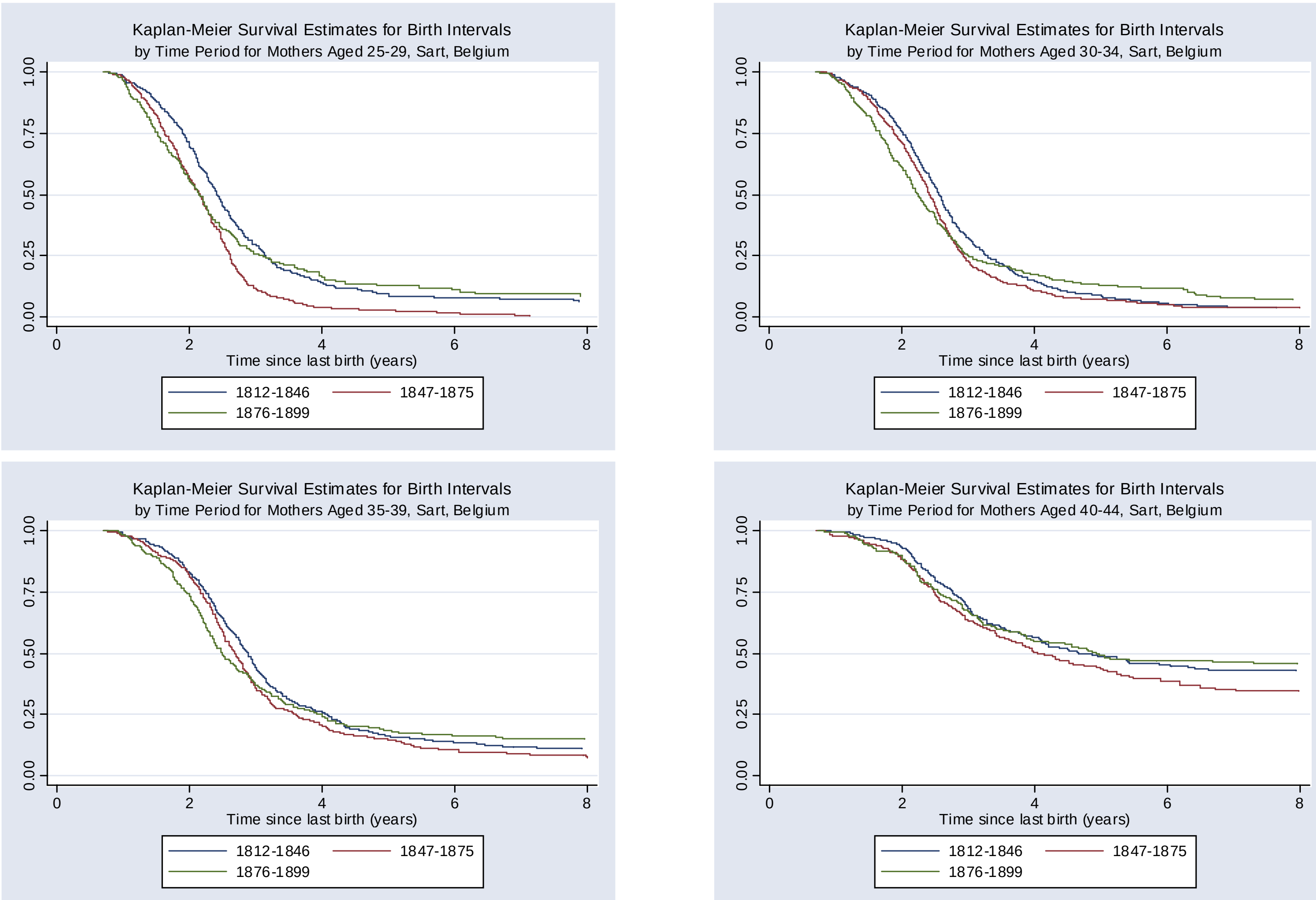

Kaplan-Meier Survival Estimates for Birth Intervals
by Time Period for Mothers Aged 25-29, Sart, Belgium
0.00
0.25
0.50
0.75
1.00
0
2
4
6
8
Time since last birth (years)
1812-1846
1847-1875
1876-1899
Kaplan-Meier Survival Estimates for Birth Intervals
by Time Period for Mothers Aged 30-34, Sart, Belgium
0.00
0.25
0.50
0.75
1.00
0
2
4
6
8
Time since last birth (years)
1812-1846
1847-1875
1876-1899
Kaplan-Meier Survival Estimates for Birth Intervals
by Time Period for Mothers Aged 35-39, Sart, Belgium
0.00
0.25
0.50
0.75
1.00
0
2
4
6
8
Time since last birth (years)
1812-1846
1847-1875
1876-1899
Kaplan-Meier Survival Estimates for Birth Intervals
by Time Period for Mothers Aged 40-44, Sart, Belgium
0.00
0.25
0.50
0.75
1.00
0
2
4
6
8
Time since last birth (years)
1812-1846
1847-1875
1876-1899

Figure 6a

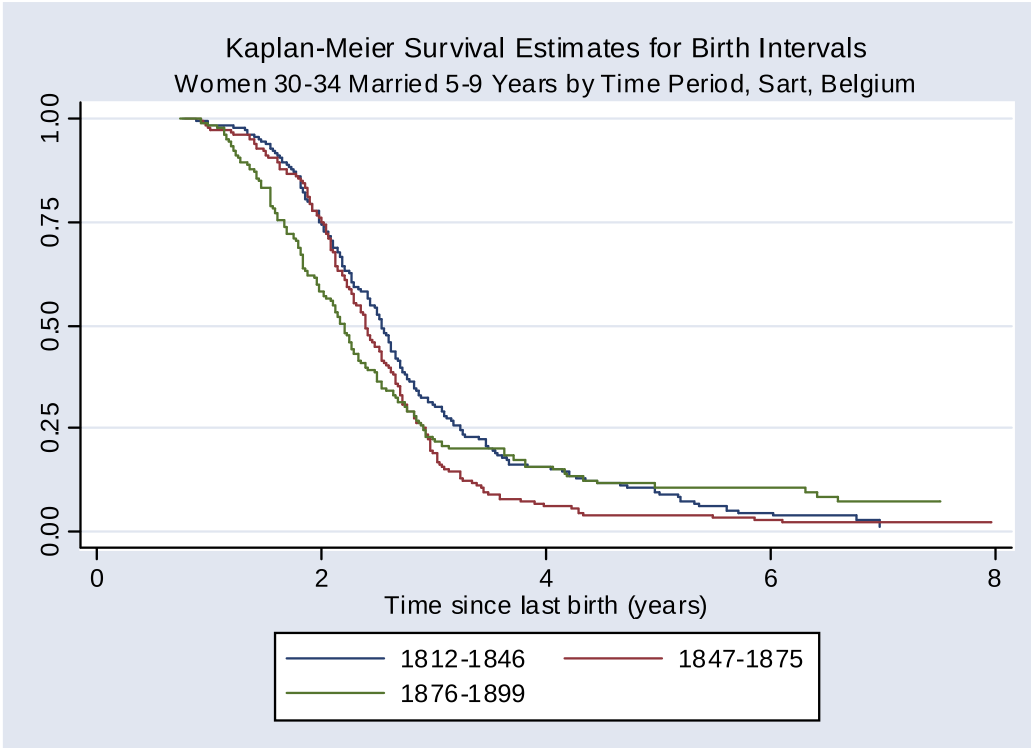


Figure 6b

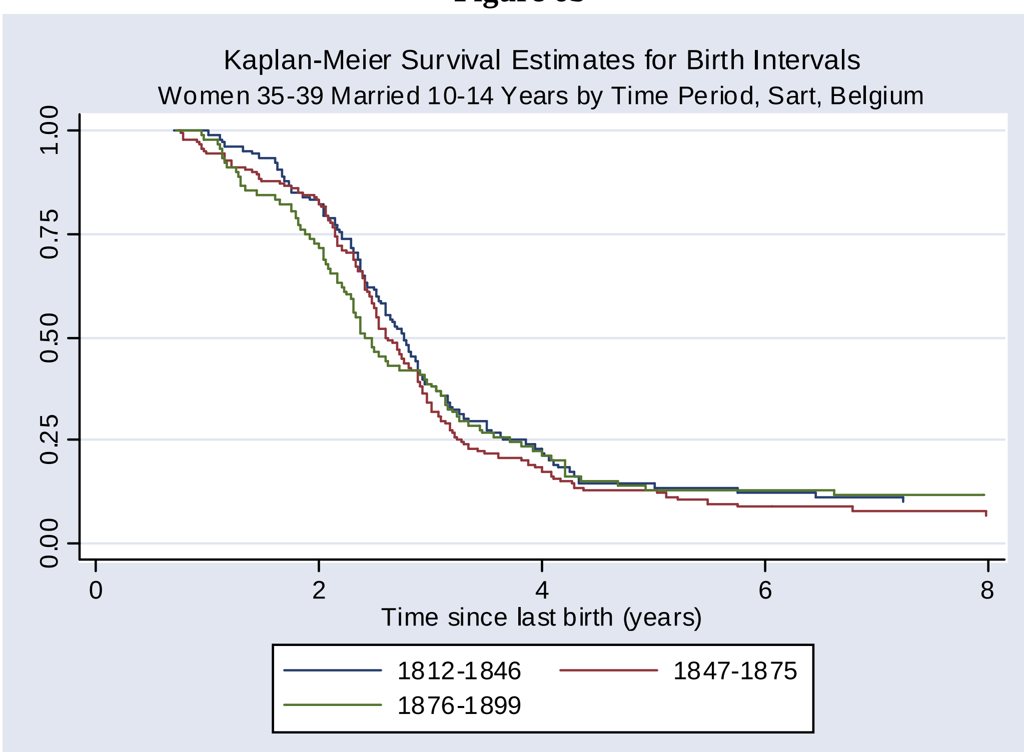


Figure 7a

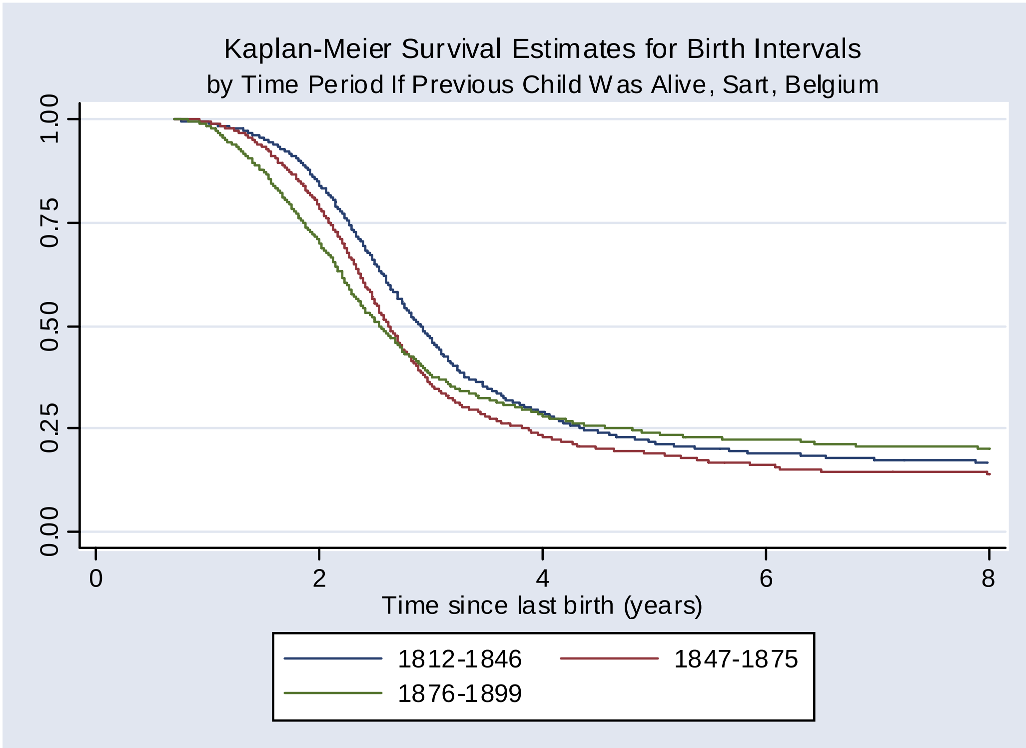


Figure 7b

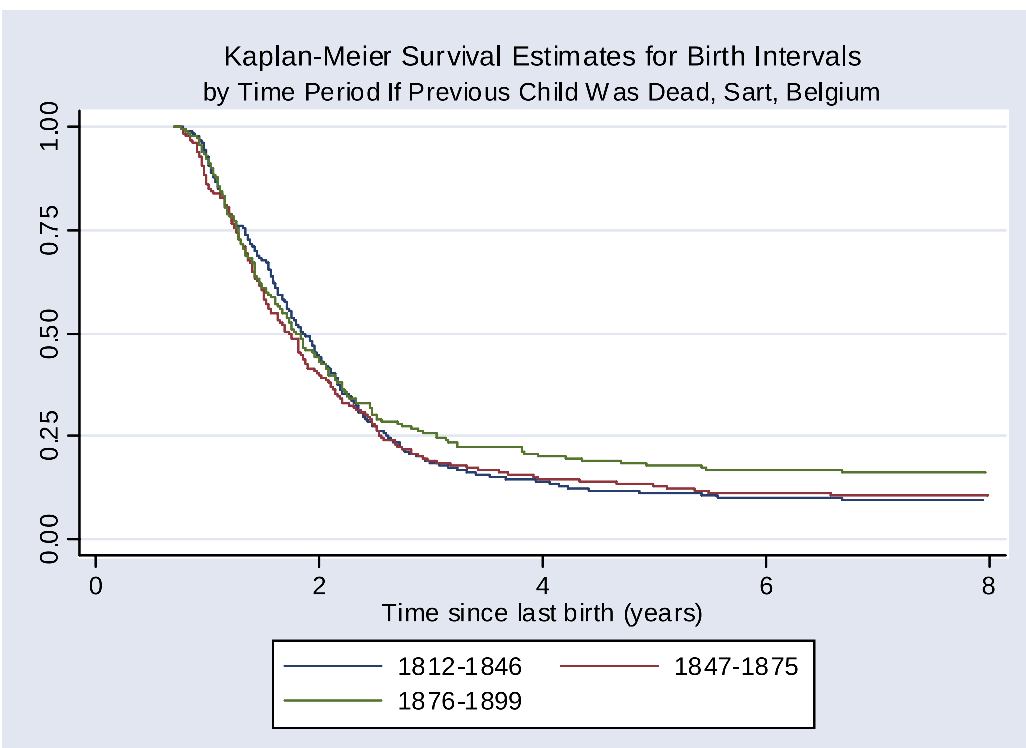


Figure 8.

Estimated Spacing Coefficients for Children Ever Born by Time Period, Sart, Belgium

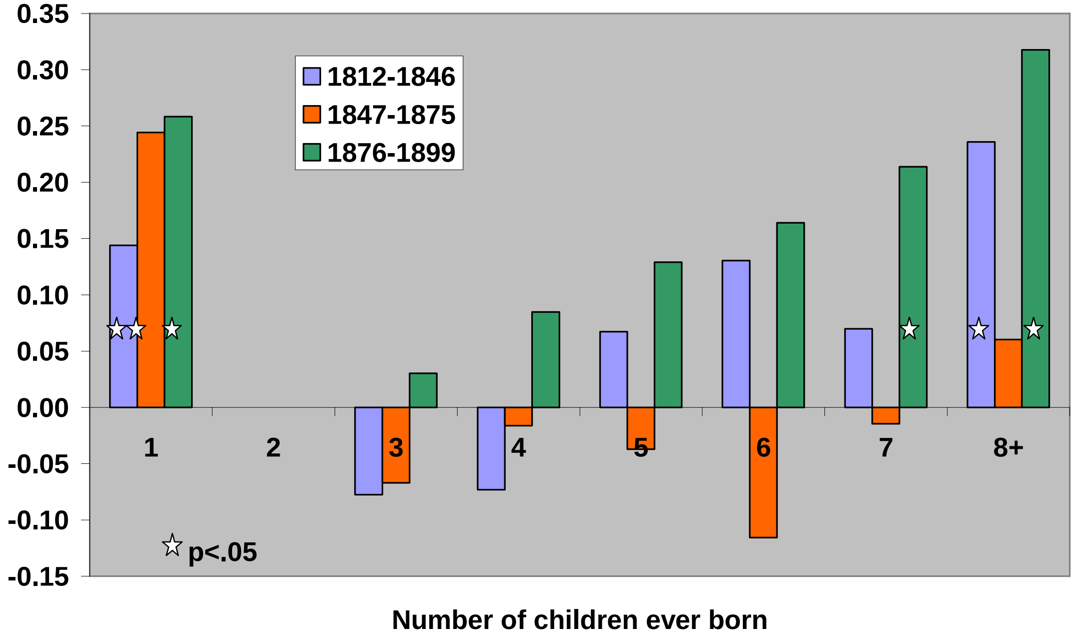
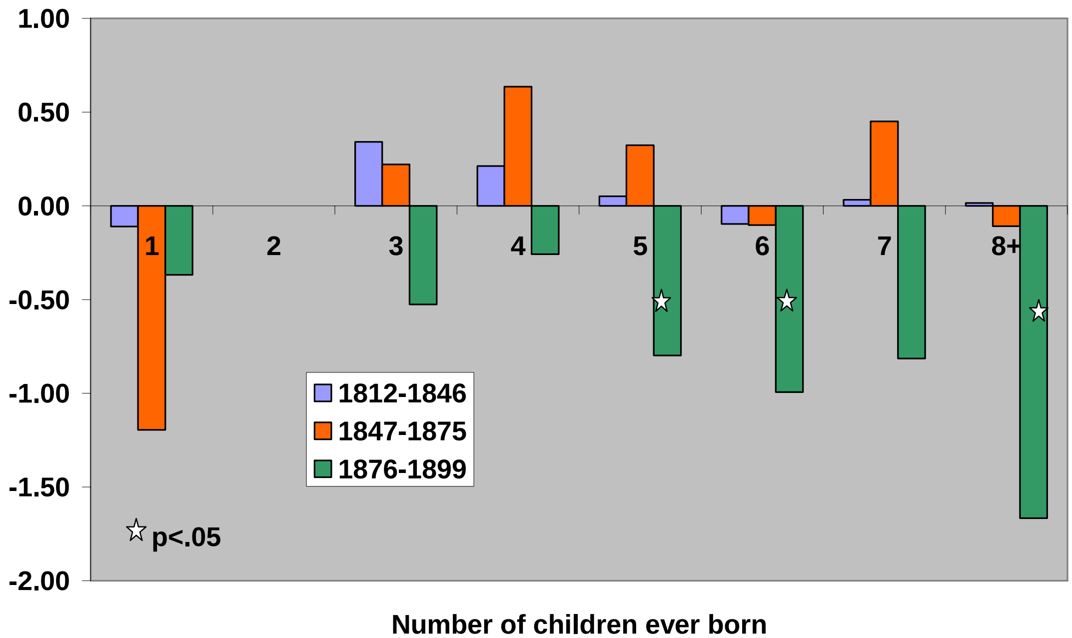


Figure 9.

Estimated Stopping Coefficients for Children Ever Born by Time Period, Sart, Belgium



References

Alter, G. 1988. *Family and the female life course: the women of Verviers, Belgium, 1849-1880*. Madison, Wis: University of Wisconsin Press.

Alter, G., M. Neven, and M. Oris. 2004. "Stature in transition - A micro-level study from nineteenth-century Belgium." *Social Science History* 28(2):231-247.

—. 2005. "Economic Development and Differential Fertility in Rural And Urban Eastern Belgium, 1812-1899." in *Chaire Quetelet 2005: Histoire de la Population de la Belgique et de ses Territoires*. Louvain-la-Neuve, Belgium.

Anderton, D.L.and L.L. Bean. 1985. "Birth Spacing and Fertility Limitation - a Behavioral-Analysis of a 19Th-Century Frontier Population." *Demography* 22(2):169-183.

Aries, P. 1980. "Two Successive Motivations for the Declining Birth Rate in the West." *Population and Development Review* 6(4):645-650.

Becker, G.S.and H.G. Lewis. 1973. "Interaction between Quantity and Quality of Children." *Journal of Political Economy* 81:S279-S288.

Bengtsson, T.and M. Dribe. 2006. "Deliberate control in a natural fertility population: Southern Sweden, 1766-1864." *Demography* 43(4):727-746.

Bledsoe, C. 1996. "Contraception and "Natural" Fertility in America." *Population and Development Review* 22(Supplement: Fertility in the United States: New Patterns, New Theories):297-324.

Brostrom, G. 1985. "Practical Aspects on the Estimation of the Parameters in Coale Model for Marital Fertility." *Demography* 22(4):625-631.

Brown, J.C.and T.W. Guinnane. 2003. "Two Statistical Problems in the Princeton Project on the European Fertility Transition." in *Yale University Economic Growth Center. Discussion Paper No. 869*: Available at SSRN: http://ssrn.com/abstract=445901.

Caldwell, J.C. 1976. "Toward a Restatement of Demographic Transition Theory." *Population and Development Review* 2(3-4):321-366.

—. 1982. *Theory of fertility decline*. London ; New York: Academic Press.

Cleland, J.and C. Wilson. 1987. "Demand Theories of the Fertility Transition - an Iconoclastic View." *Population Studies-a Journal of Demography* 41(1):5-30.

Coale, A.J. 1973. "The demographic transition reconsidered." Presented at International Population Conference. Liège, Liège.

Coale, A.J.and a.T.J. Trussell. 1974. "Model Fertility Schedules - Variations in Age Structure of Childbearing in Human Populations." *Population Index* 40:185-258.

Coale, A.J.and S.C. Watkins. 1986. *The decline of fertility in Europe : the revised proceedings of a Conference on the Princeton European Fertility Project*. Princeton, N.J.: Princeton University Press.

Cox, D.R. 1975. "Partial Likelihood." *Biometrika* 62:269-276.

David, P.A.and T.A. Mroz. 1989. "Evidence of Fertility Regulation among Rural French Villagers, 1749-1789 - a Sequential Econometric-Model of Birth-Spacing Behavior .1." *European Journal of Population-Revue Europeenne De Demographie* 5(1):1-26.

Dyson, T.and M. Murphy. 1985. "The Onset of Fertility Transition." *Population and Development Review* 11(3):399-440.

Ewbank, D. 1993. "Coarse and Refined Methods for Studying the Fertility Transitino in Historical Populations." in *Old and new methods in historical demography*, edited by D.S. Reher and R. Schofield. Oxford England :, New York :: Clarendon Press ; Oxford University Press.

Farewell, V.T. 1982. "The Use of Mixture-Models for the Analysis of Survival-Data with Long-Term Survivors." *Biometrics* 38(4):1041-1046.

Fisher, K.and S. Szreter. 2003. "They prefer withdrawal": The choice of birth control in Britain, 1918-1950." *Journal of Interdisciplinary History* 34(2):263-+.

Friedlander, D., B.S. Okun, and S. Segal. 1999. "The demographic transition then and now: Processes, perspectives, and analyses." *Journal of Family History* 24(4):493-533.

Galor, O.and D.N. Weil. 1999. "From Malthusian stagnation to modern growth." *American Economic Review* 89(2):150-154.

Guinnane, T.W., B.S. Okun, and J. Trussell. 1994. "What Do We Know About the Timing of Fertility Transitions in Europe." *Demography* 31(1):1-20.

Gutmann, M.P.and S.C. Watkins. 1990. "Socio-economic differences in fertility control. Is there an early warning system at the village level?" *European Journal of Population-Revue Europeenne De Demographie* 6:69-101.

Hajnal, J. 1953. "Age at Marriage and Proportions Marrying." *Population Studies* 7(2):111-136.

Henry, L. 1961. "Some data on natural fertility." *Eugenics Quarterly* 8:81-91.

Hutton, P.H. 1998. "The Politics of the Young Philippe Aries." *French Historical Studies* 21(3):475-495.

Knodel, J. 1987. "Starting, Stopping, and Spacing during the Early Stages of Fertility Transition - the Experience of German Village Populations in the 18Th and 19Th Centuries." *Demography* 24(2):143-162.

Knodel, J.and E. Vandewalle. 1979. "Lessons from the Past - Policy Implications of Historical Fertility Studies." *Population and Development Review* 5(2):217-245.

Knodel, J.E. 1988. *Demographic behavior in the past a study of fourteen German village populations in the eighteenth and nineteenth centuries*. Cambridge Cambridgeshire, New York: Cambridge University Press.

Knodel, J.E.and E. van de Walle. 1979. "Lessons from the Past: Policy Implications of Historical Fertility Studies." *Population and Development Review* 5(2):217-245.

Kuk, A.Y.C.and C.H. Chen. 1992. "A Mixture Model Combining Logistic-Regression with Proportional Hazards Regression." *Biometrika* 79(3):531-541.

Li, L.and M.K. Choe. 1997. "A mixture model for duration data: Analysis of second births in China." *Demography* 34(2):189-197.

Lucas, R.E. 2002. *Lectures on economic growth*. Cambridge, Mass.: Harvard University Press.

Mason, K.O. 1997. "Explaining fertility transitions." *Demography* 34(4):443-454.

Mineau, G.P., L.L. Bean, and D.L. Anderton. 1989. "Migration and Fertility - Behavioral-Change on the American-Frontier." *Journal of Family History* 14(1):43-61.

Mroz, T.A.and D.R. Weir. 1990. "Structural-Change in Life-Cycle Fertility During the Fertility Transition - France Before and After the Revolution of 1789." *Population Studies-a Journal of Demography* 44(1):61-87.

Okun, B.S. 1994. "Evaluating Methods for Detecting Fertility-Control - Coale and Trussells Model and Cohort Parity Analysis." *Population Studies-a Journal of Demography* 48(2):193-222.

Page, H.J. 1977. "Patterns Underlying Fertility Schedules: A Decomposition by both Age and Marriage Duration." *Population Studies* 31(1):85-106.

Perrenoud, A. 1988. "Espacement et arrêt dans le contrôle des naissances." *Annales de Démographie Historique*:59-78.

Plumb, J.H. 1975. "New World of Children in Eighteenth-Century England." *Past & Present*(67):64-95.

Robinson, W.C. 1997. "The economic theory of fertility over three decades." *Population Studies-a Journal of Demography* 51(1):63-&.

Sanderson, W.C. 1976. "On Two Schools of Economics of Fertility." *Population and Development Review* 2(3-4):469-477.

Santow, G. 1995. "Coitus-Interruptus and the Control of Natural Fertility." *Population Studies-a Journal of Demography* 49(1):19-43.

Schneider, J.and P.T. Schneider. 1996. *Festival of the poor : fertility decline & the ideology of class in Sicily, 1860-1980*. Tucson: University of Arizona Press.

Seccombe, W. 1990. "Starting to Stop: Working-Class Fertility Decline in Britain." *Past and Present*(126):151-188.

Skinner, G.W. 1997. "Family Systems and Demographic Processes." Pp. ix, 294 in *Anthropological demography : toward a new synthesis*

edited by D.I. Kertzer and T.E. Fricke. Chicago: University of Chicago Press.

Szreter, S. 1996. *Fertility, class and gender in Britain, 1860-1940*. Cambridge England ; New York: Cambridge University Press.

Szreter, S.and E. Garrett. 2000. "Reproduction, compositional demography, and economic growth: Family planning in England long before the fertility decline." *Population and Development Review* 26(1):45-+.

Van Bavel, J. 2004. "Deliberate birth spacing before the fertility transition in Europe: Evidence from nineteenth-century Belgium." *Population Studies-a Journal of Demography* 58(1):95-107.

Van Bavel, J.and J. Kok. 2004. "Birth spacing in the Netherlands. The effects of family composition, occupation and religion on birth intervals, 1820-1885." *European Journal of Population-Revue Europeenne De Demographie* 20(2):119-140.

Van de Walle, E. 1974. *The female population of France in the nineteenth century: a reconstruction of 82 départements*. Princeton, N.J.,: Princeton University Press.

VandeKaa, D.J. 1996. "Anchored narratives: The story and findings of half a century of research into the determinants of fertility." *Population Studies-a Journal of Demography* 50(3):389-&.

Yamaguchi, K. 1998. "Mover-stayer models for analyzing event nonoccurrence and event timing with time-dependent covariates: An application to an analysis of remarriage." Pp. 327-361 in *Sociological Methodology, Vol. 28 1998.*

—. 2003. "Accelerated failure-time mover-stayer regression models for the analysis of last-episode data." Pp. 81-110 in *Sociological Methodology, Vol 33.*

Yamaguchi, K.and L.R. Ferguson. 1995. "The Stopping and Spacing of Childbirths and Their Birth-History Predictors - Rational-Choice Theory and Event-History Analysis." *American Sociological Review* 60(2):272-298.