Cohort Childlessness Forecasts and Analysis Using the Hernes Model

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Abstract

The recent delay in first births and the increasing childlessness in many countries raises the question of long term trends in childlessness. The Hernes model has been proved efficient to estimate nuptiality in several contexts.
In this paper we check its usefulness for estimating first birth rates, and educational differences in childlessness, using a large survey that took place within the French General population census in 1999. This method can be used for men, as data on men’s first births are also available; they may also be applied with taking into account many other covariates, such as marital status.

Results are consistent for cohorts born in 1950 to 1970. The increase in childlessness appears to be limited in France, and educational differences are not increasing. Trials to run a model with linear trend and an interaction with education, as well as estimates for younger cohorts or period estimates leading to period projection of first birth life tables, were not successful. The current trends in first birth fertility do not fit well with the Hernes model, showing that the shape of first birth fertility by age goes to a different path.

This work is part of the MicMac project, funded by the European Commission under the 6th Framework Programme “Integrating and strengthening the European Research Area” (http://www.nidi.knaw.nl/en/micmac/).

1. Introduction

The recent delay in first births and the increasing childlessness in many countries raises the question of long term trends in childlessness. The Hernes model has been proved efficient to estimate nuptiality in several contexts.

In this paper we check its usefulness for estimating first birth rates, and educational differences in childlessness, using a large survey that took place within the French General population census in 1999.The aim is to produce fertility estimates allowing projection of future fertility based on a parametric model including several covariates, fixed as well as time-varying. This work is part of the MicMac project, funded by the European Commission under the 6th Framework Programme "Integrating and strengthening the European Research Area" (http://www.nidi.knaw.nl/en/micmac/).

2. Childlessness forecasts

As Sobotka (2004, p. 147) notes: "Among women born at the beginning of the 20th century, lifetime childlessness reached 19% among white women and 25% among non-white women in the U.S., 25% in France, 26% in Germany and the Netherlands, and 30% in Australia". The high childlessness in these cohorts has been attributed mostly to the economic crisis of the 1930s (Rindfuss et al., 1988).

In the Eurobarometer survey 2002, the proportion of French women aged 18-34 who answered 'none' as ideal number of children was 4%, i.e. the same level of women aged 55+ (Fahey and Spéder, 2004). In other European societies, this percentage is sensibly higher: this is particularly the case of Germany (17%) and Austria (13%) and is consistent with the decrease in ideal family size in German-speaking countries outlined by Goldstein et al. (2003). 17% is indeed the share of childless women in the cohorts of the early 1950s in the former Federal Republic of Germany, which has attracted the attention of German researchers on childlessness during the 1990s (Dorbritz and Schwarz, 1996).

3. The Hernes model for fertility

The model we propose for being used in the timing of first birth has been originally proposed to model first marriage by Hernes (1972). Its use has been advocated by some demographers, e.g. Burch (1993) and Coale and Trussell (1996); an application to the forecast of cohort proportion never married (i.e., an example very close in spirit to what we do) is presented by Goldstein and Kenney (2001). The model is a diffusion model: the hazard of marriage depends in a positive way on the proportion ever married. The idea of the Hernes model is that the hazard rate is a product of two functions:

$$h(t) = m(t)[1 - S(t)] \quad (1)$$

$m(t)$ is the "marriageability" level, and $[1-S(t)]$ represents the proportion of the cohort that has already married. In Hernes' model, marriageability declines exponentially with age:

$$m(t) = Ab^{t} \qquad (2)$$

$A>0$ is the initial level of marriageability, and $0<b<1$ is the speed of decline of marriageability.

We can interpret the model for the hazard of first birth by:

a) assuming that a diffusion process takes place within a cohort (or specific social categories, such as educational categories, within a cohort) also for what concerns the timing of first birth. This is

consistent with the literature emphasising the importance of social interactions in fertility decision making within contemporary advanced societies (see, e.g. Bernardi, 2003, Kohler, 2001);
b) assuming that there is a high level of initial sensitivity to childbearing, or "parentability", that regulates the importance of the impact of meeting peers who had children; this level declines exponentially with age. This is consistent with some evidence on fecundability, the proportion of sterile women increasing exponentially with age (see, e.g., Leridon, 2005) and on the existence of timetables regulating limits to childbearing, before the age at sterility.
The two opposing forces produce a non-monotonic shape for the hazard rate. The hazard of first birth first rises up to a maximum and then starts decreasing. Moreover, there is a share of individuals never experiencing the event.
If at time 0 there is a certain share of individuals having already experienced the event, $S(0)>0$, (1) and (2) combined give an expression for the survivor function, with $k>0$, $\log a = A/\log b$ and thus $0<a<1$

$$S(t)=\left[1+ka^{b^t}\right]^{-1} \qquad (3)$$

In this paper we use a re -parameterisation of the model, proposed by Wu (1990). The survivor function is:

$$S(t)=\left[1+\sigma^{-1}\exp\left(-\beta\lambda^t\right)\right]^{-1} \qquad (4)$$

With $\sigma=k^{-1}>0$, $\lambda=b$, $\beta=-\log a>0$. We have a straightforward expression for long-term survivors, i.e. individuals who stay childless:

$$S(\infty)=\lim_{t\to\infty}S(t)=\frac{1}{1+\sigma^{-1}}=\frac{\sigma}{1+\sigma} \qquad (5)$$

The hazard rate is:

$$h(t)=\frac{-\beta\lambda^t\log\lambda}{1+\sigma\exp\left(\beta\lambda^t\right)} \qquad (6)$$

The density function is:

$$f(t)=\frac{-\sigma\exp\left(\beta\lambda^t\right)\beta\lambda^t\log(\lambda)}{\left[1+\sigma\exp\left(\beta\lambda^t\right)\right]^2} \qquad (7)$$

Figure 1 contains an example of such functions. β is a thus a parameter inversely related to the initial fecundability, while λ expresses the speed of decline in fecundability over time. σ is connected to what in demographic analysis is known as the *quantum* of the phenomenon.

4. Data and methods

Data: A French retrospective survey

Data come from the French "Study of Family Histories" Survey, a one-percent survey that was conducted within the 1999 General Population Census. Since 1962, a similar study is included in the general population census. For the first time in 1999, this large-scale survey (380,000

respondents) included men as well as women, aged 18 and over, without any upper age limit. The forms included questions about biological children, adopted children, and also on stepchildren.
A sample of individuals received specific survey forms, in addition to the census forms. For a matter of simplicity, some census enumerators gave specific forms to all the women, others to the men. The form included several questions about present and past family situation: children, stepchildren, and partners. French data are thus subject to memory errors or more widely, reluctance to give information about past episodes. Some respondents may have preferred not to give any information about previous unions (Mazuy, Toulemon 2001). Men and women were given "gendered" forms, but the questions were the same in both forms.

Biological, adopted children, stepchildren

The forms included questions about own children (biological and adopted children) as well as about stepchildren. Questions about own children were grouped in a table, one line per child, one column per question: about the sex of each child, month and year of birth, date of arrival into the household (for adopted children), place of birth, age at leaving the parental home and place of residence (if the child was gone); eventually date of death (if the child was dead). The table is reproduced in appendix. In the present study we only look at female biological fertility.

Other information

The census form provides basic information on diploma, profession, marital status, etc. It also gives information about union history, some information about the partners, and three variables about social background: place of birth, place of birth of both parents, profession of both parents.
In this study we only use education level, coded in three categories: low (unfinished high school or less), medium (completed high school) ,and high (any university degree). Education level is known only at the time of the survey. In France most birth occur after the end of the studies (Robert-Bobée, Mazuy 2003) and we may consider that inverse causality (having a first child empeaching to complete studies) is negligible.

Using microdata allows us to split the population in as many groups as needed, as well as ti use time-varying covariates in order to estimate parameters and to project fertility with taking into account changes in family behaviours related to first birth fertility, in particular conjugal and matrimonial changes. We may also add information about stepchildren, living or not with the partner (Toulemon, Knudsen 2006).

Methods

For what concerns the methods of estimation of the model, we use maximum likelihood estimation. We maximise the following log-likelihood function, with *E* being the set of individuals having already experienced the event (i.e., having already had a birth by the time of the survey) and *Z* being the set of censored individuals

$$\ell = \sum_{i \in E} \log\left[f\left(t_i;\beta,\lambda,\sigma\right)\right] + \sum_{i \in Z} \log\left[S\left(t_i;\beta,\lambda,\sigma\right)\right]$$

Covariates are linked to the original parameter by using a link function so that linear dependence can be assumed on transformed parameters. As $\beta>0$ and $\sigma>0$, a logarithmic link is appropriate; as $0<\lambda<1$, a logit link is appropriate.

$$
\begin{aligned}
\log(\beta) &= b_0 + b_1 x_1 + \ldots + b_h x_h \\
\log\left(\frac{\lambda}{1-\lambda}\right) &= l_0 + l_1 x_1 + \ldots + l_k x_k \\
\log(\sigma) &= s_0 + s_1 x_1 + \ldots + s_m x_m
\end{aligned}
$$

Estimation is conducted using the package TDA (Rohwer and Pötter, 2005). The numerical procedure used to maximise the likelihood function is the tensor fourth-order method CES (Chow, Eskow and Schnabel, 1994) implemented in TDA.

5. Results

A good fit for cohorts born in 1950-70

Age-specific first birth rates look similar to their estimates from the Hernes models (figures 1 and 2). The Hernes model estimates are of course more smoother that observed rates. Especially, the rates are low for the ages between 20 and 25, compared to the overall level of fertility, and to the value of the rates before 20 and after 25 (figure 1). Nevertheless, the proportion childless at each age are very well estimated by the Hernes model.

Fertility Parameter estimates are presented in Table 1. As we are mainly interested in childlessness, we will focus on the "s" parameter and its equivalent estimate of childlessness (Table 2). Childlessness appears to be very stable in France, around 10% for women born in the 1950s. 10% of women born in 1950 and 1955 remained childless, and the model gives very good estimates, the difference between observed and predicted childlessness being around 0.4%.

Women born in 1960 are 38 years old at the time of the survey, and 12% are still childless. The Hernes model indicates that 19% of women still childless at the survey could ultimately have a child, so that the proportion childless would remain constant at 10%. Among women born in 1965, this proportion could even decrease to 9%. Women born in 1970 are still young in 1999, and they just reached the age at which the rates are at the highest (figure 2). Among this cohort, childlessness could be slightly more frequent, reaching 11%. It may be noticed that if cohort 1970 was censored at a younger age (for example age 23), the Hernes model would lead to a very early and low fertility schedule. The fit is very good for cohorts 1950-1970 (Figure 3), because these cohorts have reached the age where the rates are the highest.

Women born in 1975 are still too young to allow any good estimate of the final frequency of childlessness. The trend in adolescents and young adults fertility in the nineties are not perfectly consistent with the Hernes model: the decline in adolescent fertility (before age 20) diminished in the early nineties, while fertility at ages 20-24 went on declining; thus women born in 1975 seem to have a very early fertility, with a maximum at ages 22-23, according to the Hernes estimate. Despite we do not have more recent data on first birth fertility, the trends in overall fertility by age shows that this will not happen: as women born in 1970, women born in 1975 had a fertility at ages 25-29 much higher than expected for the Hernes estimate based on ages 15-23 (figure 4).

TABLES 1, 2 ABOUT HERE
FIGURES 1, 2, 3, 4 ABOUT HERE

Artificial censoring

In order to check the robustness of the Hernes model for incomplete cohorts (Billari 2000), we produced artificial censoring of fertility for women born in 1950 at the end of 1979, 1984, 1989 and

1994 (Table 3 and Figure 5). The estimates based on the years before 1980 (i.e. the ages 15-29 for women born in 1950) are biased, childlessness being overestimated. Using data up to 1984 (ages 15-34), the final value is included in the confidence interval, but childlessness is still overestimated by 1 percent point. After the age of 39 the estimate is accurate but the proportion of women already mothers at age 39 (89.7%) is very near to first birth total fertility of 90.5%.

TABLE 3 ABOUT HERE

FIGURE 5 ABOUT HERE

Educational differences

The Hernes model has been run for cohorts 1950 and 1970 with including the education covariate (tables 4 and 5). Table 5 shows that the contrasts in childlessness are not increasing from one cohort to the next. On the contrary the differences between women with a low or a high education are declining, from 3.6 to 2.1 percentage point. Women with a medium education (completed high school) do not exhibit the same increase in childlessness that the two other groups, and their projected childlessness is 11.5%, as against 12.9% for women with a lower education and 15.0 for women with higher education.

In France the polarization hypothesis is thus not confirmed.

TABLES 4, 5 ABOUT HERE

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5. Cohort and period trends

Cohort and educational level interactions

A preliminary trial of a model including period trend, education as a covariate and interaction (Table 6) leads to the estimates of childlessness presented in table 7. The assumed linear trend for cohorts leads to unlikely estimates: childlessness is then assumed to increase for women with a low level of education and to decline for the two other groups. This implies that a non linear trend has to be used, or that the time trend has to be estimated for a smaller group of cohorts. So, despite the model fits well the cohort data and the educational differentials, it does not allow to describe simply the trends in educational differentials: a model with a linear trends in the parameters and an interaction with educational level is not accurate to describe the change in childlessness by educational level with assuming a linear change in the parameters, from one cohort to the next.

TABLES 6, 7 ABOUT HERE

Period trends

Period trends are presented in table 8. The trends are almost linear for years 1980-99, leading to an estimate period life-table childlessness increasing from 12.1% in 1980-84 to 13.3% in 1995-99. This allows us to make a simple projection on the transformed parameters for the period 2000-30. Using the estimated of childlessness based on sigma values leads to a projected increase of period life table childlessness, up to 16% in 2030, according to a linear trend on log(σ). A slightly higher estimate is obtained with a parabolic fitting (2^{nd} order polynomial), leading to a projected childlessness of 0.20 (figure 6). According to recent trends in fertility in France, this estimate may be considered as a higher variant for childlessness.

Nevertheless, the delay in first births makes the Hernes model more and more problematic, as time goes up: more and more first births are assumed to occur after the age of 50 (figure 7). For instance, the period childlessness in years 2025-29 of 16% goes with an estimated childlessness at age 49 of 25%, 9% of women having a first child… after the age of 50! This shows that the Hernes model may not be simply projected for future periods using linear trends in the transformed parameters.

TABLE 8 ABOUT HERE

FIGURES 6, 7 ABOUT HERE

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6. Concluding remarks

The Hernes mode proves to be very efficient to estimate childlessness among cohorts born in 1970 or before, namely aged 34 of more at the time of the survey. It is also efficient to describe the educational differentials among cohorts 1950 to 1970. But it has some shortcomings for estimating linear trends in education differentials as well as for younger cohorts or period projections, because the current decline in childbearing does not follow a simple path: the current decline at ages 25-29, linked with an increase at ages above 30, is also linked with the stability of fertility ate ages 15-24, which makes the Hernes model less and less efficient.

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Tables and figures

Figure 1
Estimated Hernes survival, density and hazard rate functions for the 1950 birth cohort

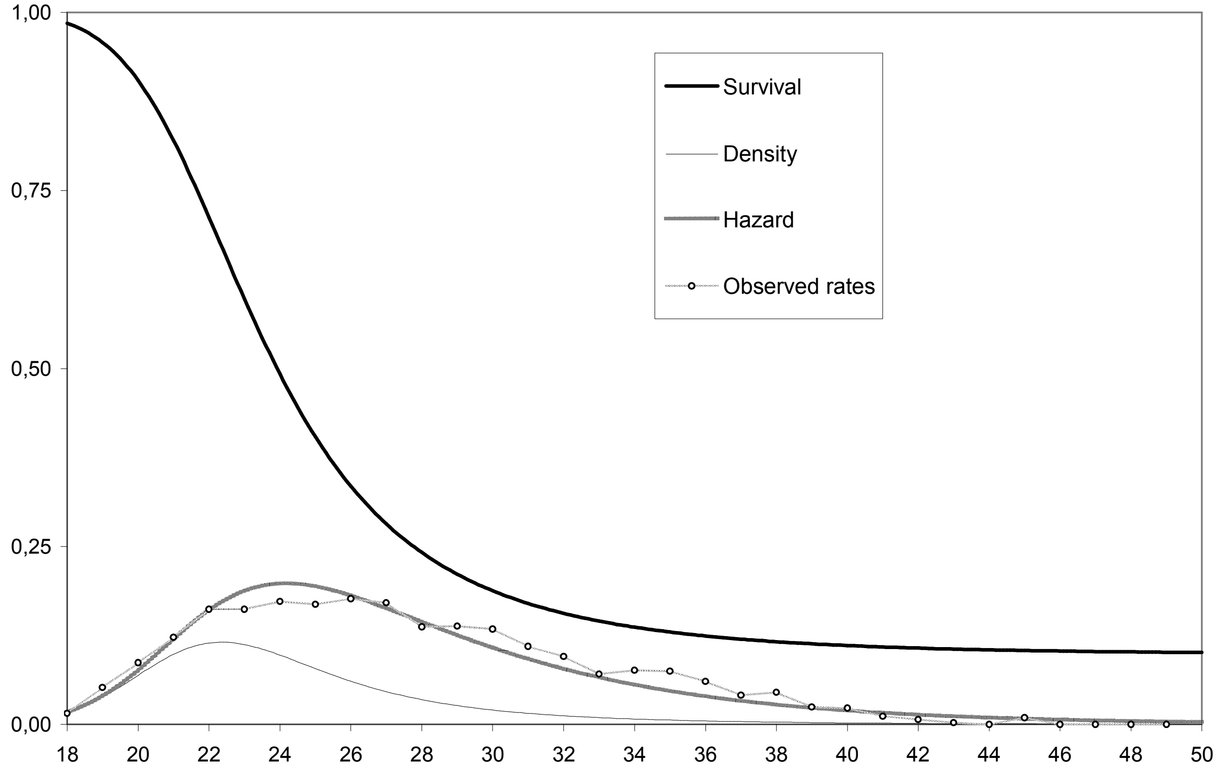

Figure 2. Estimated Hernes survival, density and hazard rate functions for the 1970 birth cohort

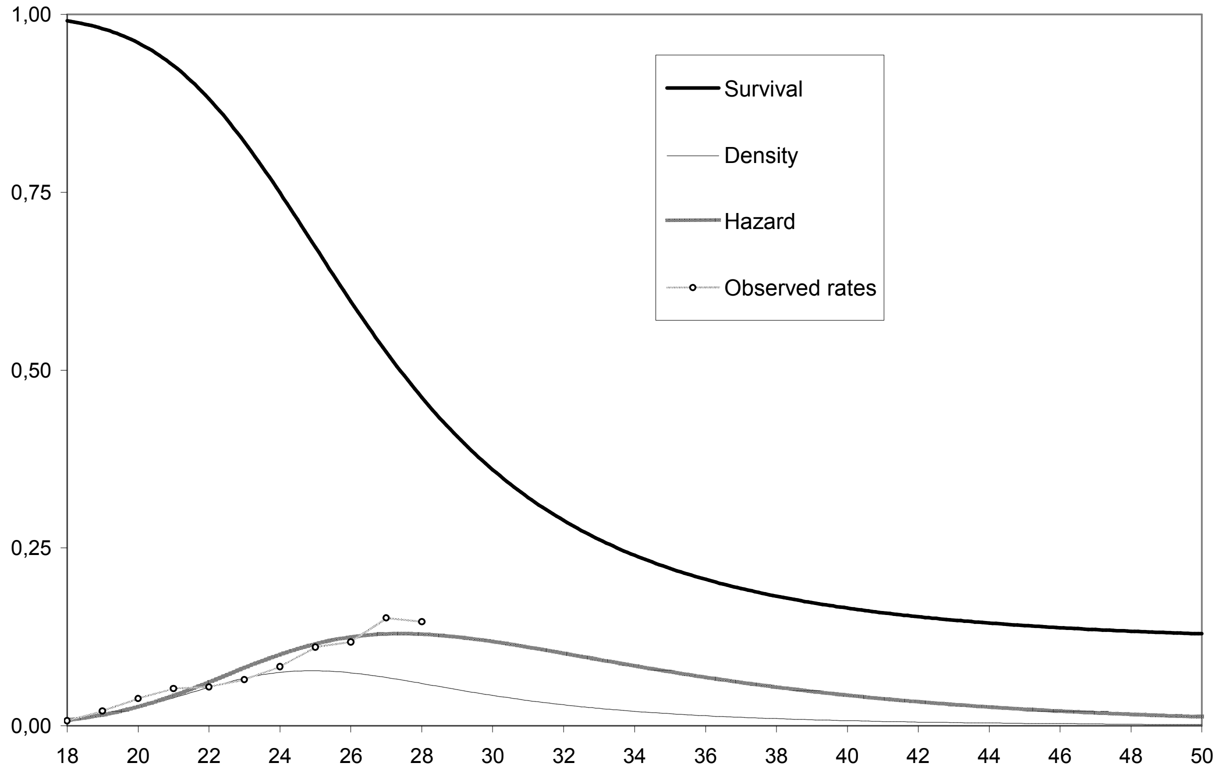

Figure 3
Comparison between the estimated Hernes (dashed) and the estimated non-parametric Kaplan-Meier survivor function (solid), 1950, 1965 and 1970 birth cohorts

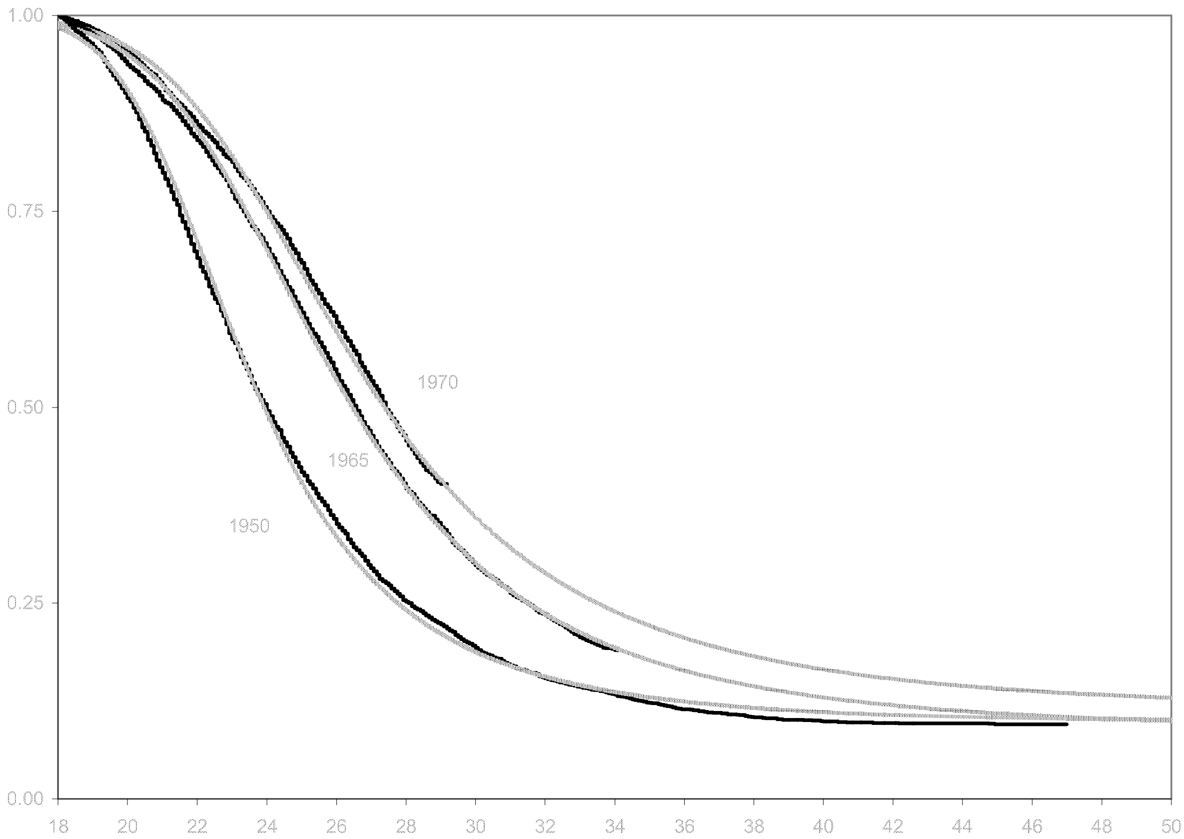

Figure 4. Overall fertility (age-specific fertility rates) in France, 1900-2005

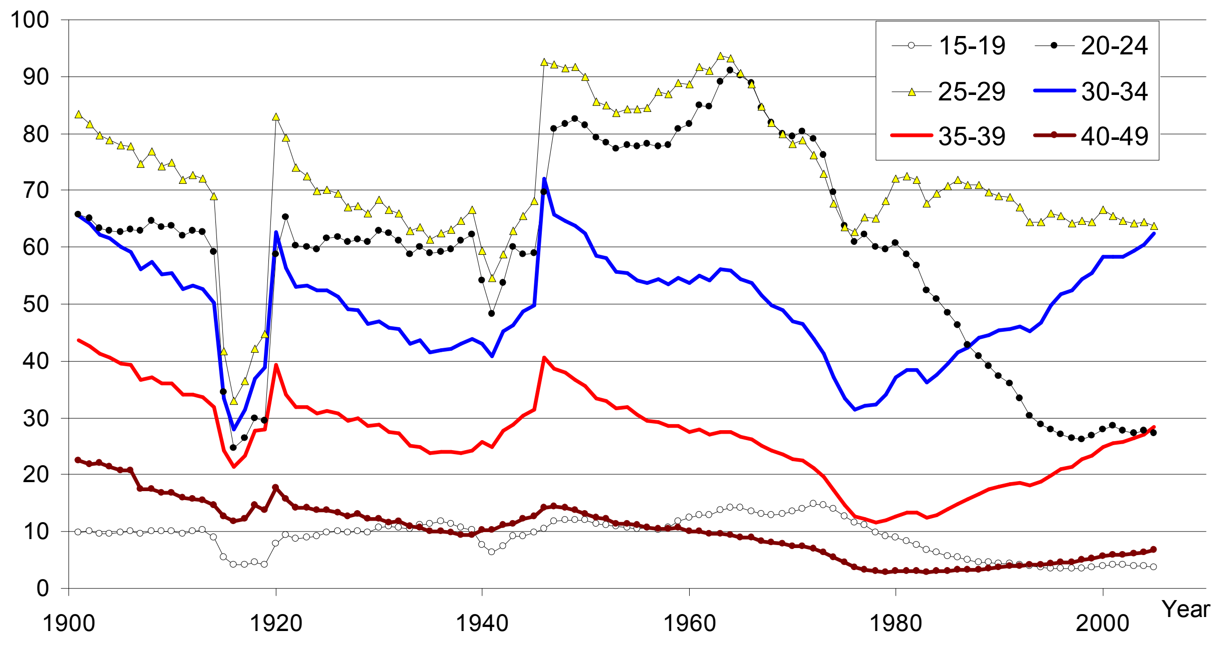

Figure 5
Childlessness: estimates from the Hernes model (see Table 1) and comparison with observed proportion childless at the time of the survey (see Table 2)

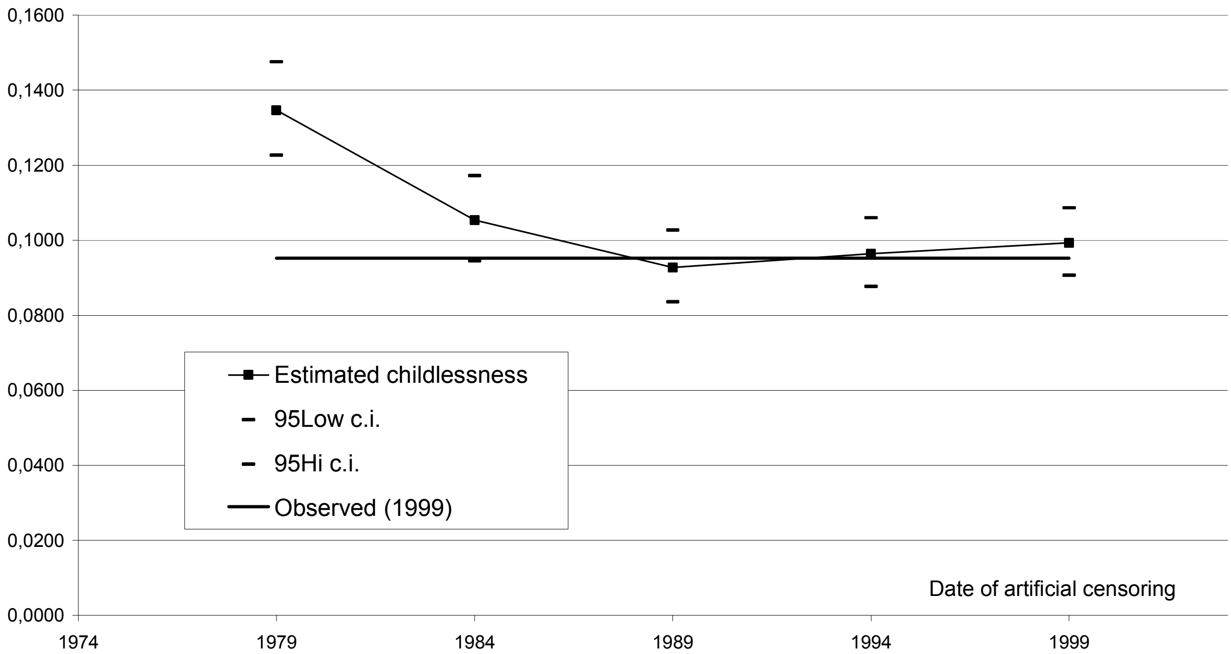

Figure 6
Childlessness: estimates from the period Hernes model, and projection according to the years 1980-98, based on results presented in Table 1

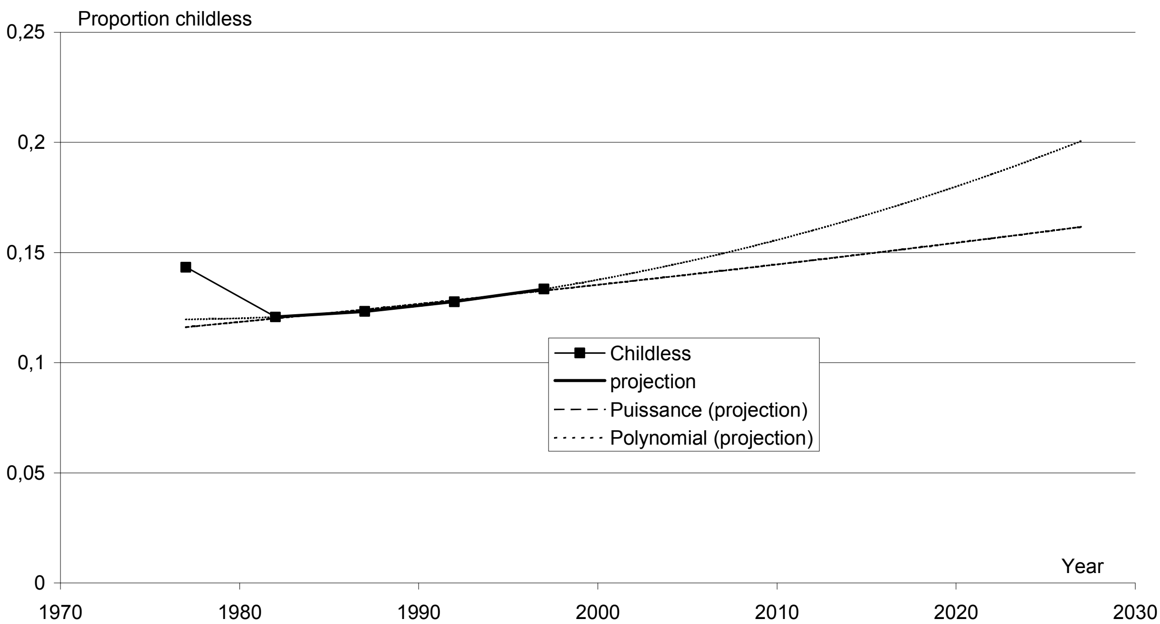

Figure 7. Estimated Hernes survivor function for periods 1975-1999 and projections for periods up to 2030. based on results presented in table 8

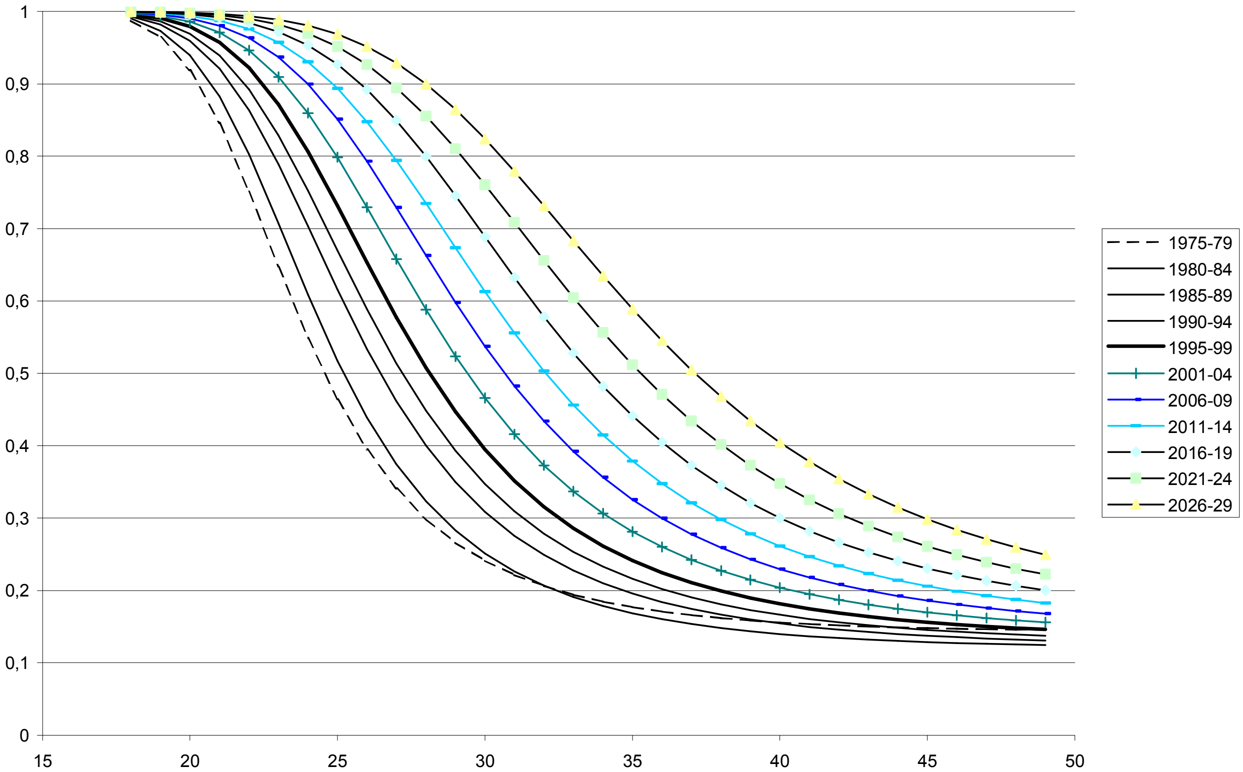

Table 1
Parameter estimates and (asymptotic) 95% confidence intervals for the Hernes model. 1950 (n=4,423), 1955 (n=4,262), 1960 (n=4,463), 1965 (n=4,508), 1970 (n=4,323), 1975 (n=3,505) birth cohort

	1950	Estimate	S.e.		Estimate	95Low c.i.	95Hi c.i.
b		1.8529	0.0133	β	6.3783	6.2142	6.5467
l		1.6271	0.0216	λ	0.8358	0.8299	0.8415
s		-2.2051	0.0513	σ	0.1102	0.0997	0.1219
	1955	Estimate	S.e.		Estimate	95Low c.i.	95Hi c.i.
b		1.7958	0.0135	β	6.0243	5.8670	6.1858
l		1.7713	0.0237	λ	0.8546	0.8488	0.8603
s		-2.1494	0.0545	σ	0.1166	0.1047	0.1297
	1960	Estimate	S.e.		Estimate	95Low c.i.	95Hi c.i.
b		1.8531	0.0135	β	6.3796	6.2130	6.5506
l		1.8278	0.0237	λ	0.8615	0.8559	0.8669
s		-2.2148	0.0545	σ	0.1092	0.0981	0.1215
	1965	Estimate	S.e.		Estimate	95Low c.i.	95Hi c.i.
b_0		1.9163	0.0135	β	6.7958	6.6183	6.9780
l_0		1.9978	0.0237	λ	0.8806	0.8756	0.8854
s_0		-2.3176	0.0545	σ	0.0985	0.0885	0.1096
	1970	Estimate	S.e.		Estimate	95Low c.i.	95Hi c.i.
b_0		1.9048	0.0135	β	6.7181	6.5426	6.8982
l_0		1.9901	0.0237	λ	0.8798	0.8748	0.8846
s_0		-2.0198	0.0545	σ	0.1327	0.1192	0.1476
	1975	Estimate	S.e.		Estimate	95Low c.i.	95Hi c.i.
b_0		1.6355	0.0135	β	5.1320	4.9980	5.2696
l_0		0.9160	0.0237	λ	0.7142	0.7047	0.7236
s_0		0.8446	0.0545	σ	2.3270	2.0913	2.5894

Table 2
Childlessness: estimates from the Hernes model (see Table 1) and comparison with observed proportion childless at the time of the survey

Cohort	Age (approx) at the survey	Estimated childlessness	95Low c.i.	95Hi c.i.	Observed proportion childless	Difference
1950	**48**	0.0993	0.0907	0.1087	0.0952	0.0041
1955	**43**	0.1044	0.0948	0.1148	0.1086	-0.0042
1960	**38**	0.0984	0.0893	0.1083	0.1217	-0.0233
1965	**33**	0.0897	0.0813	0.0988	0.1930	-0.1033
1970	**28**	0.1171	0.1065	0.1286	0.4124	-0.2953
1975	**23**	0.6994	0.6765	0.7214	0.8280	-0.1286

Table 3
Childlessness of the 1950 birth cohort: estimates from the Hernes model simulating surveys in 1979, 1984, 1989, 1994 and comparison with estimates and observed proportion childless in 1999

Time	Age (approx) at the survey	Oberved childless-ness	Estimated childless-ness	95Low c.i.	95Hi c.i.	Observed (1999)	Difference
1979	**29**	.2401	0.1347	0.1227	0.1476	0.0952	0.0395
1984	**34**	.1388	0.1053	0.0945	0.1172	0.0952	0.0101
1989	**39**	.1031	0.0927	0.0836	0.1027	0.0952	-0.0025
1994	**44**	.0963	0.0965	0.0877	0.1060	0.0952	0.0013
1999	**49**	.0952	0.0993	0.0907	0.1087	0.0952	0.0041

Table 4
Parameter estimates and (asymptotic) 95% confidence intervals for the Hernes model with covariates: educational differences for the 1950 (n=4,423) and 1970 (n=4,323) birth cohorts. Lower education is the reference group

1950	Estimate	S.e.	Sig.
b_0	1.8757	0.0171	
Medium	0.1114	0.0355	***
High	-0.1316	0.0351	***
l_0	1.5410	0.0283	
Medium	0.1624	0.0546	***
High	0.1808	0.0560	***
s_0	-2.3394	0.0693	
Medium	0.2097	0.1311	
High	0.3818	0.1274	***
1970	Estimate	S.e.	Sig.
b_0	1.8630	0.0259	
Medium	0.3569	0.0412	***
High	-0.1004	0.0561	*
l_0	1.7375	0.0757	
Medium	0.1175	0.1381	
High	0.3677	0.1534	**
s_0	-1.9114	0.1731	
Medium	-0.1284	0.3726	
High	0.1735	0.3876	

* p<0.1; ** p<0.05; *** p<0.01

Table 5
Childlessness by educational level and birth cohort. Estimates and observation at the time of the surveys for single birth cohorts (1950, 1960, and 1970).

	1950	1960	1970
Age (approx.) at survey	**49**	**39**	**29**
Estimates			
Low	0.0879	0.0894	0.1288
Medium	0.1062	0.1063	0.1151
High	0.1237	0.1149	0.1496
Childless in 1999			
Low	0.0827	0.1007	0.3059
Medium	0.1070	0.1394	0.4690
High	0.1208	0.1467	0.4798
Difference			
Low	0.0052	-0.0113	-0.1771
Medium	-0.0008	-0.0331	-0.3539
High	0.0029	-0.0318	-0.3302

Table 6
Parameter estimates and (asymptotic) 95% confidence intervals for the Hernes model with educational covariates, linear cohort trend for each parameter and interaction between education and trend; observed data on cohorts 1950-1970 (n=91,480). Lower education and cohort 1950 is the reference group

	Estimate	S.e.	Sig.
b_0	1.1819	0.0076	
Medium	0.1341	0.0149	***
High	-0.1510	0.0155	***
Trend	0.0039	0.0007	***
Medium*Trend	0.0103	0.0013	***
High*Trend	0.0038	0.0015	***
l_0	1.5668	0.0137	
Medium	0.1125	0.0245	***
High	0.1100	0.0265	***
Trend	0.0155	0.0015	***
Medium*Trend	0.0024	0.0026	
High*Trend	0.0152	0.0029	***
s_0	-2.4137	0.0339	
Medium	0.4319	0.0602	***
High	0.5542	0.0625	***
Trend	0.0118	0.0037	***
Medium*Trend	-0.0407	0.0069	***
High*Trend	-0.0319	0.0075	***

* p<0.1; ** p<0.05; *** p<0.01

Table 7. Observed and projected childlessness in France, according to the Hernes period model. Projection using years 1980 and more
Childlessness by educational level and birth cohort. Estimates (cohorts 1950-1970) and out-of-sample forecast (cohort 1980) using a linear trend model with interactions for education (see Table 5).

	1950	1960	1970	1980
Low	0.0821	0.0915	0.1018	0.1131
Medium	0.1211	0.0936	0.0718	0.0547
High	0.1348	0.1130	0.0944	0.0785

Table 8. Period estimates of the Hernes parameters, and projections

Year	beta	lambda	sigma
1975-79	6,1429	0,8284	0,1673
1980-84	6,5949	0,8465	0,1374
1985-89	6,9061	0,8615	0,1407
1990-94	7,1356	0,8671	0,1464
1995-99	7,5323	0,8714	0,1539
2001-04	7,8350	0,8805	0,1589
2006-09	8,1804	0,8874	0,1651
2011-14	8,5410	0,8939	0,1715
2016-19	8,9175	0,9000	0,1782
2021-24	9,3107	0,9058	0,1851
2026-29	9,7211	0,9114	0,1923

Note: the estimates for the years 2000 and more are based on linear trends for the years 1980-99 on the transformed parameters

Appendix: The French questionnaire

The complete questionnaire (4 pages) is available at http://www-ehf.ined.fr, as well as the survey as a whole.
This appendix is extracted from a PDF version of the questionnaire that may be downloaded at http://www-ehf.ined.fr/questionnaires/english/1999/Quest1999en.pdf.
The dataset is available for comparative research. The interested readers may contact the authors at toulemon@ined.fr.

3 **DESCRIPTION OF EACH CHILD'S SITUATION, BEGINNING WITH THE ELDEST**
(one line per child) Do not include here the other children you may have brought up

First name	Sex	Date of birth		If you have adopted this child, when did s/he begin to live with you?		Was the child born in France?	If s/he is not living in the household		If s/he is deceased	
							How old was s/he when s/he stopped living with you?	Does s/he live in France at present?	Was s/he stillborn?	If not: How old was s/he when s/he died? *If less than one year write 0 year*
	M for Male, F for Female	*Month*	*Year*	*Month*	*Year*	*Yes or No*	*Age in years*	*Yes or No*	*Yes or No*	
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										

If you have had more than nine children, please complete another form