Demography (2021) 58(1):321–344
Published online: 18 January 2021
DOI 10.1215/00703370-8937427

Cross-Sectional Average Length of Life Childless

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ABSTRACT Increases in the average age at first birth and in the proportion of women remaining childless have extended the total number of years that women spend childless during their reproductive lifetime in several countries. To quantify the number of years that reproductive-age women live without children, we introduce the cross-sectional average length of life childless (CALC). This measure includes all the age-specific first-birth information available for the cohorts present at time *t*; it is a period measure based on cohort data. Using the Human Fertility Database, CALC is calculated for the year 2015 for all countries with long enough histories of fertility available. Results show that women in the majority of the studied countries spend, on average, more than half of their reproductive lives childless. Furthermore, the difference between CALCs in two countries can be decomposed to give a clear visualization of how each cohort contributes to the difference in the duration of the length of childless life in those populations. Our illustration of the decomposition shows that (1) in recent years, female cohorts in Japan and Spain at increasingly younger ages have been contributing to more years of childless life compared with those in Sweden, (2) the United States continues to represent an exception among the high-income countries with a low expectation for childless life of women, and (3) Hungary experienced a strong period effect of the recent Great Recession. These examples show that CALC and its decomposition can provide insights into first-birth patterns.

KEYWORDS Childlessness • Fertility measurement • Life table • Decomposition • Cohort versus period

Introduction

The postponement (Kohler et al. 2002; Sobotka 2004) and, increasingly, forgoing (Frejka et al. 2010; Kreyenfeld and Konietzka 2017; Miettinen et al. 2015) of parenthood have been important family demographic trends of the past half-century in the developed world. Since the 1970s, the age at entering motherhood has increased by an average of about one year each decade in high-income countries, with substantial variation in the average age and its rate of increase across countries (Mills et al. 2011). For instance, in the United States, the mean age rose from 23.7 years in 1985 to 26.6 in 2016; in Japan, the respective increase was more substantial, from a

ELECTRONIC SUPPLEMENTARY MATERIAL The online version of this article (https://doi.org/10.1215/00703370-8937427) contains supplementary material.

readily higher mean age of 26.7 to 30.7 (OECD 2018). In the United States and in eastern European countries, women continue to enter motherhood at a particularly young age, whereas women in southern Europe and East Asia enter parenthood generally later than elsewhere, with average ages in the latter countries currently being above 30. The postponement of parenthood places women at a higher risk of remaining childless (Kneale and Joshi 2008; Schmidt et al. 2012; Toulemon 1996). In several high-income countries, remaining childless has been intensifying in the cohorts born from the 1940s to early 1970s. For example, remaining childless is particularly common in German-speaking countries and southern Europe, where slightly more than 20% of women in recent birth cohorts are childless at the end of their reproductive lives (Sobotka 2017). A notable exception to this trend is the United States, where childlessness increased until the female cohorts born in the early 1950s but has become less common for more recent birth cohorts, staying below 13% of women born in 1970 (Frejka 2017). Generally, variation in childbearing patterns across countries is strongly influenced by sociopolitical, economic, cultural, and historical factors (Frejka et al. 2010; Kreyenfeld and Konietzka 2017; Lesthaeghe and Neidert 2006).

The most common indexes used to describe the current first-birth patterns aim at capturing either the timing or quantum of first birth. For example, the mean age at first birth indicates changes in the timing of the first childbearing, and changes in the proportion of childless women in female cohorts at the end of their reproductive period at age 50 (hereafter referred to as the *childlessness proportion*) exclusively show quantum changes. In addition, age-specific first-birth rates describe the level of first-birth occurrence at each age, but it is difficult to see the quantum of childlessness based on these rates because the quantum is generally obtained from the sum of age-specific first-birth rates. Although these indexes are undoubtedly useful to study either timing or quantum changes, a comprehensive measure that captures both timing and quantum may also add insight in the attempt to understand the phenomenon of childlessness. This is especially the case in the current circumstances, in which both age at entering parenthood and lifetime childlessness have increased in several high-income countries.

One possibility is to study the length of the reproductive life that women are without children at a given time. Mogi and del Mundo (2020) defined this length as the *expected years without children* (EYWC) for women at reproductive ages. EYWC is calculated in a life table framework in which attrition is the occurrence of first birth, and it is analogous to life expectancy (Andersson et al. 2017; Bongaarts and Feeney 2006). The EYWC offers an additional view into the demographic patterns of first births and the phenomenon of childlessness in contemporary societies by emphasizing the amount of time spent childless at reproductive ages, without making the distinction between effects of timing and quantum of the first childbearing on the expectation of the length of life without children.

In times of changing fertility behavior, cohort indexes may provide an outdated picture of current fertility patterns because they are based on information on populations that are no longer at childbearing ages. The study of childbearing in the period perspective (using a synthetic cohort approach), on the other hand, faces the typical challenge that indexes exclusively based on period data do not necessarily reflect the experience of any real birth cohort (Bongaarts and Sobotka 2012; Luy 2011). In this study, to overcome the challenge of choosing between a period and cohort index to study first-birth behavior, we employ an alternative measure: the cross-sectional average length of life childless (CALC). This index uses the entire age-specific information of first-birth histories of cohorts currently at childbearing ages. The concept of CALC builds directly on an index developed and elaborated in mortality research (Brouard 1986; Guillot 2003): the cross-sectional average length of life (CAL).

The aim of this study is to present how CALC can provide an alternative perspective to the study of first-birth behavior. The value of using CALC is the ability to (1) capture changes in both timing and quantum of first childbirth; (2) complement the other period and cohort existing measures; and (3) decompose the difference in CALCs between populations into contributions from different cohorts and ages. In this study, we calculate CALC for all countries for which essential data are available in the Human Fertility Database (HFD). Further, we illustrate the use of the measure by comparisons of selected relatively high-income countries with different observed first-birth trends and social contexts for childbearing. Japan and Spain are countries characterized by late first-birth timing and high levels of childlessness, as well as particularly challenging social conditions for childbearing. By contrast, the United States and Hungary are characterized by early first births and low to moderate levels of childlessness. The U.S. context is characterized by low public support and strong cultural variation, and Hungary is characterized by a history of post-communism and current traditionalism. Sweden is taken as the country of comparison: there, first-birth timing ranges from average to late, strong catching-up of births at older ages is typical, and support of childbearing is particularly strong.

Data and Methods

Data

The HFD is used to obtain age-specific first-birth rates by cohort for the selected countries. The HFD is an open access database containing 28 countries from Europe, North and South America, and Asia. The data are heavily scrutinized through quality control, and only those countries with comprehensive high-quality information are included. To compare as many countries as possible, we selected all countries in the HFD with sufficient histories of fertility information needed for the calculation of CALC available: Belarus, Czechia, Denmark, Estonia, Hungary, Japan, Lithuania, the Netherlands, Spain, Sweden, and the United States. These countries have long-span birth cohort data available in the HFD, including women born in 1966–2003 and covering ages 12–50, and thus enabling the calculation of CALC for all these countries in year 2015. We calculated CALC and decomposed its difference between two countries by age and cohort for all these HFD countries for which the necessary data were available. In cases where cohort data for this selection were missing for some single years, we used the period data from the HFD. We conducted several sensitivity analyses for countries with complete cohort data and with hypothetical cohort data created from period data. The results for CALC based on these two data sets were very similar, thus justifying the partial substitution strategy. For example, age-specific first-birth rates calculated from both complete cohort data and hypothetical cohort data derived from period information were very similar (see section A of the online appendix).

Selection of Countries to Compare

To illustrate the strengths of the method, we highlight comparisons of four countries—Hungary, Japan, Spain, and the United States—with Sweden. This selection of countries is motivated by the observed diversity across first-birth trends as well as the different contexts for childbearing across those countries. As shown in Figures 1 and 2, Sweden has witnessed the postponement of first births since the mid-1970s and is currently characterized by average to late timing of the first childbearing (29.2 years in 2016). The level of ultimate childlessness in Sweden has remained relatively stable among birth cohorts of women born since the mid-1950s, reaching approximately 13% among women born in the late 1960s but increasing slightly in the more recent cohorts. Typical of childbearing in Sweden has been a strong catching-up effect of births at older ages, which has hindered declines in cohort fertility despite the trend of postponement (Andersson et al. 2009; Frejka and Calot 2001). Sweden represents a sociopolitical context supportive of gender equality and childbearing of dual-earner couples (Ellingsaeter and Leira 2006; Esping-Andersen 2009): public support for families is universal and generous, enabling job-protected long parental leaves with high levels of income replacement, encouraging fathers' active participation in childcare, and ensuring high childcare coverage and flexible childcare arrangements. Indeed, among European countries in 2019, Sweden ranked the highest in gender equality (European Institute for Gender Equality 2020). Sweden was not strongly hit by the global Great Recession in 2007–2013 (Matysiak et al. 2018).

Japan and Spain are countries where the postponement of parenthood has been visible only since the 1980s, and average age at entering motherhood is currently relatively high compared with other high-income countries (Figure 1). In 2016, Spain reached the highest mean age of all countries available in the HFD, at 30.8 years. Lack of fertility catching-up at older ages has contributed to strong increases in the ultimate share of women remaining childless in recent birth cohorts, reaching more than 20% and about 28% of women born in the early 1970s in Spain and Japan, respectively (Figure 2).

Japan records highest ultimate childlessness levels globally (Frejka et al. 2010). Spain, and particularly Japan, represent countries where increases in women's education and employment took place relatively late but rapidly and where conditions for family-work reconciliation for women remain difficult (Brodmann et al. 2007; Esping-Andersen 2009; McDonald 2008). The contribution of high opportunity costs of motherhood to low first-birth rates arises from less developed public support, history of family-based welfare production, less family-friendly labor market practices, and men's weaker contribution to unpaid work at home (Luci-Greulich and Thevenon 2013). Further, Japanese women often hesitate to make full use of recently improved paid leave opportunities because they fear it will signal low work commitment (McDonald 2008).

In addition, economic uncertainty is likely to have negatively affected fertility rates of young adults in Spain and Japan (Matysiak et al. 2018; McDonald 2008). Japan experienced economic hardship since 1989 for 20 years, in the so-called Lost 20 Years (Raymo and Shibata 2017). Spain was hard hit by the Great Recession in 2007–2013, and unemployment and economic uncertainty are considered to have

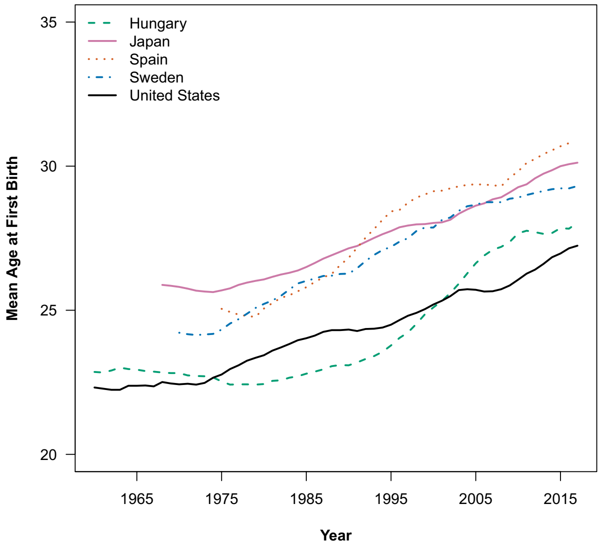

Fig. 1 Mean age at first birth in selected countries in the period 1960–2017. *Source*: Authors' calculations using the Human Fertility Database.

contributed to lower fertility rates in the subsequent years. Exclusive to Japan is that childbearing remains strongly tied to the institution of marriage: in 2017, only 2.2% of all births took place outside marriage (National Institute of Population and Social Security Research 2019); in Spain, this share increased from 3.9% in 1980 to 46.8% in 2017 (Instituto Nacional de Estadística [INE] 2019). Further, in the deeply rooted patriarchal culture of Japan, marriage for women typically means a commitment to the care of not only their own children but also their elderly parents. In light of increased career opportunities for women, these care expectations of women offer another incentive to delay family formation (Frejka et al. 2010).

Postponement of parenthood has been a prominent trend also in the United States and Hungary but to a lesser extent than in Sweden, not to mention east Asian and southern European countries, such as Japan and Spain (Figure 1). In the United States, the mean age at entering motherhood has remained lower than in most high-income countries for several decades, and the average age of 27.2 years upon entering motherhood in the United States in 2016 is low among high-income countries. Opposite to the trend in most high-income countries (Frejka and Sardon 2006; Frejka et al. 2010; Sobotka 2017), childlessness has, in fact, decreased in the United States since the early 1950s female cohorts, down to a level of 11% among women born in the early 1970s (Figure 2). In turn, in Hungary, typical of eastern and central European countries, postponement gained ground late, first occurring mainly after the fall of the Soviet Union in 1990 (Sobotka 2011). The increase was rapid in the following economic crisis, but since 2010, it seems to have come to a halt. Also typical of the eastern and central European countries (Frejka and Sardon 2006), childlessness in Hungary began to increase first in the cohorts born since the early 1960s, but the increase since has been quick, reaching 15% of women born in the early 1970s.

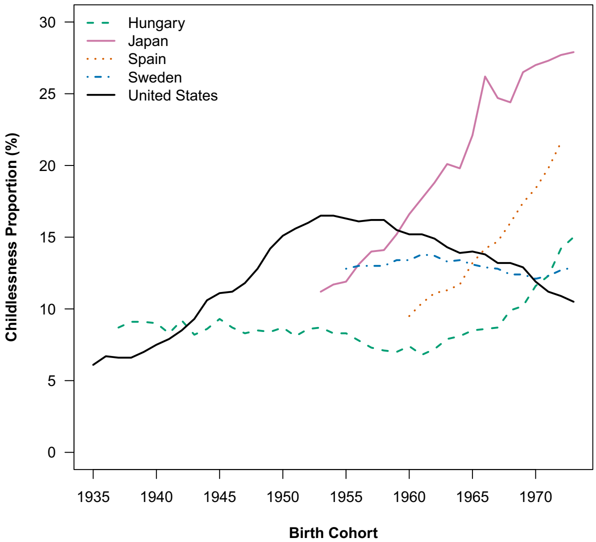

Fig. 2 Childlessness rate at age 44 or older among women born in 1935–1973 in selected countries. *Source*: Authors' calculations using the Human Fertility Database.

The United States and Hungary represent two contexts very different from Sweden as well as each other. Gender-equal practices in the family in the United States can be viewed as more developed than those in Japan, Spain, or Hungary but as somewhat less developed than those in Sweden (Esping-Andersen 2009; Korintus and Stropnik 2009; Tsuya et al. 2000). In the United States, the public support for families is weak, welfare production is strongly market-based, and interruptions in employment among mothers are comparatively short (Berger and Waldfogel 2004; Esping-Andersen 2009; Waldfogel 2001). Ethnic and religious diversity contributes to strong variation in fertility behavior in the United States, and rates of early childbearing are high in the non-White subgroups of the population (Lesthaeghe and Neidert 2006; Sutton and Mathews 2004). Further, the U.S. fertility rates were negatively affected by the Great Recession (Comolli 2017; Currie and Schwandt 2014).

In Hungary, on the other hand, traditional gender attitudes and practices remain largely prevalent, and childbirth typically leads to long work interruptions for mothers (Korintus and Stropnik 2009). For example, compared with couples in other European countries, couples in Hungary are least likely to share household tasks (Aassve et al. 2014). Public support for long leaves is generous, and young children are almost exclusively cared for at home by their mothers. Family policy since the socialist period has concentrated on providing financial aid for families in order for mothers to stay at home, and the development of policies that would enable mothers to pursue employment has been slow. Consequently, the opportunity costs of motherhood are high, and these may boost the trend of postponement as well as forgoing motherhood. Hungary, like Spain, is among the European countries that were most strongly hit by the Great Recession in 2007–2013, which is also reflected in the decreasing fertility rates since 2008 (Matysiak et al. 2018).

Methods

Expected Years Without Children (EYWC)

The concept of life expectancy has been previously used in family demography research (Andersson et al. 2017; Bongaarts and Feeney 2006, Bumpass and Lu 2000), but it has further potential to shed light on the current trends in fertility. The increases in the average age at first birth and increasing share of women remaining childless in several countries translate into an extension of the average length of life that women are childless during their reproductive years. A life table for first births follows a cohort of childless women from age 12 until age 50 where the event of interest (exiting the cohort) is the occurrence of first birth. The expected years without children (EYWC) (Mogi and del Mundo 2020) is defined for period and cohort as

$$EYWC_p(t) = \int_{12}^{50} l_p(x,t)\,dx \tag{1a}$$

and

$$EYWC_c(y) = \int_{12}^{50} l_c(x,y)\,dx, \tag{1b}$$

where $EYWC_p(t)$ and $EYWC_c(y)$ are the EYWC for year t (period) and the cohort born in year y, respectively. Similarly, $l_p(x,t)$ and $l_c(x,y)$ are the probabilities of remaining childless at age x calculated from period data in year t and for the cohort born in year y, respectively. The EYWC offers additional insight into the demographic patterns of first births and the phenomenon of childlessness in contemporary societies by placing emphasis on the amount of time lived without children at reproductive ages. Furthermore, both perspectives, the period and cohort EYWC, are the basis of the new childless measure, CALC.

Cross-Sectional Average Length of Life Childless (CALC)

$CALC(t)$ is a period measure that includes age-specific first-birth histories of all female cohorts at reproductive ages 12–50 at a given time t. Traditional period indexes use a synthetic cohort approach aggregating values from different cohorts from different ages at a given time t, but CALC utilizes real cohort data. The analogous measure to CALC is the cross-sectional average length of life (CAL), which was developed and elaborated to complement period and cohort life expectancies in mortality research (Brouard 1986; Guillot 2003). Because the event of interest is the first birth, the analytical age range corresponds to the reproductive ages 12–50, with $CALC(t)$ as follows:

$$CALC(t) = \int_{12}^{50} l_c(x,t-x)\,dx, \tag{2}$$

where $l_c(x,t-x)$ is the probability of remaining childless from age 12 to the age attained in year t—that is, x for the cohort born in year $t-x$. The $l_c(x,t-x)$ series

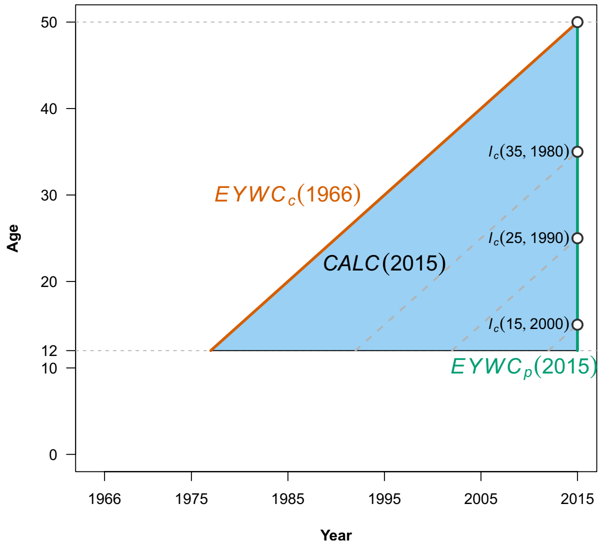

Fig. 3 Illustration of the age-specific fertility rates used in the probabilities of remaining childless for each of the three measures of duration: the expected years without children for the period of 2015, $EYWC_p(2015)$, and for the cohort of 1966, $EYWC_c(1966)$, and for the cross-sectional average length of life childless in 2015, $CALC(2015)$. $l_c(x,t-x)$ represents the life table probability of remaining childless for women reaching age x at time t who were born in year $t-x$.

are not necessarily monotonically decreasing with age x because each probability of remaining childless corresponds to a unique cohort (Guillot 2003). Figure 3 illustrates the difference between CALC from period and cohort expected years without children. The period $EYWC_p(2015)$ is an age-aggregated index of the synthetic cohort constructed with the probabilities of remaining childless by age in 2015 (the vertical line in 2015 in Figure 3). $EYWC_c(1966)$ is obtained from the probability of remaining childless by age for the cohort of 1966 (the diagonal thick line in Figure 3). Different from these unique cohort or period indicators, CALC includes all the cohort first-birth information at a given time. Thus, $CALC(2015)$ uses all the probabilities of remaining childless from the 1966 to 2003 birth cohorts, marked by the shaded triangle area in Figure 3. Each diagonal dashed line in Figure 3 corresponds to the probability of remaining childless for persons who were born in year $t-x$ and reached age x in 2015. For example, $CALC(2015)$ contains the 1966 birth cohort up to age 50, the 1967 birth cohort up to age 49, and so on until the 2003 birth cohort, which reached age 12 in 2015. Specifically, $CALC(2015) = l_c(50,1966) + l_c(49,1967) + \cdots + l_c(13,2002) + l_c(12,2003)$; calculation details using discrete-time data can be found in section B of the online appendix.

Because CALC contains all available cohort first-birth information, it captures the fertility changes over cohorts. Simulations fixing the age-specific first-birth rates across different cohorts helps to understand the dynamics of CALC. For example, if all U.S. women of reproductive age in 2015 had the age-specific first-birth rates of women of the post-baby boom of 1966, with relatively early entry to motherhood (mean first-birth age of 25.13 years) and a moderate proportion remaining childless (13.8%), then CALC in 2015 would be 17.64 years as opposed to the observed 18.67 years. That is, the postponement (Figures 1 and 2) of fertility in the later-born U.S.

cohorts had a substantial impact on the expectation of years remaining childless in 2015. Another example is using the Japanese fertility of the 1966 birth cohort, with late first birth (mean first-birth age of 28.01) and high childlessness proportion (26.2%), for the later-born female cohorts. This would result in a 2015 CALC of 22.91 years, which is about 1.5 years lower than the observed value of 24.40 years. Cohorts born later than 1966 postponed their childbearing more, and a higher share of women remained childless (Figures 1 and 2), both of which increased the overall number of years remaining childless in 2015.

The CALC measure as defined in Eq. (2) considers only first birth as the possible exit from the population, assuming that no other competing way of attrition is present. To test the sensitivity of this assumption, we incorporated information on mortality for women (although properly only mortality for childless women should be included) from the HMD in an adjusted CALC including both first birth and mortality. Table A1 in the online appendix shows the comparisons between period and cohort EYWC and CALC, and their adjusted values when mortality was included. All three measures show minor deviations from those values presented in Table 1, and thus the rest of the analysis include only the first birth in the CALC results.

Cohort-Decomposition of the Difference Between Two CALCs

General methods of decomposition are widely known and used (Gupta 1978; Horiuchi et al. 2008; Kitagawa 1955; Vaupel and Canudas-Romo 2002). Our current interest lays in examining the differences between CALCs of two populations and partitioning them by age and cohort. As such, the decomposition method that Canudas-Romo and Guillot (2015) developed for the mortality measure CAL is employed to decompose the difference analogously for CALCs. Let the CALC for population i be denoted as $CALC_i(t)$. The difference in CALC between two populations A and B is then

$$CALC_B\left(t\right)-CALC_A\left(t\right)=\int_{12}^{50} l_{c,B}\left(x,t-x\right)-l_{c,A}\left(x,t-x\right)dx, \tag{3}$$

where $l_{c,i}(x,t-x)$ is the probability of remaining childless at age x for the cohort born in year $t-x$, and the integral corresponds to cohorts aged 12–50 and present at time t. The differences in cohort probabilities of remaining childless, seen on the right side of Eq. (3), allow identification of the fertility contribution of each of the cohorts present in a given year.

Each of the cohorts presented in Eq. (3) can be further decomposed by their age contributions to the difference in CALCs. These age contributions allow a comparison of cohorts in different populations and an assessment of their fertility transitions over the life course.

Age Decomposition of the Difference Between Two CALCs

The decomposition of the change in CALC over a continuous variable is explained first. Equations in continuous terms are elegant and easy to elaborate, but demographic data are discrete, so in this section, we combine the continuous formulations with the estimation procedures for discrete data.

We assume that CALC and all the derived measures are functions of a variable ξ and then examine the derivatives of CALC with respect to this variable to assess differences between populations. The derivative of $CALC(t,\xi)$ with respect to the continuous variable ξ is

$$C\dot{A}LC\left(t,\xi\right)=\int_{12}^{50}\dot{l}_c\left(x,t-x,\xi\right)dx, \tag{4}$$

where the dot above the variable denotes its derivative with respect to ξ. Similar notation for derivatives has facilitated the development of decomposition methods (Canudas-Romo and Guillot 2015; Vaupel and Canudas-Romo 2002). The rest of the decomposition requires the use of age-specific probabilities of remaining childless. We denote ${}_1p_a(t-x)$ as the probability of remaining childless from age a to age $a+1$ for the cohort born in year $t-x$. Thus, we can express the probability of remaining childless up to age x as the product of single age probabilities of remaining childless from 0 to age x as $l_c(x,t-x,\xi)={}_1p_0(t-x,\xi)\,{}_1p_1(t-x,\xi)\cdots{}_1p_{x-1}(t-x,\xi)$, with the radix of the life table being equal to 1. The derivative of the probability of remaining childless on the right of Eq. (4) can then be rewritten as

$$\dot{l}_c\left(x,t-x,\xi\right)=\sum_{a=12}^{x-1}{}_1\dot{p}_a\left(t-x,\xi\right)\prod_{b\neq a}{}_1p_b\left(t-x,\xi\right).$$

Rearranging and substituting inside the integral in Eq. (4), we obtain

$$C\dot{A}LC\left(t,\xi\right)=\int_{12}^{50}l_c\left(x,t-x,\xi\right)\left[\sum_{a=12}^{x-1}\frac{{}_1\dot{p}_a\left(t-x,\xi\right)}{{}_1p_a\left(t-x,\xi\right)}\right]dx. \tag{5}$$

In Eq. (5), the relative derivatives with respect to ξ of the probability of remaining childless, denoted as $\frac{{}_1\dot{p}_a(t-x,\xi)}{{}_1p_a(t-x,\xi)}$, correspond to the age a contribution of the cohort reaching age x at time t—namely, $l_c(x,t-x,\xi)$—in the overall change in CALC. For comparisons between populations, we also use Eq. (5). If data for two populations are available—for example, for countries A and B—we can estimate the relative derivatives in Eq. (5) as the logarithm of the ratio of probability functions, $\frac{{}_1\dot{p}_a(t-x,\xi)}{{}_1p_a(t-x,\xi)}=\dot{\ln}[{}_1p_a(t-x,\xi)]\approx\ln\left[\frac{{}_1p_a(t-x,B)}{{}_1p_a(t-x,A)}\right]$. Similarly, cohort survival to age x, $l_c(x,t-x,\xi)$, is taken as the average of the two populations. The age-cohort contribution to the difference in CALCs between populations A and B is estimated as the elements inside the integral in Eq. (5) as

$$\Delta\text{age}-\text{cohort}\left(a,t-x\right)=\left[\frac{l_c\left(x,t-x,B\right)+l_c\left(x,t-x,A\right)}{2}\right]\ln\left[\frac{{}_1p_a\left(t-x,B\right)}{{}_1p_a\left(t-x,A\right)}\right]. \tag{6}$$

Then, the overall difference in CALCs between the two populations is calculated as the sum of all the age-cohort contributions over cohorts and ages as

$$CALC_B(t) - CALC_A(t) = \sum_{x=12}^{50} \sum_{a=12}^{x} \Delta\text{age} - \text{cohort}(a, t-x). \tag{7}$$

Equations (3) and (5) in continuous format and Eq. (7) in discrete format are different from period or cohort decompositions, which can be applied to measures such as the expected years without children (EYWC) and can reveal only current fertility conditions or conditions for one specific cohort, respectively. Cohort fertility differs from year to year and from age to age, and CALC condenses the available fertility history of a number of cohorts present at time *t* into one measure. It is precisely the decomposition shown in Eq. (7) that allows identifying age- and cohort-specific contributions to differences in CALCs.

Decomposition of the Difference in CALCs

The decomposition analysis illustrates how each birth cohort contributes to the difference in CALCs between the two populations by age. Figures 4–7 in the Results section correspond to the cumulative age and cohort contributions. In other words, the figures depict how a cohort is progressing in their duration of life spent childless at reproductive ages compared with the respective cohort in the comparison population. The cumulative contributions of different cohorts at time *t* sum to the total difference in *CALC*(*t*). Thus, the inspection of the cumulative contributions allows studying how a cohort difference between two countries evolves over time and age. Alternatively, the contribution to the difference of CALCs of two countries can be illustrated with noncumulative age- and cohort-specific contributions, which can be found in Table 2 and corresponding figures shown in section C of the online appendix. Comparisons and decompositions between any two of the studied countries are shown in an interactive online application (https://rmogi.shinyapps.io/CALC/).

Results

Table 1 shows CALC in 2015 as well as EYWC for the year of 2015 (period) and the cohort born in 1966 in 11 countries. These three indexes contain different information, as shown in Figure 3; thus, the values and rankings differ somewhat across indexes. In general, the cohort EYWCs are lower than period EYWCs. This is a reflection of ongoing childbearing postponement, which increases the expectation of childless life in the period compared with the cohort perspective. Further, country rank is strongly correlated between the measures, but in some cases, the country rank differs substantially across the three measures. For instance, Hungary ranks much higher in the period EYWC than the cohort EYWC, thus illustrating a case where a period and a cohort measure give a different picture because of recent demographic changes. In Hungary, the period age at first birth rose rapidly from an initial low level in the late 1990s and early 2000s (Figure 1). Likewise, the proportion of women

Table 1 Three measures of childlessness duration and their rankings: CALC in 2015, and EYWC for the year of 2015 (period) and the cohort of 1966 in 11 countries

Country	*CALC*(2015)	$EYWC_p$(2015)	$EYWC_c$(1966)
Japan	23.23 (1)	23.57 (2)	21.78 (1)
Spain	22.49 (2)	23.68 (1)	18.97 (3)
The Netherlands	20.86 (3)	21.58 (4)	20.49 (2)
Hungary	20.38 (4)	22.29 (3)	13.54 (8)
Denmark	20.01 (5)	20.98 (5)	18.42 (4)
Sweden	19.83 (6)	20.75 (6)	18.02 (5)
Czechia	19.15 (7)	20.44 (7)	12.55 (11)
Lithuania	18.12 (8)	18.67 (10)	15.56 (7)
Estonia	18.00 (9)	20.32 (8)	13.21 (9)
United States	17.45 (10)	19.37 (9)	16.57 (6)
Belarus	15.97 (11)	17.45 (11)	13.06 (10)

Source: Authors' calculations based on the Human Fertility Database.

remaining childless remained low in the female cohorts born until the early 1960s but has increased strongly in the more recent cohorts (Figure 2).

CALC shows that except for Belarus, Estonia, Lithuania, and the United States, women in the studied countries spend, on average, more than half of their reproductive lives childless (i.e., more than 19 years). Women in Japan and Spain record the highest CALCs: in 2015, women in these countries spent an average of almost 60% of their reproductive life without children (23.23 and 22.49 years, respectively). Czechia, Denmark, Hungary, the Netherlands, and Sweden have a CALC ranging between 19.15 and 20.86 years. Sweden is the country with the median expected length across the studied countries. Swedish women spend an average of 19.83 years without children between ages 12 and 50. Women in Belarus, Estonia, Lithuania, and the United States have lower CALCs. The lowest values are found in Belarus and the United States, where women spend (respectively) 15.97 and 17.45 years childless.

To illustrate the decomposition of CALC, we study which ages and cohorts contribute to the difference in CALC between our four selected countries (Hungary, Japan, Spain, and the United States) and the country of comparison (Sweden). Among these four countries, Japan has the highest 2015 CALC (23.23 years), and the United States has the lowest (17.45 years). The differences in CALC of Japan, Spain, Hungary, and the United States compared with Sweden are 3.40, 2.66, 0.55, and –2.38 years, respectively. Thus, the United States is the only one of the four countries with a lower expectation of childless life in 2015 than Sweden. The decompositions of the differences in CALC in 2015 between countries are presented in Figures 4–7.

Figure 4 illustrates the decomposition of the 3.40-year CALC difference between Japan and Sweden. A positive contribution from a particular age and cohort in Figure 4 means that Japanese women belonging to that cohort are contributing to a higher expectation of childless life up to that age than Swedish women. By contrast, a negative contribution would correspond to a contribution to higher childlessness years by a particular cohort and up to that specific age in Sweden than Japan. Positive

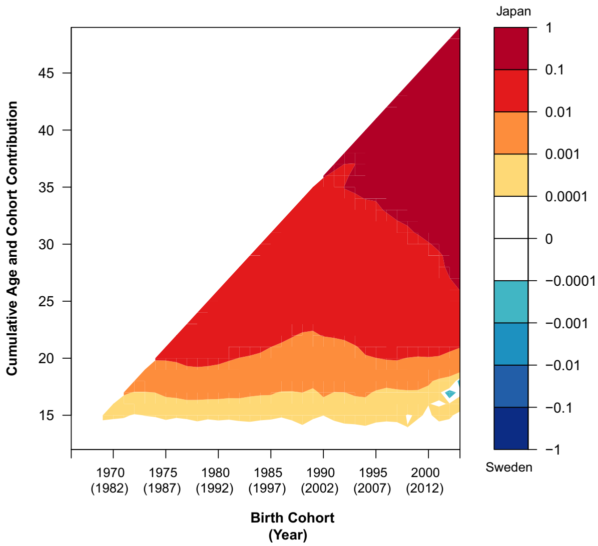

Fig. 4 Lexis surface for the cumulative age- and cohort-specific contributions to the difference in CALCs between Sweden (19.83) and Japan (23.23) in 2015 for the 1966–2003 birth cohorts. Positive values correspond to a higher risk of remaining childless in Japan than in Sweden; negative values represent a lower risk of remaining childless in Japan than in Sweden. *Source*: Authors' calculations based on the Human Fertility Database.

contributions are observed at all ages and birth cohorts, meaning that women in Japan across cohorts and ages contribute to a longer expectation of childless life than women in Sweden in all cohorts of childbearing age in 2015. Especially from age 20 onward, across cohorts, the differences in the cumulative contribution to the expected length of life remaining childless between Sweden and Japan are relatively large, at 0.01 to 0.1 years. Furthermore, although the difference increases further around age 35 among the older cohorts born in the late 1960s, the gap increases gradually at younger ages among the younger cohorts. This figure clearly illustrates that changes in first-birth trend after age 30 are the key to understanding the increasing difference between Sweden and Japan in the expected length of childless life (see also Figure A2 in the online appendix, which graphs results of noncumulative age and cohort contributions).

The 2.66-year CALC difference between Spain and Sweden is presented in Figure 5. As in the case of Japan, there is a clear age pattern for this comparison, with some changes across cohorts. Unlike in the case of Japan, teenage motherhood is more common in Spain than in Sweden among all cohorts, especially in the cohorts born after the mid-1980s. Beyond the teens and early 20s, positive values are observed in all cohorts: Spanish women beyond these ages have accumulated a contribution to a longer childless life than Swedish women. In the cohorts born until the mid-1970s, the contribution to the expectation of childless life remains relatively stable at high ages. In the younger cohorts, however, an increasing difference is observable at increasingly young ages, similar to that found for Japan. This finding illustrates that the more recent cohorts of women in Spain are postponing their entry into motherhood more

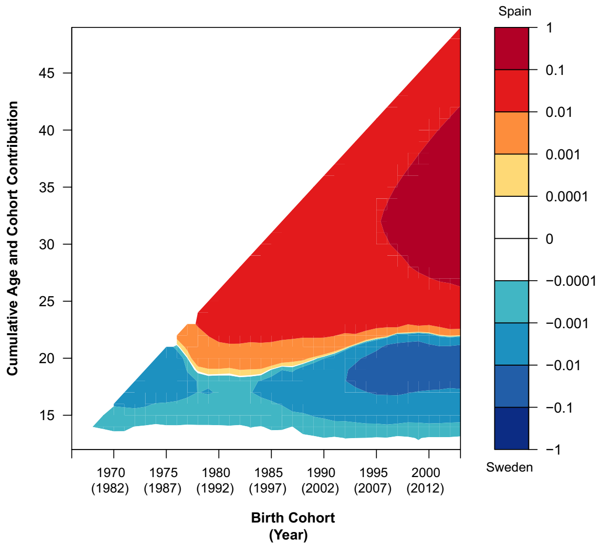

Fig. 5 Lexis surface for the cumulative age- and cohort-specific contributions to the difference in CALCs between Sweden (19.83) and Spain (22.49) in 2015 for the 1966–2003 birth cohorts. Positive values correspond to a higher risk of remaining childless in Spain than in Sweden; negative values represent a lower risk of remaining childless in Spain than in Sweden. *Source*: Authors' calculations based on the Human Fertility Database.

than the respective cohorts in Sweden, which increases Spain's CALC and widens the difference in CALC compared with Sweden.

Interestingly, the two lowest-low fertility countries, Japan and Spain, show similar yet different trends: the similar trends are the positive contributions after age 20 in all cohorts and increasing postponement in younger cohorts. In both countries, contributions to longer life spent childless are intensifying in younger female cohorts compared with Sweden. The higher CALCs of Japan and Spain compared with Sweden are largely due to low first birth after age 20. The difference between Japan and Spain in comparison to Sweden is mainly the contribution from teen ages. Whereas contributions at teen ages are negative (favoring lower CALC) in the case of Spain (Figure 5), the comparison of Japan with Sweden does not reveal negative contributions at any ages (Figure 4). The latter finding may reflect the strong linkage of childbirth and marriage in Japan, contributing to low teenage fertility rates there.

The decomposition of the 0.55-year CALC difference between Hungary and Sweden, shown in Figure 6, reveals a pattern very different from those presented earlier. In cohorts born until the early 1970s, women in Hungary accumulated a lower expectation of childless life than women in Sweden by the end of their reproductive life. However, this pattern is reversed in the cohorts born thereafter: by the age they have reached by 2015, these women have accumulated a positive contribution to the difference in CALCs. Interestingly, this positive contribution is evident only at higher ages, reflecting higher birth rates at younger ages in Hungary than Sweden. The comparison of Hungary and Sweden is likely to illustrate a period effect beginning with around 2009 because several cohorts are being affected at different ages at the same

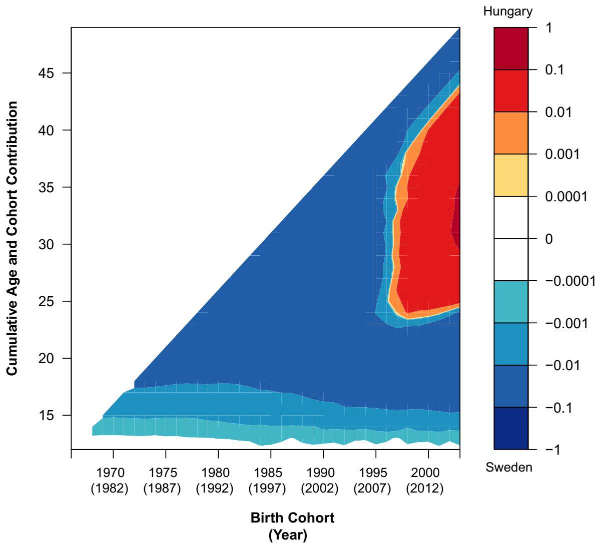

Fig. 6 Lexis surface for the cumulative age- and cohort-specific contributions to the difference in CALCs between Sweden (19.83) and Hungary (20.38) in 2015 for the 1966–2003 birth cohorts. Positive values correspond to a higher risk of remaining childless in Hungary than in Sweden; negative values represent a lower risk of remaining childless in Hungary than in Sweden. *Source*: Authors' calculations based on the Human Fertility Database.

point in time. This pattern is likely to have been influenced by the recent Great Recession in 2007–2013, which depressed first-birth rates in Hungary compared with Sweden across all ages beyond the early 20s.

Finally, Figure 7 shows the cumulative age and cohort contributions to the –2.38-year CALC difference between U.S. and Swedish women in 2015 (i.e., reflecting 2.38 fewer years of childless life in the United States than in Sweden). Figure 7 shows that Swedish cohorts born up to the mid-1970s contribute to higher CALC until their late 30s compared with their U.S. counterparts; at higher ages, though, the cumulative contribution turns to favor higher childless life expectancy in the United States. In later-born cohorts, this pattern reverses: across cohorts born since the mid-1970s, the contribution to CALC in 2015 is negative at all ages. This negative contribution results in Swedish women having a higher CALC in 2015—a pattern that even intensifies in the cohorts born in the mid-1980s, with a stronger difference favoring childlessness in Sweden compared with the United States for women in their 20s. This intensifying pattern may reflect stronger postponement of births in Sweden than in the United States, which dominates the cumulative childlessness despite the noncumulative age-specific patterns favoring higher childlessness at higher ages in the United States compared with Sweden.

Table 2 illustrates the case of the U.S.-Sweden CALC difference, showing the age and cohort contributions for selected cohorts. The columns in Table 2 show both the noncumulative age and cohort contributions as calculated in Eq. (6) (denoted as "Δ age contribution") as well as the cumulative contributions as presented in Figure 7 (denoted as "$\Sigma\Delta$ age contribution") for the cohorts of 1966, 1978, and 1991. The 1966 birth cohort starts with higher first-birth rates in the United States than Sweden

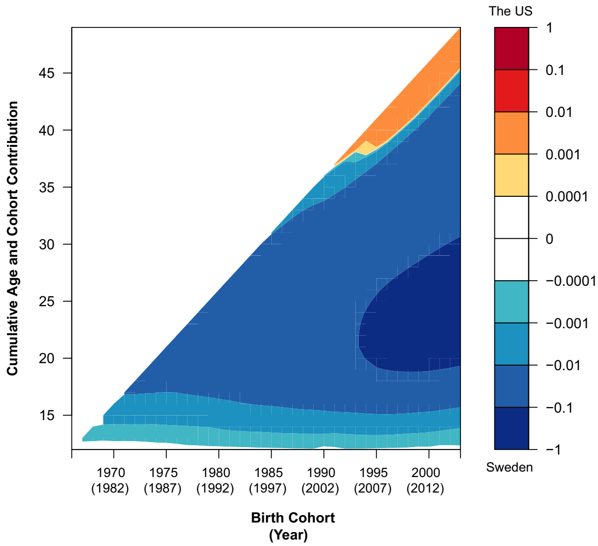

Fig. 7 Lexis surface for the cumulative age- and cohort-specific contributions to the difference in CALCs between Sweden (19.83) and the United States (17.45) in 2015 for the 1966–2003 birth cohorts. Positive values correspond to a higher risk of remaining childless in the United States than in Sweden; negative values represent a lower risk of remaining childless in the United States than in Sweden. *Source*: Authors' calculations based on the Human Fertility Database.

(negative contribution to the CALC difference) until age 23, when the reverse occurs such that first-birth rates are higher in Sweden (positive contribution to CALC difference). However, for this cohort, it is not until age 37 when the cumulative contribution of childlessness proportion switches from higher levels in Sweden than in the United States. We interpret this as the long-lasting effect of first-birth postponement and catching up at later age for Swedish females.

Table 2 also illustrates that younger cohorts of Swedish females accumulate more years of childless life than the older cohorts, as seen in the comparisons for the 1966, 1978, and 1991 birth cohorts. For example, in the 1978 cohort, the catching-up process at later ages is also observed: the cumulative negative difference starts decreasing from age 28 onward, but given larger differences accumulated at earlier ages and up to a higher age, the negative cumulative difference remains up to the observed age of 37. In the 1991 cohort, only ages up to 24 can be observed. These ages are characterized by contributions to more years of childless life in Sweden than in the United States, and these contributions are larger than those in previous cohorts. Taken together, the earlier first-birth timing of U.S. women more strongly dominates the picture in the later-born cohorts.

Discussion

This study aims to present an alternative way of studying first-birth trends in a period perspective by using information on first-birth histories of female cohorts in

Table 2 Age-specific contributions to the differences in CALCs of –2.38 years between the United States (17.45) and Sweden (19.83) up to 2015, and age- and cohort-specific contributions of the 1966, 1978, and 1991 birth cohorts

	All Cohorts		1966		1978		1991	
Age	Δ Survival	ΣΔ Survival	Δ Age Contribution	ΣΔ Age Contribution	Δ Age Contribution	ΣΔ Age Contribution	Δ Age Contribution	ΣΔ Age Contribution
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	–0.0001	–0.0001
13	–0.0002	–0.0002	–0.0001	–0.0001	–0.0002	–0.0002	–0.0004	–0.0005
14	–0.0011	–0.0013	–0.0005	–0.0006	–0.0009	–0.0011	–0.0018	–0.0023
15	–0.0045	–0.0058	–0.0017	–0.0023	–0.0028	–0.0039	–0.0061	–0.0084
16	–0.0124	–0.0182	–0.0034	–0.0057	–0.0053	–0.0092	–0.0132	–0.0216
17	–0.0269	–0.0451	–0.0051	–0.0108	–0.0077	–0.0169	–0.0212	–0.0428
18	–0.0520	–0.0971	–0.0064	–0.0172	–0.0097	–0.0266	–0.0292	–0.0720
19	–0.0878	–0.1849	–0.0059	–0.0231	–0.0104	–0.0370	–0.0338	–0.1058
20	–0.1255	–0.3104	–0.0042	–0.0273	–0.0095	–0.0465	–0.0302	–0.1360
21	–0.1577	–0.4681	–0.0024	–0.0297	–0.0075	–0.0540	–0.0219	–0.1579
22	–0.1805	–0.6486	–0.0006	–0.0303	–0.0065	–0.0605	–0.0160	–0.1739
23	–0.1898	–0.8384	0.0010	–0.0293	–0.0048	–0.0653	–0.0096	–0.1835
24	–0.1861	–1.0245	0.0026	–0.0267	–0.0039	–0.0692	–0.0026	–0.1861
25	–0.1776	–1.2021	0.0033	–0.0234	–0.0025	–0.0717		
26	–0.1650	–1.3671	0.0036	–0.0198	–0.0023	–0.0740		
27	–0.1562	–1.5233	0.0032	–0.0166	–0.0006	–0.0746		
28	–0.1456	–1.6689	0.0021	–0.0145	0.0008	–0.0738		
29	–0.1229	–1.7918	0.0017	–0.0128	0.0026	–0.0712		
30	–0.1102	–1.9020	0.0021	–0.0107	0.0057	–0.0655		
31	–0.0950	–1.9970	0.0015	–0.0092	0.0065	–0.0590		
32	–0.0823	–2.0793	0.0016	–0.0076	0.0067	–0.0523		
33	–0.0722	–2.1515	0.0019	–0.0057	0.0052	–0.0471		
34	–0.0487	–2.2002	0.0017	–0.0040	0.0046	–0.0425		
35	–0.0420	–2.2422	0.0021	–0.0019	0.0030	–0.0395		
36	–0.0356	–2.2778	0.0015	–0.0004	0.0019	–0.0376		
37	–0.0362	–2.3140	0.0018	0.0014	0.0014	–0.0362		

Table 2 (continued)

	All Cohorts		1966		1978		1991	
Age	Δ Survival	ΣΔ Survival	Δ Age Contribution	ΣΔ Age Contribution	Δ Age Contribution	ΣΔ Age Contribution	Δ Age Contribution	ΣΔ Age Contribution
38	–0.0401	–2.3541	0.0021	0.0035				
39	–0.0386	–2.3927	0.0020	0.0055				
40	–0.0309	–2.4236	0.0013	0.0068				
41	–0.0293	–2.4529	0.0009	0.0077				
42	–0.0255	–2.4784	0.0004	0.0081				
43	–0.0185	–2.4969	0.0006	0.0087				
44	–0.0109	–2.5078	0.0001	0.0088				
45	–0.0020	–2.5098	0.0001	0.0089				
46	0.0047	–2.5051	0.0001	0.0090				
47	0.0082	–2.4969						
48	0.0039	–2.4930						
49	0.0090	–2.4840						

Notes: Δ Age contribution presents the age contribution to the difference in CALCs between the United States and Sweden, as in Eq. (6); ΣΔ Age contribution means the cumulative age contribution over age to that difference; Δ Survival is the cumulative age-specific contribution until the age attained in 2015, and ΣΔ Survival is the addition of ΔSurvival among all ages, as in Eq. (7). The deviation between the difference of CALCs (–2.38) and ΣΔ Survival at age 49 (–2.48) is caused mostly by our approximation procedures in Eqs. (6) and (7).

reproductive ages in a given period. We introduce a new measure, cross-sectional average length of life childless (CALC), to the study of first-birth behavior. This measure offers three advantages. First, it is comprehensive: whereas traditional common indexes definitely carry value in examining either timing or quantum of first birth, CALC has value in capturing changes in both. Additionally, it integrates the life table concept of duration in the study of family demography (Andersson et al. 2017; Bongaarts and Feeney 2006, Bumpass and Lu 2000). The level of CALC indicates the total amount of life spent childless, including women who eventually have children and those who do not. In this way, CALC can complement existing indexes of tempo and quantum of first births, such as mean age at first birth and the proportion of remaining childless.

Our illustrative results show that reproductive-age women in most of the 11 countries analyzed spend more than one-half of their reproductive period remaining childless. Exceptions to this among the studied countries available in the HFD are Belarus, Estonia, Lithuania, and the United States. On the other hand, women in Japan and Spain spend almost 60% of their reproductive life childless—on average, 23.2 and 22.5 years, respectively, between ages 12 and 50. Clearly, these examples illustrate that CALC may reflect trends in both timing and quantum of first births given that Japan and Spain are countries characterized by late timing of first births and high childlessness, whereas an early timing and relatively high occurrence of first births are common in Belarus and the United States.

The second and most important advantage of CALC lies in its ability to provide a period measure that is informative not only of the childbearing behavior of a given period but also of fertility behavior of female cohorts who are at reproductive ages in that period. This characteristic is evident in the decomposition of the differences of the measure between two countries. Because CALC includes all age-specific cohort first-birth information, it allows the decomposition of the differences in the measure into contributions from different cohorts and ages. CALC can thereby reveal cohort, period, and age patterns—something that conventional period indexes based solely on data from the current period do not allow. Traditional period measures of fertility are not informative of how different cohorts or prior periods contribute to them. CALC, however, allows understanding of changes (or lack of them) in first-birth behavior across different cohorts, periods, and ages and can provide insight into how current childbearing patterns and trends are influenced by the recent past. In our view, this is the main strength of the measure. As we illustrate, the results of the decomposition can also be presented in an informative way visually.

In this study, four country comparisons serve as examples of using the decomposition of the CALC. Sweden, the country of reference, is characterized by average to the late timing of first births, moderate levels of childlessness, and a strong tendency of birth catching-up at higher ages. The comparison of Sweden with Japan and Spain, which had a particularly high CALC in 2015, reflects the later timing of motherhood in these two countries. These two countries display a larger risk of remaining childless at reproductive ages across all cohorts compared with Sweden, with the exception that first-birth rates are higher in Spain than Sweden at very young ages. In addition, the younger cohorts of Japan and Spain contribute to more years of childless life from increasingly earlier ages. This illustrates the intensifying phenomenon of childless life at reproductive ages in these countries compared with Sweden. In Japan, this may reflect the increase in the never-married female population, which directly influences fertility because of the strong link between childbirth and marriage in this context (National Institute of Population and Social Security Research 2019). On the other hand, in Spain, the overall late transition to adulthood (i.e., leaving the parental home and forming a union) may play a key role in the prolongation of childless life (Esteve et al. 2020).

The decomposition of the differences in CALC between the United States and Sweden reflects the impact of the high first-birth rates at young ages in the United States on one hand, and the catching-up process of childbearing at later ages in Sweden on the other hand, among women born from the late 1960s to mid-1970s. In the younger cohorts, born from the mid-1970s, there are indications that the difference in life spent without children at reproductive ages in the United States compared with Sweden is intensifying. A factor that helps explain this difference is the significant variation in first-birth behavior by race/ethnicity in the United States (Sullivan 2005). Hispanic White and non-Hispanic African American women continue to enter motherhood relatively early in life, whereas a pattern of late motherhood is present among non-Hispanic White women. Given these heterogeneous trends in first-birth behavior by race/ethnicity, women in the United States have, on average, lived fewer years of childless life compared with women in Sweden, in which first births are concentrated at later ages. In addition, the decomposition of the difference in CALC between Hungary and Sweden is particularly interesting because it shows how different cohorts are affected at different ages at the same point in time, thereby showing a period as opposed to a cohort effect on first births. This period effect occurred in the years following the onset of the Great Recession in 2007, and it seems probable that the recession contributed to more years spent childless at reproductive ages in Hungary than in Sweden.

The third advantage of CALC is that it bypasses the distorting effect of changing the timing of first childbearing over a period. Previous fertility research has mostly focused on ways to overcome the distorting effect of changing timing when assessing period quantum—for example, period quantum that is being depressed when births are being postponed and may therefore not be informative of quantum of childbearing of any real birth cohorts (Bongaarts and Feeney 1998, 2006; Bongaarts and Sobotka 2012; Schoen 2004). By including all cohort information, CALC circumvents the confounding effect of the period tempo effect on the expectation of childless life. In this way, CALC is an alternative solution to period tempo distortions in the study of first-birth behavior.

The proposed measure, CALC, also has limitations. CALC requires a long history of first-birth data, thus restricting its use to countries that can provide data extending back several decades. However, CALC can also be calculated as a truncated measure using incomplete cohort first-birth information, similar to the truncated cross-sectional average length of life, a measure developed and used in mortality research (Canudas-Romo and Guillot 2015). The truncated version of CALC could be used particularly in the middle- or low-income countries, where detailed fertility data extending back decades are less often available. The age-cohort decomposition for truncated CALC comparisons between countries with the same length of fertility series can still be adapted and applied. Additionally, the estimates of period EYWC do often not differ substantially from the values of CALC. Thus, period EYWC, which can be calculated using period data only, can be a proximate estimate for CALC if the long historical data are not available.

Another limitation is that CALC may be biased by mortality and migration at reproductive ages. Our sensitivity analysis using the HMD showed that mortality at reproductive ages influences CALC only marginally. However, the age-specific mortality data available were not further disaggregated by motherhood status. Because mortality rates of women differ according to their childbearing history (Barclay et al. 2016; Einiö et al. 2016), this issue could be further investigated using age- and parity-specific mortality data where available. In the high-income countries where mortality at reproductive ages is generally low, we expect mortality to bias the results only marginally. However, larger bias is possible when CALC is applied in middle- and low-income countries where maternal mortality and other young adult female mortality is higher (Canudas-Romo et al. 2014). In addition, in- and out-migration might potentially affect CALC. The data set used, the HFD, assumes that migrants and nonmigrants do not differ in their birth histories. Although this assumption can be questioned, the data needed to further disentangle the contribution of migration on CALC are not widely available. Where possible, future research should empirically assess this issue.

Further, similar to other fertility measures, CALC does not distinguish between voluntary and involuntary childlessness: the calculation of CALC covers women who remain either voluntary and involuntary childless, and women who enter motherhood both intentionally and unintentionally. However, earlier work has shown that the distinction between voluntary and involuntary childlessness is challenging (Berrington and Pattaro 2014; Keizer et al. 2007; Kreyenfeld and Konietzka 2017; Kuhnt and Trappe 2016).

From a more general perspective, CALC can provide useful information for policymakers in the areas of employment, pensions, and public health. For instance, CALC is likely to reflect employment rates of women at working ages, at least in countries where mothers typically have lower employment rates than childless women. Furthermore, as shown earlier, the decomposition can be used to study which age groups and cohorts contribute to population-level differences in childlessness, and it can also reveal period effects on fertility. From a policy perspective, this characteristic of the CALC is valuable because, for example, specific population subgroups still at reproductive ages may be identified and targeted if considered necessary. However, given that CALC in a given year is influenced by the first-birth histories of all cohorts present, it is challenging to analytically relate it to structural factors, such as employment rates, in a regression framework. Cohorts are influenced by such factors throughout their reproductive lives, and CALC in a given year is a composite of different cohorts' experiences. Comparisons of CALC between countries can and should, however, be motivated and discussed in the light of contextual information.

To conclude, CALC is a rich tool of description to disentangle patterns and trends of first-time childbearing. CALC is a period measure of a woman's life spent without children at reproductive ages, which is based on all available first-birth information for female cohorts at reproductive ages present at a given time. This measure follows the core demographic life table methodology applied here to first births. Family demography researchers can benefit from the rich visualization that the decomposition of differences between two CALCs provides, which highlights the contribution to that gap of each of the cohorts at reproductive ages. Moreover, the application of the cross-sectional length of life to family demographic outcomes is not restricted to the study of first births. For instance, the expectation of time to higher parities or to family demographic events other than births could be studied with this approach. ■

Acknowledgments The first author is part of the project GLOBFAM (RTI2018-096730-B-I00) funded by the Spanish Ministry of Science, Innovation and Universities, National R&D&I Plan. The contribution of Jessica Nisén was supported by the Academy of Finland (decision numbers 332863 and 320162). We are grateful to Marilia Nepomuceno for her initial contribution.

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