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A Bayesian approach based on parity-specific fertility estimates using harmonized survey data

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A Bayesian approach based on parity-specific fertility estimates using harmonized survey data

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Abstract

This article provides new measures allowing comparing within-country differences in current fertility behavior in Europe. By mobilizing data from the European Union's Survey of Income and Living Conditions (EU-SILC), we measure the educational gradient of female period fertility for a large set of European countries. A semi-retrospective approach serves to observe fertility behavior of cohorts that are currently at childbearing age, while at the same time recording the educational level correctly. Bayesian statistics allow us to obtain credible intervals for the age, education- and parity specific birth probabilities for each country. These birth probabilities are then combined into a multi-state life table in order to obtain parity-specific and total birth intensities by education. A post-stratification of birth probabilities leads us to be consistent with national fertility estimates, enabling international comparisons for specific groups (e.g. highly educated women) or for particular dimensions of fertility behavior (e.g. childlessness). This analytical set-up allows us to reveal if there are significant differences between education groups in fertility behavior within each European country and in how far these differentials vary between European countries. More precisely, we answer the question if –all birth orders combined– heterogeneity in period fertility behavior is larger among the higher or the lower educated across Europe. In addition, we show for which parity the heterogeneity between education groups is the largest.

This study is based on data from Eurostat, EU Statistics on Income and Living Conditions [2011,2012,2013]. The responsibility for all conclusions drawn from the data lies entirely with the authors.

Keywords: total fertility rates, period fertility by education, tempo, quantum, Europe

JEL Codes: J11, J13, J16, 011

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1. Introduction

Fertility is currently stagnating or decreasing anew in many European countries, leading to fertility levels below the average of two children per women, and therewith below replacement level, in all European countries. The current COVID-19 crisis accelerated the trend of declining fertility and, after an eventual stabilization in many countries, may have unpredictable consequences. Fertility levels and trends –and therewith long-term trends of population aging– in Europe which has important impacts not only on economic but also on social outcomes, must be monitored in detail.

While European cross-country differences in total fertility rates (TFR) are rather well-documented today (see for example OECD Family Data Base: https://www.oecd.org/els/family/database.htm; or Human Fertility Database https://www.humanfertility.org/cgi-bin/main.php), we currently lack a comprehensive overview of within-country differentials of period fertility behavior covering all European countries.

It is thus currently unclear if differences in period fertility levels between education groups are important within European countries, in how far the educational gradient of period fertility differs between European countries and if fertility levels currently converge or diverge between education groups. However, knowledge of the micro-level components of fertility behavior is important to understand the mechanisms that drive aggregate fertility trends in Europe.

In this article, we measure how period fertility behavior differs between education groups, within each European country. By combining several demographic tools (semi-retrospective approach, Bayesian statistics, post-stratification) and by using a data set that has not yet been used for this kind of demographic analysis (European socio-economic survey data: EU-SILC), we are quantifying the educational gradient of fertility for those cohorts who are currently at childbearing age (ages 15 to 49) for the large majority of European countries.

Therewith, our country-by-country analysis allows getting a deeper insight in the educational composition of period fertility levels in Europe, as well as their components by birth order. Our measures of the educational gradient of period fertility reveal whether fertility differentials are currently important in each European country. This is particularly relevant in a context of Total Fertility Rates ranging below replacement level in all European countries: measuring the educational gradient of period fertility allows one to better understand which group is currently the most restricted in terms of fertility behavior, and whether the contrasts by education are larger for the entry into motherhood or for the progression from one birth to the next. Consistent measures for each European country allow for international comparisons and the modelling of context-dependency.

The article is organized as follows: Section 2 presents the state of the art, section 3 our methodology, section 4 the results and section 5 concludes.

2. State of the Art

To our knowledge, so far there exists no study that delivers measures of the educational gradient of period fertility levels for a comprehensive set of European countries.

Since the pioneer work from Whelpton (1946), parity, i.e. the number of children ever born, is used as a major covariate of fertility, in addition to age, in order to accurately measure period fertility. Hitherto existing measures of the educational gradient of period fertility are often limited to a specific birth order (as for example Van Bavel and Rozanska-Putek 2010, Klesment et al. 2014, Trimarchi and Van Bavel 2018 and 2019, or Rendall and Shattuck 2019), without describing how parity-specific gradients contribute to aggregated fertility levels. In addition, many studies on gradients of period fertility behavior in Europe focus on single countries (as for example Rondinelli et al. 2010, Schmitt 2012, Pailhé and Solaz 2012 or Jalovaara et al. 2019), which hinders modelling context dependency.

The focus on specific parities and single countries that prevails in demographic research analysing period fertility behavior in Europe exists due to a lack of harmonized international data that combines high quality demographic with comparable socio-economic measures. Some European countries deliver survey data combining demographic and socio-economic measures, be it cross-sectional or longitudinal, such as Germany (SOEP) or the United Kingdom (UK) (BHPS), for example. However, as not all available panel surveys are harmonized (socio-economic variables such as education and labor market participation are not always coded the same way), comparative analysis combining several countries is difficult, and the small number of panel surveys makes it impossible to carry out multi-level analyses. Studies which are based on single countries, or which cover only a small group of countries, are therefore unable to model the context-dependency of demographic behavior. An alternative to consider is Census data, but questionnaires are also not fully harmonized across European countries and censuses are not available on a yearly basis, which makes it impossible to observe yearly fluctuations of period fertility behavior. In addition, the risk of undercounting young children is not negligible in census data (O'Hare 2017, Toulemon 2017, Tomkinson 2021).

A harmonized demographic survey is the Gender and Generation Survey (GGS). In the first round of data collection (GGS-I) from 2004-2012, data was collected from 20 countries. Currently, the GGP is engaged in the second round of data collection (GGS-II).Therewith, GGS still has a relatively limited country- and time-coverage. More socio-economically oriented surveys therewith emerge as alternatives, due to their larger country-and time-coverage. The European Union's Labor force surveys (EU-LFS) could be used as a harmonized large-scale dataset to estimate fertility (see for example Bordone et al. 2009), but it comes with several technical shortcomings. First, fertility is not covered explicitly, and omission of young children is therefore likely to occur. Second, dwellings are followed-up, and not individuals, so that attrition due to family moves, especially frequent before or after births, may strongly bias the samples (which puts together different waves). Third, the released data do not include exact age, but only five-year age groups[1], which makes it complicated to compute period fertility measures with the own-children method. .

[1] https://ec.europa.eu/eurostat/documents/1978984/6037342/EULFS-Database-UserGuide.pdf

A harmonized large-scale dataset, which observes not only households but also individuals and includes exact age, is the European Union's Statistics of Income and Living Conditions (EU-SILC). EU-SILC covers the whole set of European countries, and years from 2004 on for most countries, and even comes with a short rotational panel, following up individuals and households for a period of four years. However, EU-SILC does not provide straight fertility measures, which makes the use of EU-SILC for the analysis of socio-economic differentials of period fertility behavior rather inconvenient. Nevertheless, Greulich and Dasré (2017) evaluated positively the accuracy of period fertility measures derived from the cross-sectional database when taking certain precautionary measures (see section 3 for more details). So far, a small number of demographic studies related to period fertility have been undertaken with EU-SILC. De Santis et al. (2014) used the Italian short EU-SILC panel to estimate group-specific fertility rates. Rendall and Greulich (2016) demonstrated the feasibility of using the Polish short panel in EU-SILC to incorporate labor-market related predictor variables on both the woman and her partner that are observed sufficiently prior to a birth event to reduce problems of endogeneity that compromise studies of fertility using cross-sectional data. Rendall et al. (2014), Klesment et al. (2014), Greulich et al. (2016 and 2017) and Nitsche et al. (2018) modelled educational gradients of parity-specific transition probabilities (individual-level regressions). However, aggregate levels of period fertility differentiated by education have not yet been modelled so far with EU-SILC for a large set of European countries and several time periods.

Besides the difficulty of choosing the appropriate data source, the absence of measures of period fertility levels differentiated by socio-economic characteristics comes from methodological problems: education, labor market status and income evolve over the life cycle (and thus vary with age). Also, the age at birth (also called the 'timing' of births) varies across socio-economic groups. The evolution of socio-economic variables over the life cycle poses a problem when it comes to calculating age-specific period fertility rates differentiated by education. For example, as education is not completed at young ages (between 15 and 25), period fertility rates for low-educated women would be largely underestimated in a cross-sectional research design: everyone at age 15 would be considered as "low-educated", including those women who will continue education and who are likely not to have children at very young ages.

To avoid any distortions due to differences in the timing of birth between groups and the variation of socio-economic characteristics over age, it is common in demographic research to calculate socio-economic differentials in fertility by focusing on education, as education evolves uniformly over age, and by taking into account only those cohorts who have already completed their childbearing ages. For the latter reason, most fertility measures focus on women only, as their 'reproductive ages' are more restricted than those of men.

'Completed cohort fertility rates' differentiated by levels of female education have recently been provided for a large set of developed countries by Tomas Sobotka (www.cfe-database.org). For most European countries, completed fertility rates have a negative educational gradient (Sobotka 2020), suggesting that it was mainly the higher educated women who were limiting their fertility 10 to 20 years ago in Europe (at the time of their fertility decisions). Nisén et al. (2021) measure women's completed fertility by educational level and region by harmonizing data from population registers, censuses, and large-sample surveys for

15 European countries and document an overall negative gradient between the CFR and level of education. The focus on cohorts whose fertility decisions were affected by past –but not current– policies is, however, problematic when the objective is to identify specific groups within each European country that are currently the most likely to be restricted in terms of fertility behavior.

So far there exists no comparative study that goes beyond cohort- or parity-specific analysis and quantifies the demographic impact of current socio-economic differentials on levels of period fertility. Consequently, we do not exactly know which specific groups are currently having the lowest fertility levels within European countries, and to what extent these groups contribute to the relatively low total fertility rates in each country. Recent studies analyzing the determinants of the transition to a first or second child suggest that, in several European countries, it is no longer the highly educated couples who have the lowest probability of starting and enlarging a family (Greulich et al. 2017, d'Albis et al. 2017a, 2017b, Nitsche et al. 2018). Without a combination of all birth orders, it is, however, unclear whether these higher first and second birth transition ratios for highly educated women result in higher overall period fertility levels for this group.

In order to allow statements about socio-economic differentials in current fertility levels, a broader analytical spectrum is thus necessary. Such research needs to go beyond cohort measures, aggregate fertility levels and specific countries. This study quantifies the educational gradient of current fertility levels for the whole set of European countries. This undertaking is challenging, as we need information about age-and parity specific fertility behavior for different education groups, covering a large number of countries. To meet this challenge, we proceed in four steps:

(1) We use the cross-sectional samples of EU-SILC to compute period fertility levels differentiated by education for the whole list of European countries by applying a series of precautionary measures to reduce measurement bias in fertility. For example, to reduce attrition bias, we apply the own-children method on the cross-sectional database rather than the rotational panel and use a delay between the year of observed childbirth and the survey year, as suggested by Greulich and Dasré (2017). To obtain sufficient sample size, we group together several waves.

(2) We combine a longitudinal and a cross-sectional approach from EU-SILC cross-sectional data (semi-retrospective approach) rather than focusing on completed cohort fertility (retrospective approach only). This serves to observe fertility behavior of cohorts which are currently at childbearing age (15 to 49), while at the same time recording the educational level correctly.

(3) Bayesian statistics allow us to obtain credible intervals for the age-, education- and parity specific birth probabilities for each country. These birth probabilities are then combined into a multi-state life table in order to obtain parity-specific and total birth intensities by education.

(4) A post-stratification of birth probabilities leads us to be consistent with national fertility estimates. This enables international comparisons for specific groups (e.g. highly educated women) or for particular dimensions of fertility behavior (e.g. childlessness).

This analytical set-up allows us to reveal if there are significant differences between education groups in fertility behavior within each European country and in how far these differentials differ across European countries. More precisely, we will answer the question if -all birth orders combined- heterogeneity in period fertility behavior is larger among the higher or the lower educated across Europe. In addition, we will see for which parity the heterogeneity between education groups is the largest.

3. Methodology

a. Measuring period fertility

To obtain period fertility measures, we use the European Union Statistics of Income and Living Conditions (EU-SILC). The EU-SILC is a European survey provided by Eurostat. It was created in 2003 to replace the European Community Household Panel (ECHP) and now includes 32 European countries. The survey provides information on individual and household characteristics with a particular focus on harmonized and comparable measures of education, labor market participation, income and living conditions.

We use the cross-sectional database of the EU-SILC, which provides nationally representative probability samples for all countries. The cross-sectional data in EU-SILC is available from 2004 on for most countries, which enables covering almost 20 years when computing period fertility levels. In this methodological paper, however, we focus on childbirths around the year 2010. This makes our educational gradients of period fertility levels comparable with those based on Census data, allowing for additional data quality checks. These comparisons are out of scope for this paper, but the provision of our SILC-based measures of period fertility by education as well as the provision of a detailed data compilation protocol enables the research community to pursue work in this direction.

Computing period fertility levels around the year 2010 means that we observe child births in three calendar years: 2009, 2010 and 2011. We group together three years to obtain sample sizes that are large enough to calculate birth probabilities which are at the same time country-, age-, parity- and education-specific.

A pitfall of the EU-SILC for fertility analysis is that fertility is not observed directly. There is no question on the number of children in and outside the household in the questionnaire. However, children have their proper register file containing their basic demographic information (age, sex…) as well as a mother- and father-id. This allows assessing fertility with the 'own children method'[2] by merging parents with their children. Potential biases appear, however, for period fertility measures calculated with EU-SILC. First, due to unobserved children living outside the household, fertility might be underestimated and birth orders not correctly attributed. Second, as the annual cross-sectional data in EU-SILC is produced from

[2] This method consists of calculating fertility rates by age for a certain year by considering children who are living in the observed household at the time of the survey and who are born in the particular year of interest (Grabill and Cho 1965, Rindfuss 1976, Desplanques 1994).

the longitudinal panel (integrated design[3]), the cross-sectional data is potentially affected by attrition. Attrition can be fertility-linked, as childbirth (be it planned, expected, or just completed) might cause the individual or household to move. This would lead to an underrepresentation of households with young children in the cross-sectional sample. The sampling and the weighting procedures in EU-SILC are not directly designed to ensure unbiased fertility. Consequently, measures of periodic fertility obtained with EU-SILC are likely to be biased due to fertility-linked attrition and sample selection.

Greulich and Dasré (2017) calculate total fertility rates for the calendar year before the survey year by using EU-SILC and find a systematic underestimation of fertility for a majority of covered countries (between -10 and -20% depending on the country). The fertility rates for ages 20 and 25 are particularly concerned. However, they also find that there are no socioeconomic differentials in attrition in the longitudinal sample. In addition, the country ranking in terms of fertility levels based on their EU-SILC measure is approximately the same compared to unbiased fertility measures coming from the Human Fertility Data Base or the World Bank World Development Indicators. They also find that the downward bias in period fertility disappears when allowing for a certain time delay between the childbirth year and the survey year, as families who recently have moved due to childbirth re-enter the probability sample. For the analysis proposed in this study, a time delay of two years emerges as the best compromise to meet two different goals when it comes to measure period fertility with EU-SILC: reducing the attrition-linked measurement bias in period fertility while at the same maintaining information as up to date as possible in a cross-sectional setting.

We allow thus for a time delay of two years when calculating our period fertility measures with EU-SILC, i.e., we observe births during the calendar year 2010 by using the survey wave of 2012. Following the same logic, we use the survey wave of 2011 for observing births during the year 2009, and the wave 2013 for births during the year 2011. Using survey waves 2011, 2012 and 2013 of the cross-sectional EU-SILC sample allows us covering 28 European countries[4].

b. *Recording education-specific period fertility behavior*

To obtain education-specific period fertility measures, we apply a semi-retrospective approach. This approach serves to observe fertility behavior of cohorts which are currently at childbearing age, while at the same time recording the educational level correctly.

For the variable measuring education we use the UNESCO ISCED classification to distinguish three levels (uniform categories across all countries): ‘low education’ for pre-primary, primary, and lower secondary education; ‘medium education’ for upper secondary and post-secondary

[3] The longitudinal dataset of EU-SILC is a rotational panel of four years, which means that for most countries, individuals are observed for a maximum period of four years. The integrated design allows for many observations for the cross-sectional database. In the cross-sectional database a quarter of individuals are observed for the first time, a quarter for the second time, a quarter for the third time, and a quarter for the fourth time. This integrated design reduces measurement bias due to accumulated respondent burden and sample attrition.
[4] Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom.

non-tertiary education; and 'high education' for first stage of tertiary education (not leading directly to an advanced research qualification) and second stage of tertiary education (leading to an advanced research qualification).

The objective is to observe age-specific fertility behavior of women of the different education levels, by at the same time recording their completed educational level. The problem is that when we observe fertility behavior of women, who have not yet completed education, by applying a purely cross-sectional perspective, we risk underestimating fertility levels of low educated women. The main problem comes from the fact that educational level increases with age (Ní Bhrolcháin and Beaujouan, 2012). Consequently, when calculating the probability of having a child at the age of 20, the denominator of the probability may well include women whose educational level at that stage is only average but who, within a year or two, will achieve a high level (Hoem and Kreyenfeld, 2006). This overestimation of the denominator leads to an underestimation of the probability of having a child at the age of 20 for women with low and middle education. To avoid this underestimation, we follow Greulich et al. (2017) and apply a retrospective approach for women to observe fertility at ages 15 to 25. We therefore select women aged 27 in each cross-sectional sample. For these women, we have information on their education level at age 27 and on the number and ages of the children currently living in their household. Based on this information, we can reconstruct information on these women's order-specific fertility behavior, retrospectively for ages 15 to 25. We stop at age 25 and not at age 27 because of the two-year delay mentioned in the section above.

Education is observed at age 27, as this is the age by which most women in our sample have completed their education, independent of the country. Figure A.1 in appendix A illustrates exemplarily for six countries that from age 27 on, the percentage of women reporting to be in education drops uniformly below 20%[5]. When considering all European countries of our sample (28 in total), we observe that -despite some country heterogeneities- the biggest drop in this percentage occurs between ages 25 and 27 in all countries. We do not choose an age over 27 for our longitudinal approach to maintain the largest possible cross-sectional perspective. This allows us to obtain fertility measures by education that are as close as possible to pure period measures. Age 27 emerges thus as a compromise between an age high enough for most women to have ended their studies, and low enough for most of the fertility history to be observed in the same period[6]. We use the same threshold age for all educational groups and each country, in order to consider the "cohort wise" part of our fertility tables from the same cohorts (aged 27 in 2009-2011), thus avoiding additional cohort effects.

From age 26 on, childbirth by age and education is observed by applying a cross-sectional approach, i.e. information on age-, parity- and education-specific fertility behavior is obtained by observing women aged 28 to 51 in each of the three cross-sectional samples. For these

[5] These six countries (France, Germany, Poland, Italy, Sweden, and the UK) will be used in the latter analysis to illustrate our results in detail. As argued in section 6, each of these countries is relatively representative for a specific region in Europe.

[6] After age 27, women still in education may have already reached a high educational level (and their educational level is thus definite with our definition); furthermore, the stable proportion enrolled by age from age 27 on is primarily related to adult education, not to initial studies.

women, we observe children born during the calendar year that occurs two years prior to the survey year, to estimate fertility rates at ages 26 to 49.

In comparison to a complete retrospective approach for women aged 45+, this semi-retrospective approach allows capturing the fertility behavior of those women who were actually at childbearing age at the time of the survey[7]. The figures in appendix B illustrate with a Lexis diagram the logic of our semi-retrospective approach, including the two-year delay based on one wave (2012; Figure B.1), respectively on three cross-sectional waves (2011, 2012 and 2013; Figure B.2).

c. *Combining tempo and quantum information*

To see if and in how far differences in the timing of births between women of different education levels are likely to transform into differences in fertility levels, we first use our sample to calculate women's probability of having a child – while we differentiate by age, education level as well as parity.

We use order-specific birth probabilities (quotients) and not order-specific birth rates (incidence rates). Therewith, we observe, for each age and parity, only those women who are "at risk" of childbirth, rather than observing women of all parities. This allows us to run fertility tables free of structure effects (Feeney 1983; Rallu and Toulemon 1994; Kohler, Billari and Ortega 2002).

We estimate birth probabilities by age x and birth order r as the ratio of births at age x and of birth order r to women at age x, of parity r-1 and with an education level e:

$$q(x,r,e) \;=\; B(x,r,e)\,/\,W(x,r-1,\mathrm{e})$$

with:
$q((x,r,e)$: birth probability at age x and birth order r among women with education e
$B(x,r,e)$: number of births at age x and birth order r to women with education e
$W(x,r\text{-}1,e)$: number of women at age x, parity r-1 and education e

As mentioned in the above section, we use the EU-SILC in t+2 in order to estimate birth probabilities in t. For ages 15-25, we consider women aged 27 (aged reached in t+2) and estimate $B(x,r,e)$ as the number of births at age x in t-25+x (age 15 reached in t-10, age 25 in t). The number of women at risk $W(x,r\text{-}1,e)$ are estimated among the total W(27,e) in t+2, their parity r being estimated at the beginning of the year when age x is reached. For ages 26 and more, we estimate $W(x,r\text{-}1,e)$ and $B(x,r,e)$ from women aged x+2 in t+2. In order to limit random variations, the birth probabilities in t are estimated with adding women and births in t-1, t, and t+1, estimated from SILC waves t+1, t+2 and t+3 (see appendix B, Figure B.2).

[7] Note that a semi-retrospective approach has also been used for migrants' fertility, in order to consider children born before and after migration (Toulemon 2004, 2006a, 2006b).

These birth probabilities are then combined into a multi-state life table (Rallu and Toulemon, 1994), starting with 100 women aged 15 and at parity 0 for each educational level e, based on the recurrence formulas:

- $P(15,0,e) = 100$
- $P(x+1,0,e) = P(x,0,e) - q(x,1,e)\,P(x,0,e)$ for $x > 15$
- $P(x+1,r,e) = P(x,r,e) + q(x,r,e)\,P(x,r\text{-}1,e) - q(x,r+1,e)\,P(x,r,e)$ for $r>0$ and $x > 15+r$

The distribution by parity is final at age 49.

The births by order (events of the life table) are given by:

- $B(x,1,e) = q(x,1,e)\,P(x,0,e)$ for $x > 15$
- $B(x,r,e) = q(x,r)\,P(x,r\text{-}1,e)$ for $r>1$ and $x > 14+r$

Based on B, the birth intensity and mean age at birth by order can be estimated as:

- Birth intensity: $I(r,e) = \Sigma\,B(x,r,e)$ over x
- Mean age at birth: $a(r,e) = [\,\Sigma\,x\,B(x,r,e)$ over $x]\,/\,I(r)$

In order to present the timing and quantum of births by level of education e, we plot the partial cumulated births up to age x:

- $CB(x,r,e) = \Sigma\,B(y,r,e)$ over y, $y<x$
- $CB(x,all,e) = \Sigma\,B(y,r,e)$ over r and y, $y<x = \Sigma\,CB(x,r,e)$ over r

The parity-specific birth intensity for birth order r can be interpreted as the percentage of women, by age, who have at least r children. Note that these birth intensities are based on a synthetic cohort approach from ages 26 on. This means that we create a fictional cohort for ages 26 and higher: in contrast to a standard Kaplan Meier or Cox approach, we do not follow a real cohort but observe, from age 26 on, women of different ages at a given moment. The hypothesis is that among the period multistate life table, birth probabilities of women aged x at date t can be combined with birth probabilities of women aged $x+1$ at t. As we construct parity-specific life tables, we assume that each age- and parity-group is homogenous[8].

By summing up the different parity-specific birth intensities, we obtain the total birth intensity. For age 49, this total birth intensity can be interpreted as the average number of children that would be born to a woman by the time she ended childbearing if she were to pass through all her childbearing years conforming to the age-specific birth probabilities of the observed time period.

The fertility multi-state life table method allows adjusting for compositional effects which could lead to bias the TFR and especially its components by birth order (Kohler, Billari and Ortega, 2002). This allows us to make our comparisons as simple as possible - all the more that our country-, age-, parity- and education-specific estimations are sometimes based on relatively small sample sizes (which implies some additional cleansing; see next section). As we consider

[8] This hypothesis may be strong, as many other variables could be considered: duration since last birth (Rallu and Toulemon, 1994), but also couple status, professional activity, place of residence, etc.

the level of education as fixed after 27, and use education at age 27 for classifying women for ages 15-25, we run separate multi-state life tables for each educational group, allowing us comparing three different groups of women in each country each year, consistent over the age range.

Note that adjusting for tempo-changes could have been envisioned, be it to estimate cohort fertility (Bongaarts and Feeney, 1998) or to "adjust" for tempo bias without any explicit reference to cohort behavior (Bongaarts and Feeney, 2006). Other methods have been proposed to consider tempo bias (e.g. Bongaarts and Sobotka, 2012), but we consider here that life table estimates need not to be adjusted for tempo change (Ni Bhrolchain and Toulemon 2005; Ni Bhrolchain 2011). They represent the tempo and quantum of births by order for each group of women defined by level of education at one point in time, without an explicit aim to represent cohort fertility (Van Imhoff, 2001), and without any assumption on the current change in mean age at birth. This is particularly justified here because this tempo change is likely to vary by educational level. A "correction" would therefore distort our comparison of interest, namely the differences between educational groups in cumulated fertility by age for different birth orders.

d. *Obtaining credible estimates and intervals for birth probabilities*

For some of our education-, age-, and order-specific birth probabilities, we obtain relatively high values in some countries. This is notably the case for some of the probabilities of birth of higher order for low educated women between 15 and 19 years old. In rare cases, these can obtain up to 80%. These high values are most likely not only caused by relatively small sample size in some countries, but also because fertility behavior can indeed be very specific when it comes to higher order birth of very young mothers (Bongaarts and Feeney 1998). For example, one could think that it is quite likely that a woman who already has one (or two) children at the age of 17 will have a second (or third) child at age 18 (Kalmuss and Brickner Namerow 1994, United Nations, 2020).

Be these high birth probabilities at young ages caused by substantial or technical reasons - they can lead, in their accumulated form, to quite unstable birth intensities from relatively early ages on, with large variances. We also find zero-estimates for many probabilities, when no birth is observed among a small sub-group of the population.

We therefore apply Bayesian statistics to obtain smoother estimates with lower variance for each country. We first compute the age-specific fertility rates (priors n°1). Then we estimate age- and parity-specific probabilities based on events and exposures, by using priors n°1 to limit large random variations for producing our priors n°2. Finally, we estimate age- and parity-specific probabilities for each educational group, using priors n°2. Bayesian statistics thus allow us to obtain probabilities that are less sensitive than Bernouilli estimates to random variations caused by specific outliers.

This is peculiarly useful for estimates of parity-specific probabilities at young ages, for high parities (x close to $15+r$). With these priors we introduce a slight bias (assuming that fertility is not parity-specific, and then that the probabilities are not varying with education), but we also diminish the variance dramatically, thus increasing the robustness of our estimates. Using Laslier (1989) on probability estimates based on priors, we proceed in three steps.

In order to get sensible variance estimates and reliable tests, we standardize the weights for each country sample with a mean one, so that the weighted total is equal to the sample size (for women aged 15-49).

Let us define:

Age x age from 15 to 49; birth order r from 1 to 5+ (all orders after 4 are merged together in our sample); level of education e with values low, medium, and high.

$n(x,r,e)$ the weighted number of births at age x, order r, whose mother's level of education is e

$N(x,r,e)$ the weighted number of women aged x, of parity r-1 (thus eventually having a birth of order r, r from 1 to 5+), with a level of education e

$w(x,r,\text{all})$ the mean weight of women aged x, parity r-1

The Bernouilli estimates of birth probabilities are defined as:

$$p(x,r,e) = \frac{n(x,r,e)}{N(x,r,e)}$$

1. We estimate prior probabilities n°1 $p(x,\text{all},\text{all})$ at all ages x

The probabilities are simply the age-specific fertility rates (all parities, all educational levels).

$$p(x,\text{all},\text{all}) = \frac{n(x,\text{all},\text{all})}{N(x,\text{all},\text{all})}$$

2. We estimate prior probabilities n°2 $p(x,r,\text{all})$ for age x and parity r-1, based on the age-specific priors $p(x,\text{all},\text{all})$

We first average the mean weights $w(x,r,\text{all})$ for low ages and high parities (r>1)

$$for\ x < x(r), we\ have: w(x,r,\text{all}) = mean(w(y,r,\text{all}))\ over\ y$$

$$with\ x(r) < y < 50\ with\ x(2) = 17, x(3) = 20, x(4) = 23, x(5+) = 28$$

We chose these limits empirically in order to avoid undefined weights. Then we have:

$$p(x,r,\text{all}) = \frac{n(x,r,\text{all}) + 2w(x,r,\text{all})\,p(x,\text{all},\text{all})}{N(x,r,\text{all}) + 2w(x,r,\text{all})}$$

This allows estimating $p(x,r,\text{all})$ even if $N(x,r,\text{all})$ is very small. We then use these age- and parity-specific probabilities as our priors n°2.

In case of an empty cell in the survey (N=0), the estimate is the prior: $p(x,r,\text{all}) = p(x,\text{all},\text{all})$.

3. We finally estimate the probabilities used in our multi-state life tables by age, parity and education, using the age- and parity-specific priors n°2 $p(x,r,\text{all})$

$$p(x,r,e) = \frac{n(x,r,e) + 2w(x,r,e)\,p(x,r,\text{all})}{N(x,r,e) + 2w(x,r,e)}$$

In case of an empty cell in the survey (*N*=0), the estimate is the prior: $p(x,r,e) = p(x,r,\text{all})$.

In practice, the final estimates are very close to the Bernouilli estimates, but they can be estimated even in case of missing data, and their variance is much smaller because at each step when a subgroup size is very small the final estimate is close to the prior estimate. Proceeding in two steps allowed us to test the sensitivity of our estimates to the weight given to the priors. The use of a small prior (two individuals with mean fertility added in each cell) allowed avoiding computations errors (i.e. estimations of the rates in empty cells), but did not alter the results from the surveys.

We calculate confidence intervals for birth *intensities* by age and education, all birth orders combined, by using the standard errors that we obtain when computing the fertility *rates* by age and education.

Appendix C proposes additional and more detailed information about our calculation method of posterior estimates and variances.

Note that an alternative for limiting the random variations would have been to use parametric fertility schedules. This would be even more efficient that a limited number of parameters (related to intensity, modal age, and standard deviation of ages) may accurately represent the fertility schedules constrained by a single mode and zero-values at ages 15 and 50. However, non-parametric estimates of probabilities are closer to the raw data and –as far as we can limit huge random variations using our Bayesian approach– allow producing our synthetic indices. We proceeded in two steps: We first estimate birth probabilities for all education levels together, in order to produce a life table by age and parity, allowing us post-stratifying with other fertility data (see below). We then use these probabilities as priors for estimating education-specific life table probabilities (by age and birth order).

e. Post-stratification

To be consistent with national fertility estimates, we post-stratify our birth probabilities in order to get estimates leading to the published values. This allows international comparisons for specific groups (e.g. highly educated women) or for particular dimensions of fertility behavior (e.g. childlessness). Due to our post-stratification procedure, these comparisons are not biased by overall biases in fertility differences between countries.

We therefore identify, in a first step, the relative difference between total fertility rates coming from official statistics (the World Bank World Development Indicators - WB WDI) and total fertility rates calculated with our EU-SILC database. In a second step, we post-stratify fertility rates by a multiplicative factor for each country to suppress this difference.

Appendix D compares the estimates of the Total Fertility Rates obtained with EU-SILC with the ones coming from the WB WDI. Figure D.1 illustrates, for each country in our sample, the relative difference between the two measures. The EU-SILC measure is the sum of age-specific rates obtained with the cross-sectional modules of 2011, 2012 and 2013, all educational groups combined, while applying the semi-retrospective setting and the two-year delay. Total fertility rates with EU-SILC are thus calculated for calendar years 2009, 2010 and 2011 (combined sample). The WB WDI measure represents the average TFR for years 2009, 2010 and 2011.

Figure D.1 illustrates that there is no systematic difference between the two measures, but that the relative difference is rather equally distributed around zero. For most countries (21 out of 28), the relative difference is below the absolute value of 10%, and for only four countries the bias is between 10 and 20%. Exceptions are Romania and Bulgaria, for which the EU-SILC measure is more than 20% smaller than the WB WDI measure, and Hungary, for which the EU-SILC measure the total fertility rate coming from the WB WDI by over 20%.

The difference between the two measures can be caused by two factors:

- TFRs from the WB WDI are calculated based on a purely cross-sectional approach (sum of age-specific fertility rates in a given calendar year), while for the TFRs calculated with our EU-SILC database, fertility for ages 15 to 25 is observed retrospectively.
- Childbirths might still be somewhat over- or underrepresented in EU-SILC, despite the applied two year-delay between the survey year and the calendar year for which childbirth is observed (which allowed to reduce attrition-linked fertility bias, but not to circumvent sample bias).

When we calculate TFRs with EU-SILC by applying a purely cross-sectional perspective (all by using the cross-sectional modules 2011, 2012 and 2013 with a two-year delay), the relative differences between the EU-SILC measure and the WB WDI measure barely change from the ones illustrated in Figure D.1. This suggests that the main reason for differences between our EU-SILC measures and the total fertility rates coming from the WB WDI is the over-, respectively under-representation of children in EU-SILC (sample bias).

To apply a simple post-stratification strategy, we assume that the fertility-specific sample bias in EU-SILC is not education-specific, nor age- and birth-order specific, and thus apply the same multiplicative factor to all rates.

Greulich and Dasré (2018) suggest that there are no systematic socioeconomic differentials in the fertility bias in EU-SILC. The absence of a systematic bias in the raw estimates lead us to choose the simplest possible assumption, namely a uniform bias in each country. However, Greulich and Dasré (2018) also show that measurement biases appear in particular for lower ages and lower birth orders. Appendix E therefore compares different methods of post-stratification for reconciling the estimates with the official TFR (elaborating on Devolder, 2018): post stratification for all parities altogether or by parity, ex-post adjustment using odds ratios, and age-specific adjustments. It shows that adjusting all fertility probabilities at the same pace for each age, parity and education level appeared as the most careful solution, minimizing the impact of the post-stratification on the observed results, while making them consistent with published TFRs. We thus used this method to produce consistent estimates of the TFRs as well as of fertility intensities by birth order for each educational group.

4. Results

a. The educational gradient in the intensity of childbirth

To give a first comprehensive and compact overview of results, Table 1 presents total birth intensities (cumulated at age 49 from fertility life tables), as well as Total Fertility Rates (TFRs), by education and overall, for each of the 28 covered countries in our sample.

Table 1 about here

Table 1 shows that in 2010, TFRs vary from 1.27 to 2.15 children per woman, and our overall fertility intensity index shows a similar dispersion between countries. The country-specific contexts are related to more diversity among highly educated women than among women with a medium or low education: the unweighted standard deviations (SD) between countries in terms of total birth intensity at age 49 are 0.31 for highly educated, 0.24 for middle educated, and 0.26 children per woman for low educated women. The overall total birth intensity at age 49 is less diverse, due to compensatory effects (SD=0.24), and is more strongly correlated to fertility levels of highly educated than of low educated (unweighted correlation coefficients R=0.90 for highly educated, 0.78 for middle educated, and 0.59 for low educated). In almost all countries, low educated women have the highest fertility. However, the educational gradient is not negative in all countries. In one third of European countries, period fertility levels in 2010 exhibit a U-shaped pattern, with middle educated having the lowest fertility. As in comparison to Total Fertility Rates, our index of total fertility intensity at age 49 reduces the bias due to the delay in childbearing, it leads to higher fertility estimates for the highly and middle educated, relatively to the low educated, and thus to lower fertility differentials in most countries, with less extreme values, and more consistent estimates.

To go in deeper detail, Figure 1 to 6 present the age-and education-specific birth intensities for birth order one, two and three as well as for all birth orders combined. As the focus of this paper is a methodological one, age- and parity-specific results are not presented here for the whole list of European countries. We focus in the following on six countries, illustrating the diversity of European period fertility in 2010: France, Germany, Italy, Poland, the UK and Sweden. Each of these countries is taken as a representative for a specific region in Europe: Germany for the German-speaking countries including Austria and Switzerland, France for the Continental countries including Belgium, the Netherlands and Luxembourg, the UK for the English-speaking countries including Ireland, Italy for the Mediterranean countries, Poland for the Central and Eastern European countries, and Sweden for the Nordic countries. These regional groups are considered to differ in their contextual and normative setting, and in particular in their institutional support for reconciling work and family life (Esping Andersen 1999; Thévenon 2013). There is, of course, within-group heterogeneity concerning the contextual and normative setting. In this article, we are not addressing the contextual impact on the educational gradient of period fertility. The purpose of the descriptive analysis proposed in the following is to give some illustrative examples of how our measures can be used to link the educational gradient of period fertility to age- and parity-specific fertility behavior.

Figure 1 presents the birth intensities by age and education for France. For first childbirth, Figure 1 illustrates that low-educated women tend to have their first child before age 30 and that 94% of low-educated women have at least one child by the age of 49. Middle educated women do not necessarily start childbearing later than the low educated, but their intensity of first childbirth is somewhat lower from ages 25 on. High educated women start childbearing much later than the low and middle educated women in France, from ages 25 on. However, according to our period fertility intensity measure, it seems that they catch up quite rapidly with middle educated women in terms of first childbirth. Their intensity of first childbirth catches up with those of middle educated women at age 32 and even exceeds it from ages 36 on. At ages 49, ninety one percent of highly educated women have at least one child in France. Therewith, in France the intensity of first childbirth is higher for the highly educated than for the middle-educated women (88%).

Figure 1 about here

The picture changes, however, for births of higher order in France. For second childbirths, we certainly still observe a relatively high birth intensity for high educated women in France (70% at age 49), but this birth intensity is lower than for the low and middle educated women (77% and 72% at age 49). Whereas there are again no striking differences in the timing of second child births between low and middle educated women in France, higher educated women have their second children later, between ages 27 and 40.

The educational gradient becomes most important when looking at births of order three in France, not only in terms of timing, but also in terms of quantum: with almost 41% at age 49, low educated women have a much higher intensity of third childbirth than middle educated and highly educated women (28% and 21%). They also tend to have their third children before age 35, whereas highly educated women tend to have them between age 35 and 40.

When combining all birth orders, we observe a classic educational gradient of fertility in France, with highest fertility levels for the low educated. Our semi-retrospective approach suggests that by the age of 49, low educated women have on average 2.42 children, against 2.06 children for the middle and 1.88 children for the highly educated. More age-specifically, we see that middle-educated women do not have a lower number of children than low educated women until the age of 30. However, differences increase from ages 30 on, mainly because low educated women are more likely than middle educated women to have a birth of order 3+. For each age, highly educated women have a lower total birth intensity than middle and low educated women. This is mainly because they have their first child later and because they are less likely to have a birth of order 2+ in comparison to middle and low educated women.

Figure 2 illustrates the birth intensities for Germany. When it comes to first childbirth, the contrast to the French case is quite striking for highly educated women. Not only do German highly educated women start childbearing much later than in France (the intensity of first childbirth at age 30 for highly educated women is 56% in France, against only 28% in Germany). The proportion of highly educated women who are childless by the age of 49 is also much higher in Germany (30% in Germany against 9% in France).

Figure 2 about here

Another striking difference between Germany and France is that in Germany, middle educated women are much more similar to highly educated women in times of childbearing behavior, whereas in France, the middle educated are more similar to the low educated, at least for birth orders one and two. This means that middle educated women in Germany start childbearing quite late in comparison to France, and their proportion of childlessness at age 49 is, with 27%, close to the one of the highly educated women in Germany.

The difference we observe in Germany in the intensity of first childbirth for low educated women on the one side and middle and high educated women at the other side translates to important differences for births of higher order: over 50% of middle and high educated women with one child do not have a child of higher order by the age of 49, and the percentage of middle and highly educated women who have at least three children by the age of 49 is below 14%.

Consequently, there is a strong difference in the total birth intensity between low and higher educated women in Germany: While low educated women have on average 1.92 children by the age of 49, middle and highly educated women have a much lower average number of children (1.43 for the middle educated and 1.28 for the high educated).

Figure 3 illustrates the birth intensities for Italy. For highly educated women in Italy, the fertility patterns are very similar to those of German highly educated women. Middle-educated women in Italy are situated on an intermediate path when compared to their counterparts in Germany and France when it comes to first childbirth, but their intensities of birth of higher order are on similarly low levels than those of the highly educated in Italy and Germany.

Figure 3 about here

Highly educated women in Italy have the lowest transitions to childbirth in comparison to middle and low educated women, and this is the case for all birth orders, from birth order one on. While 88% of low educated and 80% of middle educated women have at least one child at age 49, the percentage is only 71% for highly educated women in Italy. Therewith, the proportion of childless women among the highly educated is, with 29% at age 49, similarly high than in Germany. Highly educated women in Italy start childbearing even later than in Germany: Only 20% among them have at least one child at age 30, against 28% in Germany.

Only around 48% of middle and highly educated women with one child have at least a second child, and below 10% of higher educated women have at least 3 children.

All birth orders combined, our total birth intensities suggest that middle and high educated women in Italy end up with a similarly low average number of children at the age of 49: 1.40 children per woman for the middle and 1.31 for the high educated - while the number amounts to 1.96 for the low educated.

Figure 4 illustrates the birth intensities for Poland. Poland has a relatively low fertility level, similar to Germany and Italy (TFR lower than 1.5), but in contrast to Germany and Italy, childlessness among highly educated women in Poland is relatively small (23% in Poland against 29% in Italy and 30% in Germany).

Figure 4 about here

Highly educated women in Poland start childbearing later than middle and low educated women, but they catch up with the middle and low educated ones relatively rapidly, between ages 25 and 35, according to our period fertility intensity measure. From age 30 on, the intensities of first childbirth converge to similar levels between the low, middle and highly educated (at age 49: 86% for the low educated, 81% for the middle educated and 77% for the highly educated).

Strong differences between education groups emerge, however, from the second childbirth on: Less than one out of two highly educated women with one child has a second child, and less than 6% of highly educated women in Poland have at least three children by the age of 49.

Middle educated women in Poland are situated on an intermediary birth intensity path in comparison to high and the low educated women, and this is valid for all birth orders. 57% of middle educated women have a second child by the age of 49, and 19% of middle educated women end up with at least three children.

Total birth intensities follow therewith a classical educational gradient, with 2.04 children per woman on average by the age of 49 for the low educated, 1.61 for the middle and 1.28 for the high educated.

Figure 5 presents the birth intensities for the United Kingdom. The UK has relatively high birth intensities for first childbirth for young low educated women, but middle educated women exceed low educated women in terms of first birth intensities from ages 29 on. Highly educated women almost completely catch up with low educated women in terms of first birth intensities at age 38. 20% of highly educated women and 17% of low educated women in our sample are childless by age 49, while only 10% of middle educated women stay childless in the UK. At the same time, highly educated women have strikingly lower birth intensities of higher order in comparison to low and middle educated women, resulting in the fact that all birth orders combined, birth intensities for women at age 49 are, with 1.62 children per woman on average, much lower for highly educated women than those of middle and low educated women (2.19 and 2.31 children per woman respectively).

Figure 5 about here

Figure 6 illustrates the birth intensities for Sweden. In comparison to the other five countries illustrated above, Sweden is the country with the lowest educational gradient in fertility – and this is valid for the timing as well as for the quantum of births.

Figure 6 about here

When it comes to first childbirth, there is almost no difference in the fertility pattern between low, middle and highly educated women in Sweden. Highly educated women in Sweden start childbearing only somewhat later than their middle and low educated counterparts (around age 25), and they catch up very rapidly according to our period fertility intensity measure. Consequently, the intensity of first childbirth converges between the three education groups around age 30 already. From age 32 on, highly educated women in Sweden even have a somewhat higher intensity of first childbirth than the middle and low educated. At age 49, the intensity of first childbirth is 90% for highly educated women, against 87% for middle and low educated women.

The picture is similar for second childbirth. Highly educated women in Sweden make their transition to a second child somewhat later than the middle and low educated, but they catch up in the early thirties. Their intensity of second childbirth even exceeds those of the lower educated ones from age 35 on. Over 78% of highly educated women with one child have a second child by the age of 49 in Sweden.

Differences emerge, however, for births of order three and higher, with low educated women having much higher birth intensities than higher educated women in Sweden. It is important to remark, nevertheless, that in comparison to the other four countries presented above, Swedish higher educated women have relatively high birth intensities for birth order three. By the age of 49, almost 25% of highly educated and almost 20% of middle educated women have at least 3 children, while the intensity of 3rd childbirth is below 20% for highly educated women in Poland, Italy and Germany and France.

All birth orders combined, differences in the total birth intensity are strikingly low in Sweden, while the birth intensities are all situated on relatively high levels in comparison to the other countries. The educational gradient is not negative but U-shaped: Middle educated women in Sweden have the lowest average number of children at the age of 49 in comparison to low and high educated women: The number amounts to 1.98 children per woman for highly educated women, 1.85 for middle educated and 2.13 for low educated women.

b. *The educational gradient of fertility levels – a comparative overview*

Figure 7 presents total birth intensities (all birth orders combined at age 49) by education for the six selected European countries.

Figure 7 about here

In all six countries, total birth intensities are the highest for the low educated. The total birth intensities for low educated women are on relatively similar high levels for all six countries. Germany, Italy and Poland, which are countries with relatively low overall fertility levels (TFR <1.5), show a strong negative educational gradient: middle and high educated women have a much lower fertility level than low educated women, while the fertility level of the middle and highly educated women is similarly low.

Confidence intervals are larger for low educated women in comparison to those of middle and highly educated women in all countries. This is not only because low educated women represent the smallest group in all six countries, as shown by Table F.1 in appendix F, which presents the distribution of women over education groups for all countries of our sample.

France, the UK and Sweden have higher fertility levels for middle and highly educated women than Germany, Poland and Italy. France and the UK still show a negative educational gradient of fertility, but fertility levels are relatively high for the middle and highly educated. This is particularly the case for the high educated in France and for the middle educated in the UK. In Sweden, there is no clear educational gradient, and the differences in fertility levels between education groups are not significant. Figure 7 suggests that in Sweden, it is the middle educated that have the lowest fertility level in comparison to the low and the high educated.

The relatively high fertility levels for middle and highly educated women are combined with a higher proportion of women being highly educated in Sweden, France and the UK in comparison to Germany, Poland and Italy. More than 50% of women in Sweden, almost 50% of women in the UK and 45% of women in France are highly educated in our sample, while highly educated women represent less than 40% of women in our sample in Germany, Poland and Italy; see Table F.1). This results in the fact that the overall levels of period fertility are higher in France, Sweden and the UK (TFR and total birth intensity at age 49 > 1.5 children per women, see Table 1) compared to Germany, Italy and Poland.

Figure 8 resents the educational gradient of fertility by normalizing fertility levels for our six countries. This allows focussing on fertility differences between education groups by eliminating the differences in fertility levels between countries.

Figure 8 about here

Figure 8 confirms that the educational gradient of fertility is negative for all countries except for Sweden. Fertility differences between the low educated on the one side and the middle and high educated on the other side are most important in Italy, followed by Germany and Poland. France and the UK also show a negative educational gradient in fertility, but the gradient is much more mitigated. In the UK, the difference in fertility levels between low and middle educated women is lower than in the other five countries, and the difference in fertility levels between middle and highly educated women is higher. In Sweden, highly educated women have higher fertility levels than middle educated women.

Table 1 shows that this is the case for most Nordic countries. In Iceland, Denmark and Finland, highly educated women have higher total birth intensities (at age 49) than middle educated women. In Norway, highly educated women only have a minimally lower total birth intensity (at age 49) than middle educated women. Table 1 shows furthermore that total birth intensities are higher for highly than for middle educated women in five additional countries: Belgium, the Czech Republic, Estonia, the Netherlands and Slovenia. Therewith, the educational gradient of period fertility is *not* strictly negative for 9 out of 28 European countries, which represents one third of countries in our sample.

Figure 9 about here

Figure 9 finally illustrates for which birth order the heterogeneity is the lowest, by showing parity progression ratios for each country and education group (left panel: standard; left panel: normalized). The left panel of Figure 9 shows that transitions to first (a_0) and second childbirth (a_1) are quite uniformly situated on relatively high levels for low educated women in the six countries, while they differ strongly for higher educated women: Higher educated women are much more likely to have at least one and at least two children in France, Sweden and the UK compared to Germany, Poland and Italy. For transitions to a third child (a_2), the picture is somewhat different. Transition ratios are uniformly situated on a relatively low level for highly educated women in all six countries, while low educated women are more likely to have at least three children in the UK, France and Sweden than in Germany, Poland and Italy. The right panel of Figure 9 focuses on differences between education groups within countries and shows that in comparison to low educated women, middle educated women are particularly less likely to stay childless in the UK and particularly more likely to stay childless in Germany. The educational gradient in terms of transition to first childbirth between low and highly educated women is negative in Poland, Italy and Germany (and in Germany and Italy similarly strong), while there exists no important gradient between low and high educated women in Sweden, France and the UK. The gradient is, however, much stronger in France and the UK between low and highly educated women for transitions to a second child. Highly educated women are less likely to have a second child than low educated women in 5 out of 6 countries (France, the UK, Germany, Italy and Poland), while the educational gradient is most negative for Poland. Only Sweden shows a positive gradient, implying that highly educated women have a higher likelihood to have a second child than low educated women. For third childbirth, the educational gradient is clearly negative for all six countries, and transition ratios are similarly low for highly educated women in comparison to the ones of low educated women in all six countries.

Conclusion

In this study, we used harmonized socio-economic European survey data, the EU-SILC, to quantify the educational gradient of period fertility in European countries, around the year 2010. Period fertility levels differentiated by education were provided for 28 countries, and age-and parity-specific results were illustrated for six countries in this article: France, Germany, Italy, Poland, the UK and Sweden.

We showed that across European countries, period fertility levels are more diverse among highly educated women than among women with medium or low education, and that overall fertility levels are more strongly correlated to fertility levels of highly educated than of lower educated women. In almost all countries, low educated women have the highest fertility, but the educational gradient is not negative in all countries. In one third of European countries, period fertility levels in 2010 exhibit a U-shaped pattern, with middle educated having the lowest fertility.

Our focus on six selected countries confirmed that total birth intensities are on quite similar levels for the low educated, but differ importantly between education groups in five out of six countries. The educational gradient is highest in Poland, followed by Italy and Germany. In these three countries, middle and highly educated women have a much lower total birth intensity in comparison to low educated women. In France and the UK, middle and highly educated women also have lower intensities, but they are situated on much higher levels in comparison to Poland, Italy and Germany. This is particularly the case for the middle educated. It seems thus that the overall levels of period fertility in Poland, Italy and Germany are quite low in comparison to the other three countries not only due to lower birth intensities for highly educated, but also and in particular for middle educated women. Finally, in Sweden, the total birth intensity (at age 49) of highly educated women is on a similarly high level than the one of low educated women, with middle educated women having a lower level than low and highly educated women.

Our focus on six countries has also allowed to analyse age- and parity-specific fertility behavior in more detail. While the transitions to first and second childbirth are quite uniformly situated on relatively high levels for low educated women in the six countries, they differ strongly for higher educated women: Higher educated women are much more likely to have at least one and at least two children in France, Sweden and the UK compared to Germany, Poland and Italy. The difference between countries is most striking for middle educated women: they are particularly less likely to stay childless in the UK and particularly more likely to stay childless in Germany in comparison to low educated women. At the same time, higher educated women have similarly low transition ratios to third childbirth in all six countries compared to the low educated. It seems thus that the higher overall period fertility levels in Sweden, the UK and France in comparison to Poland, Germany and Italy are mainly due to higher transitions to a first and second child not only for highly, but also for middle educated women. In terms of age-specific behavior, it seems that highly educated women start childbearing later than the low and middle educated women in all six countries, but, according to our period fertility intensity measure, they catch-up with lower educated women in France and Sweden around the age of 30. The novelty of our analytical approach is to be able to propose this kind of analysis for the large majority of European countries (28 in our sample). Similar as for Sweden, we find that total birth intensities (at age 49) are lower for middle than for highly educated women also in Iceland, Denmark, Finland, Belgium, the Czech Republic, Estonia, the Netherlands and Slovenia. Therewith, the educational gradient of *period* fertility is *not* strictly negative for 9 out of 28 European countries, which makes up one third of European countries. This finding contrasts with the main currents of the existing empirical literature, which find that the educational gradient of *completed cohort* fertility is negative for the large majority of European countries (Sobotka 2020, Nisén et al. 2021). Our focus on *period* fertility levels represents thus a major updating of the present state of knowledge about associations between education and fertility in Europe.

The large country and time coverage (28 European countries, with calculations on a year-by-year basis from 2005 on) allows now to empirically model the institutional determinants of heterogeneities in the educational gradient of period fertility levels between countries in a next step. This will reveal in how far the educational gradient of period fertility behavior is sensitive to region- and country-specific context such as economic development, labor market conditions, family policy settings, gender and family norms etc. With the measure of the educational gradient being available on a yearly basis from 2005 on, it is also possible to identify which educational group contributes the most to the fertility decline that has recently occurred in several European countries - while taking into account potential structure effects (caused by the evolution of the distribution of education among women). Finally, the provision of measures of period fertility levels by education for a large set of European countries, covering almost two decades, contains the potential to improve fertility forecasts and micro-simulation models.

A major condition for the realization of these research tracks is to reassure that the provided educational gradients of age and parity-specific fertility rates are not biased by measurement errors caused by the use of EU-SILC (sample bias, attrition). Building on the analyses provided by Greulich and Dasré (2017), we have reinforced the quality of period fertility measures based on EU-SILC by applying Bayesian statistics as well as post-stratification. Giving access to these measures as well as to the detailed compilation protocol allows the research community now to retrace our compilation of measures as well as to pursue and improve the data quality check. One possibility is to compare the SILC-based measures to those based on national censuses and register data - for those countries and years for which these alternative data sets are available.

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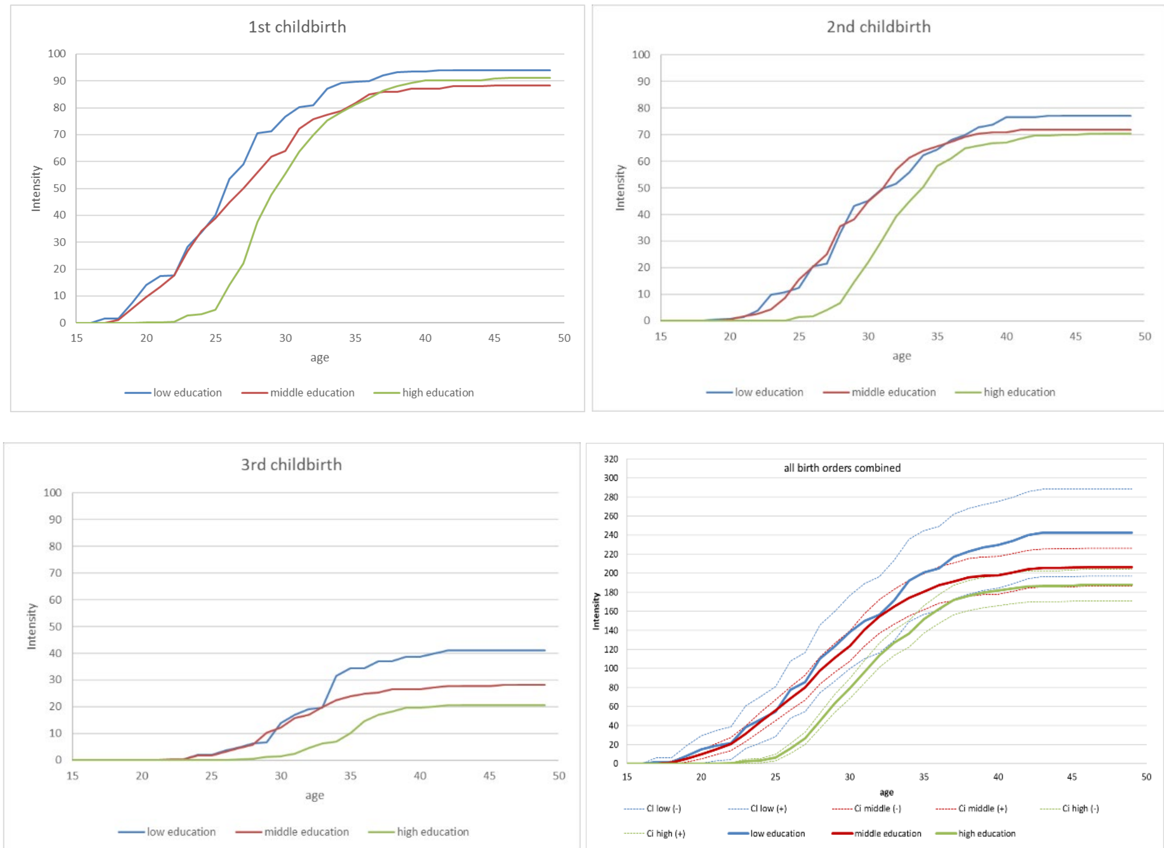
Figures and Tables

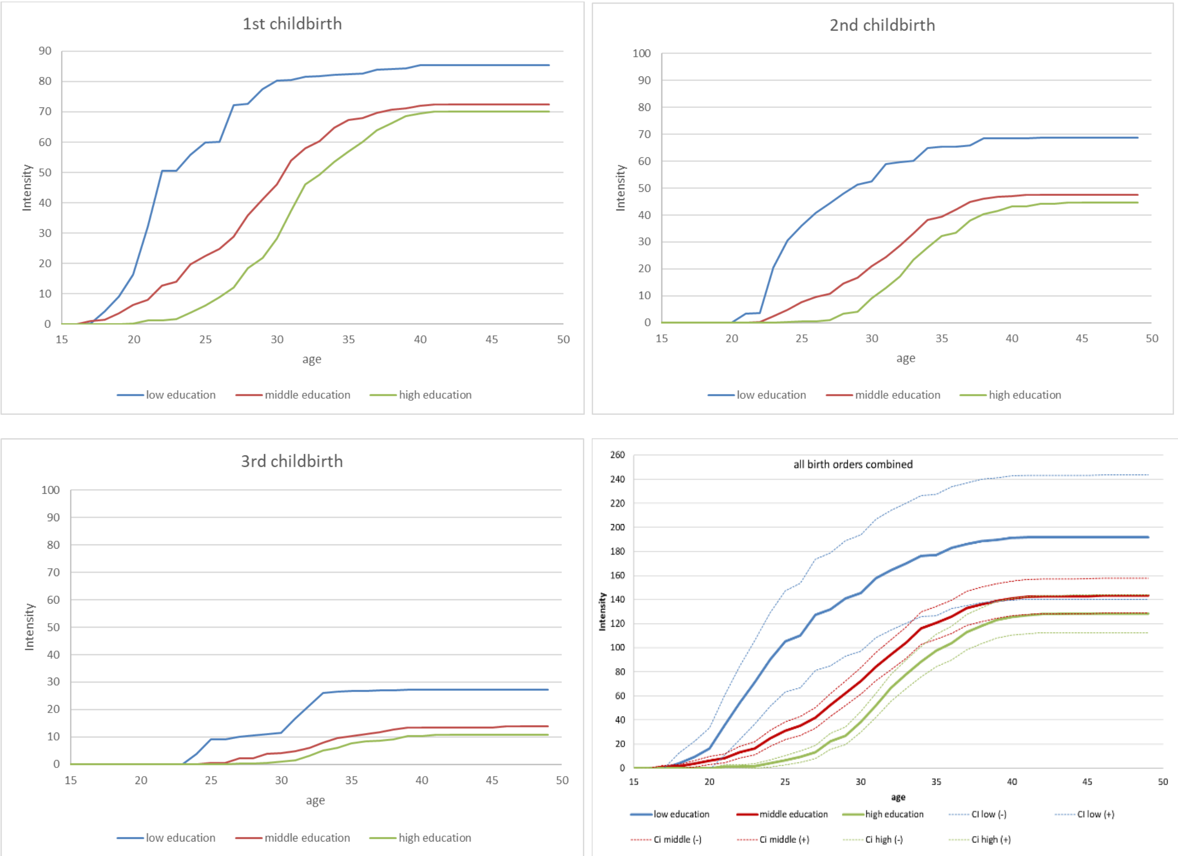
Figure 1: Birth intensities by age and education - France (births per 100 women)



Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013: childbirths observed in 2009, 2010 and 2011

Women aged 15-49, semi-retrospective approach

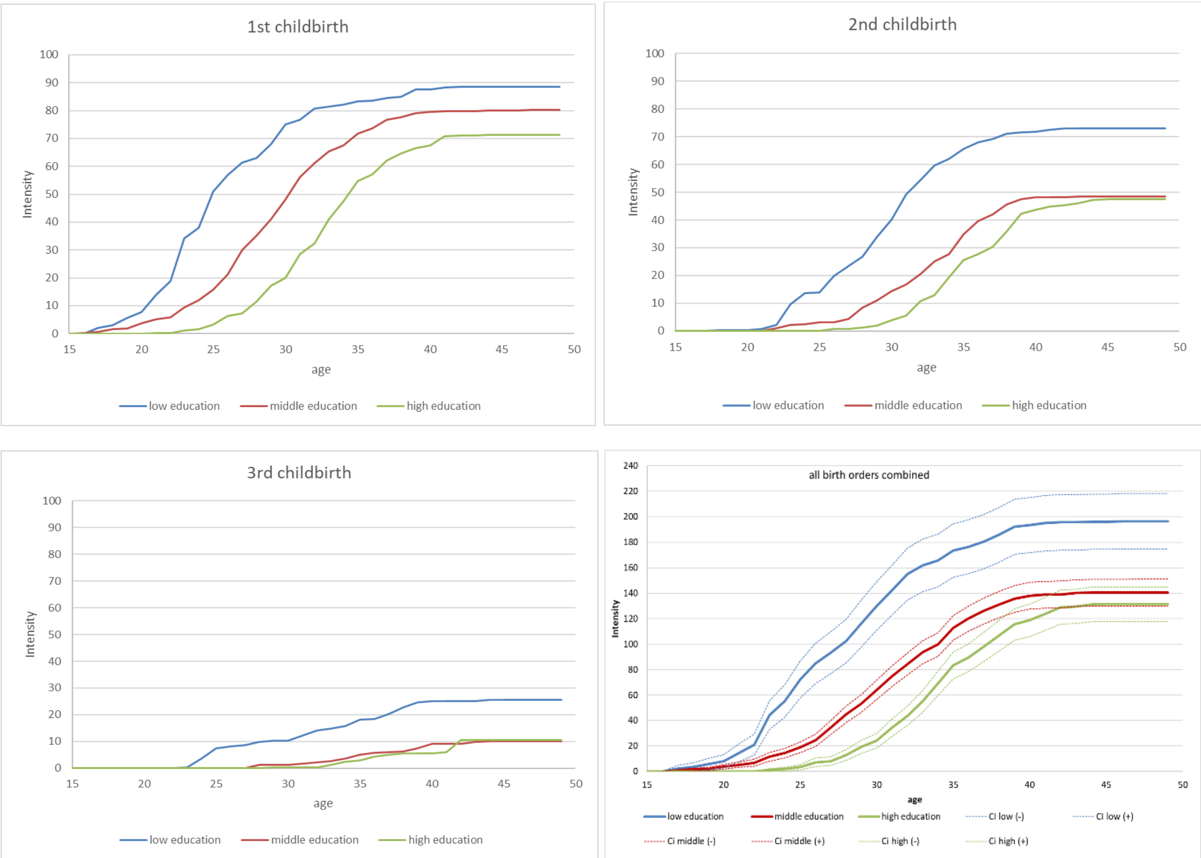
Figure 2: Birth intensities by age and education – Germany (births per 100 women)



Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013: childbirths observed in 2009, 2010 and 2011

Women aged 15-49, semi-retrospective approach

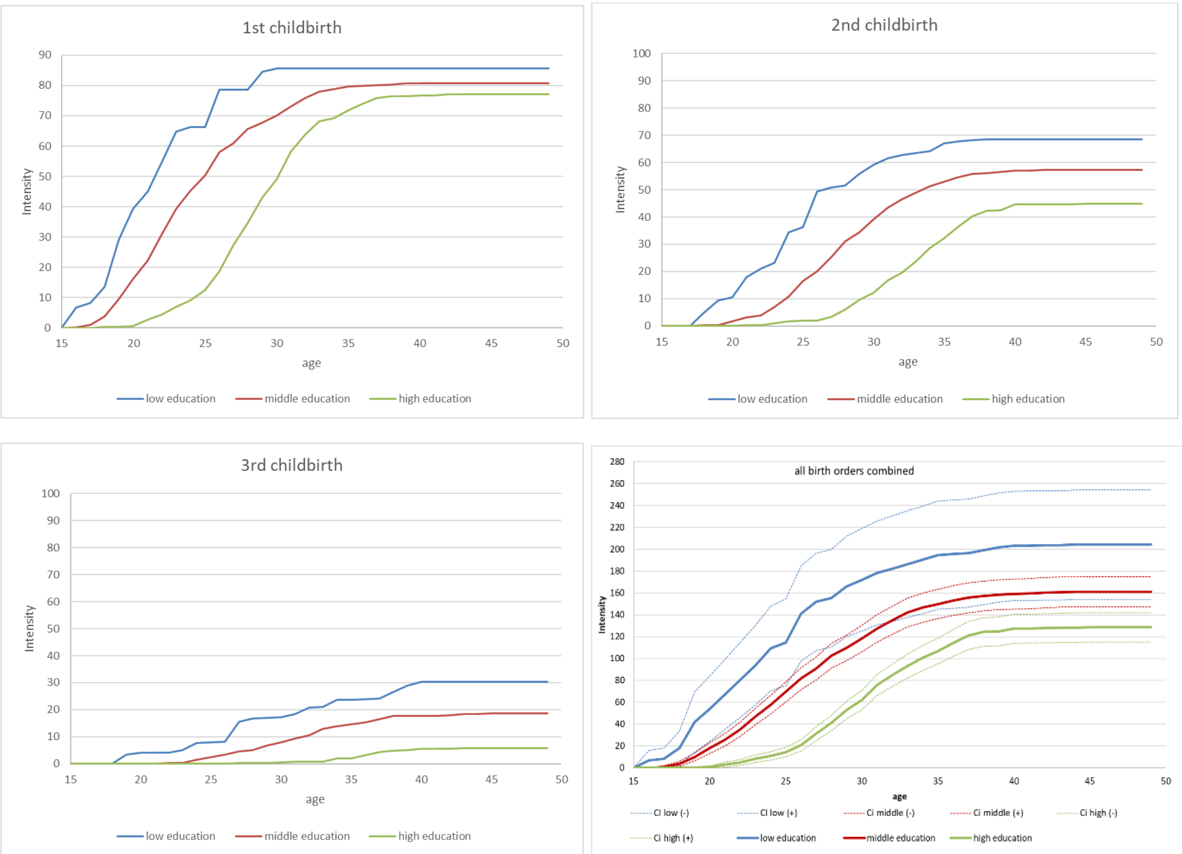
Figure 3: Birth intensities by age and education – Italy (births per 100 women)



Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013: childbirths observed in 2009, 2010 and 2011

Women aged 15-49, semi-retrospective approach

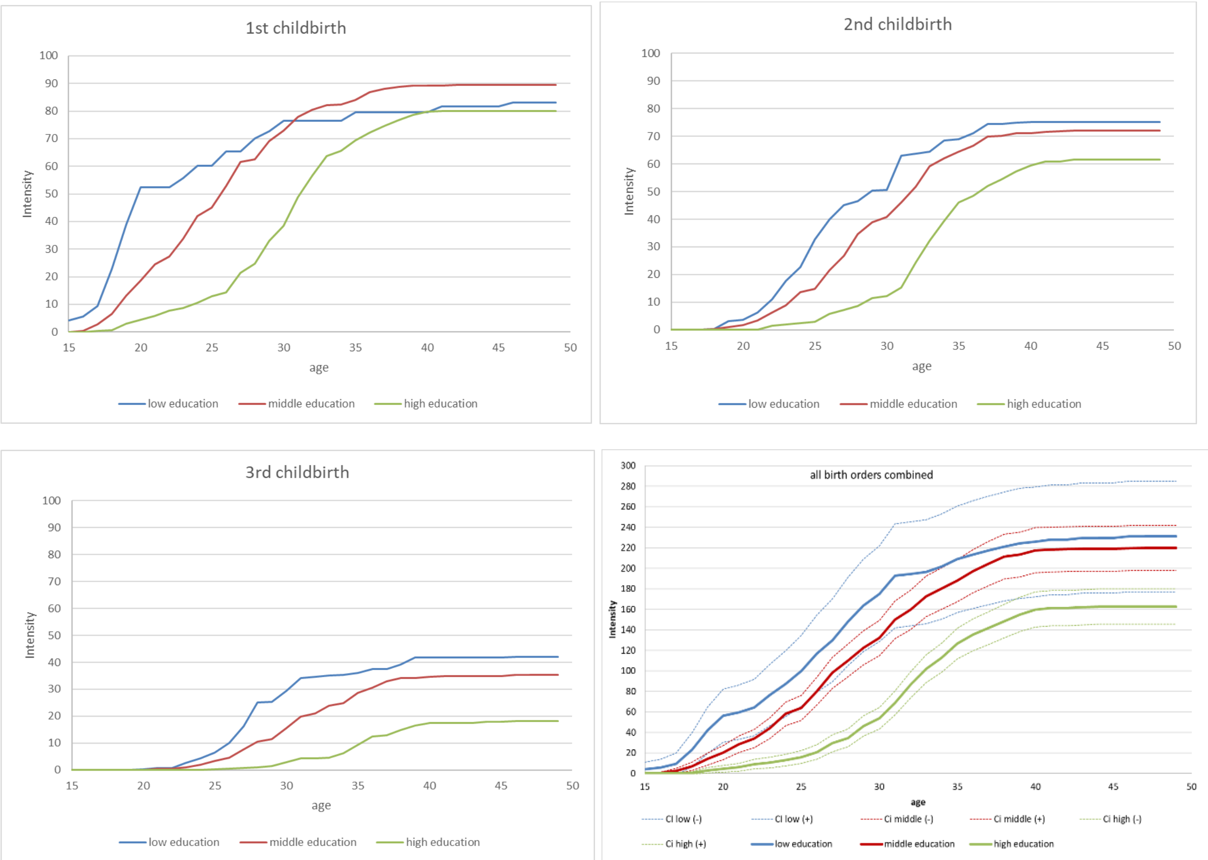
Figure 4: Birth intensities by age and education – Poland (births per 100 women)



Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013: childbirths observed in 2009, 2010 and 2011

Women aged 15-49, semi-retrospective approach

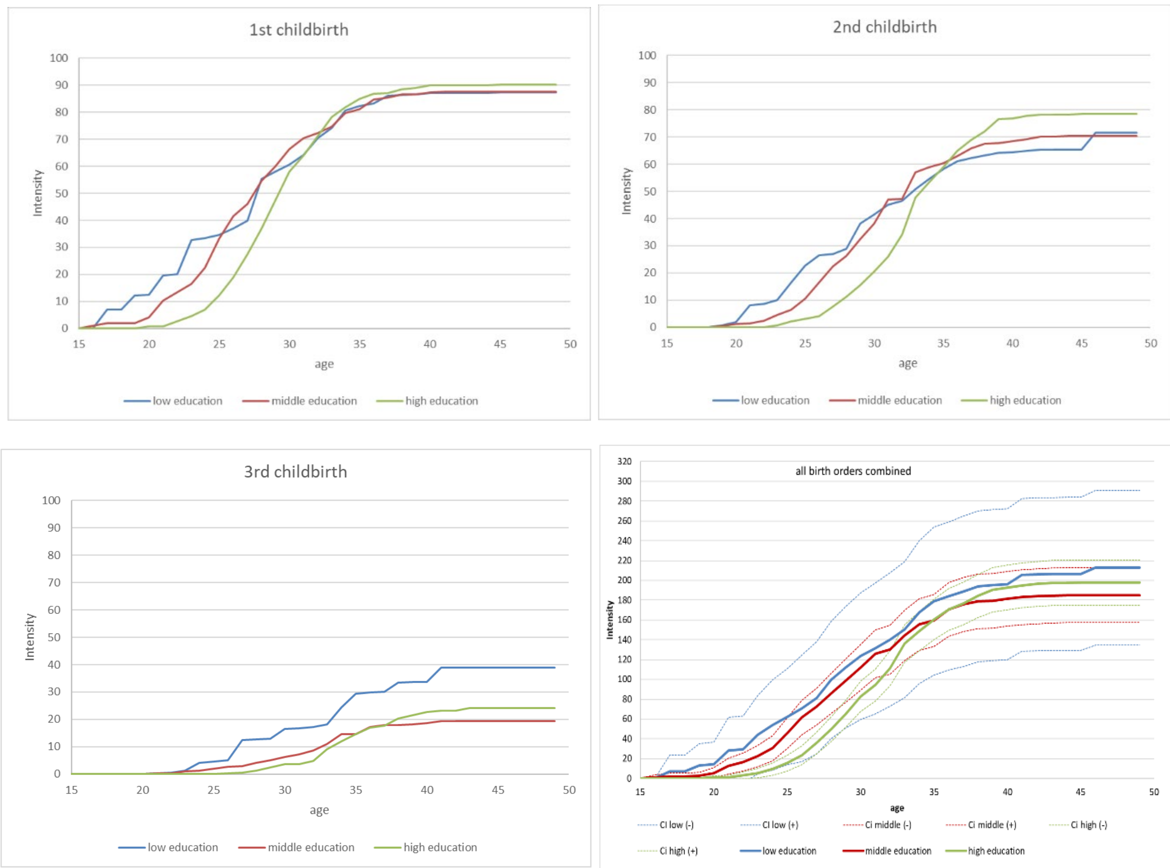
Figure 5: Birth intensities by age and education – UK (births per 100 women)



Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013: childbirths observed in 2009, 2010 and 2011

Women aged 15-49, semi-retrospective approach

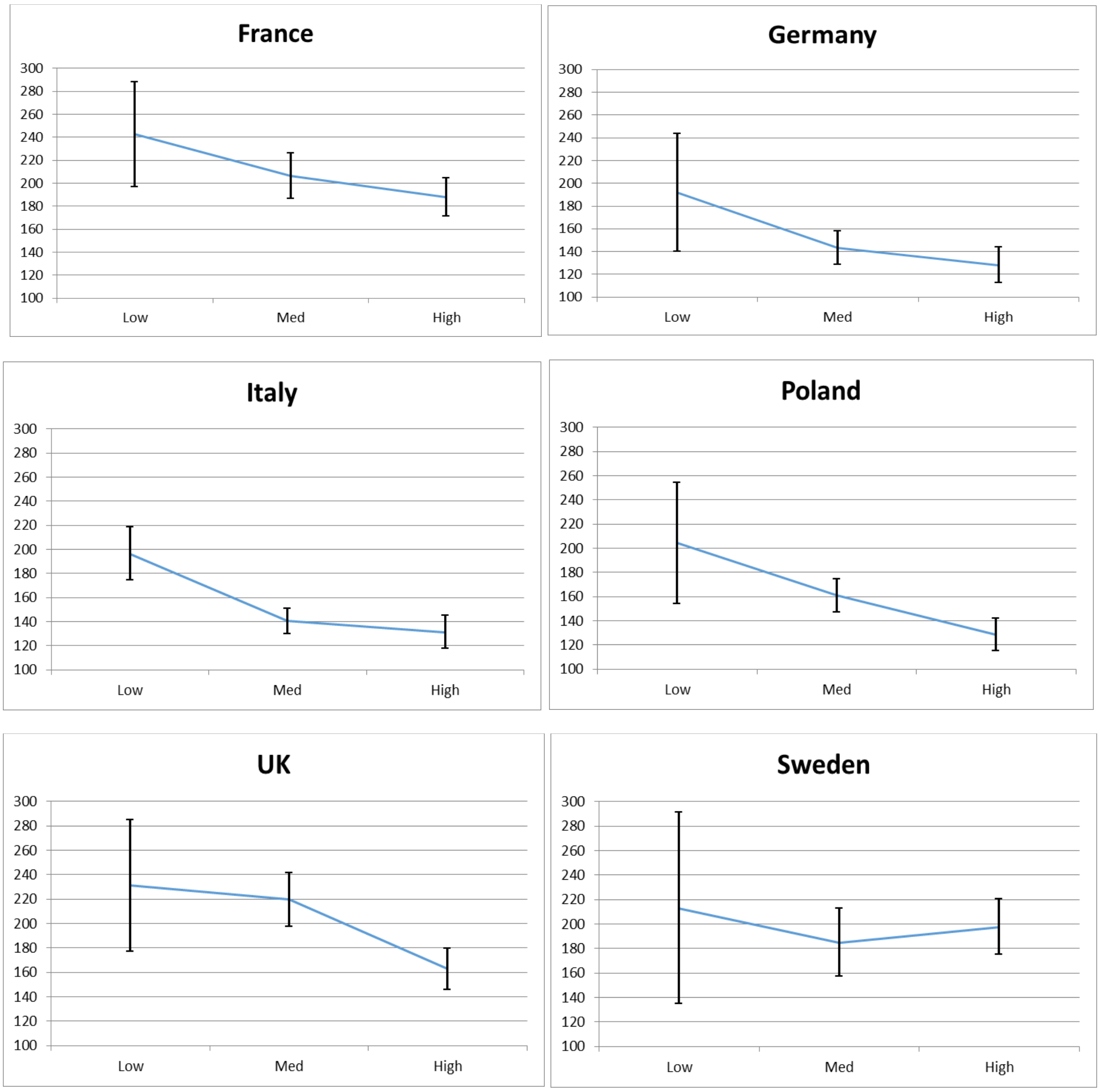
Figure 6: Birth intensities by age and education – Sweden (births per 100 women)



Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013: childbirths observed in 2009, 2010 and 2011

Women aged 15-49, semi-retrospective approach

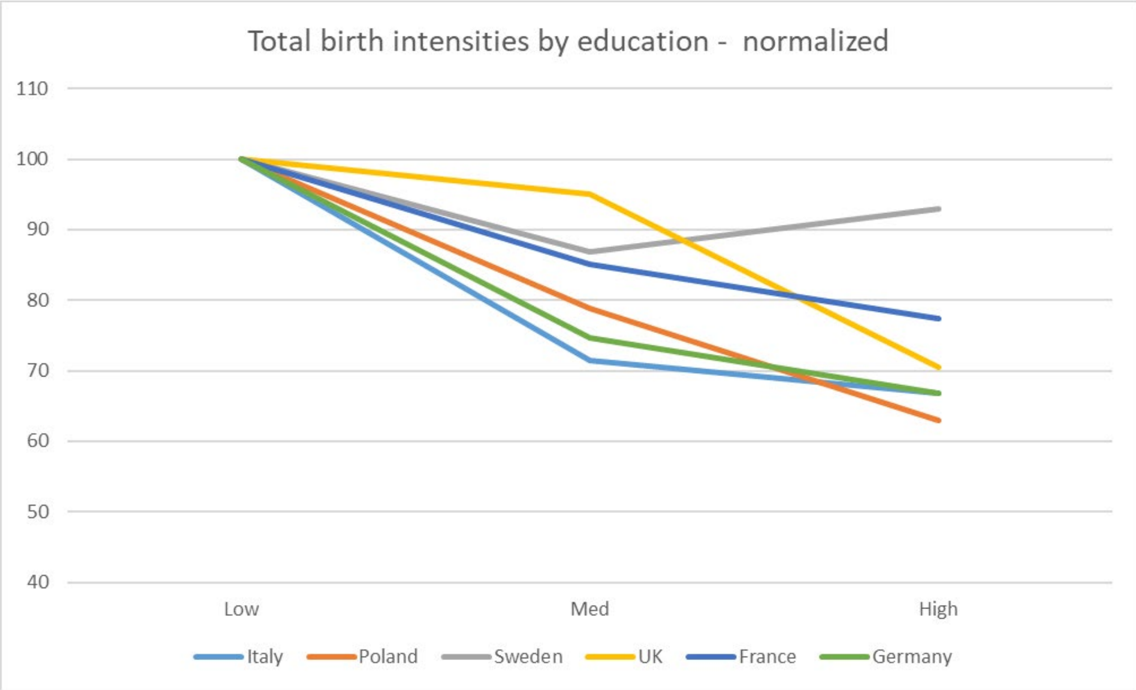
Figure 7: Total birth intensities by education and country (births per 100 women)



Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013: childbirths observed in 2009, 2010 and 2011

Women aged 15-49, semi-retrospective approach

Figure 8: Normalized total birth intensities by education



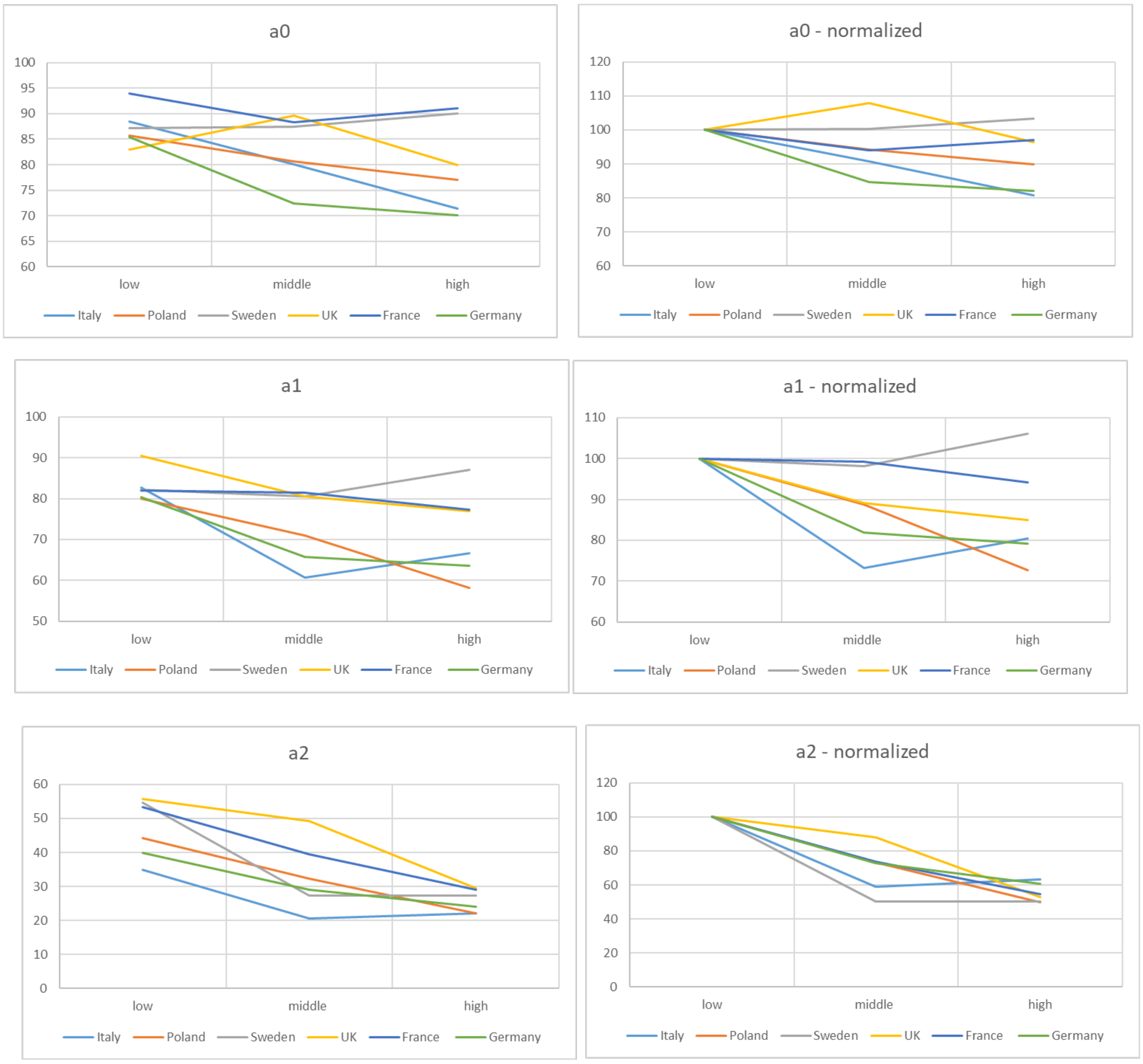
Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013, childbirths observed in 2009, 2010 and 2011

Women aged 15-49, semi-retrospective approach

Figure 9: Parity Progression Ratios (percent)

Left panel: parity progression ratio to the first, second and third birth

Right panel: same data, base 100 for low educated women



Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary
Data source: EU-SILC, CS 2011-2013, childbirths observed in 2009, 2010 and 2011.

Women aged 15-49, semi-retrospective approach

Table 1: Overview of results – country by country

	Total birth intensity at age 49, by education (children per woman)[1]				Total fertility rate, by education (children per woman)[2]			
	low educated	middle educated	high educated	All	low educated	middle educated	high educated	All
Austria	2,15	1,38	1,34	1,43	2,22	1,32	1,40	1,42
Belgium	2,16	1,60	1,79	1,84	2,17	1,57	1,83	1,84
Bulgaria	2,34	1,40	1,05	1,51	2,64	1,34	1,30	1,58
Czech Republic	2,12	1,52	1,66	1,54	2,45	1,47	1,68	1,48
Denmark	1,92	1,58	1,90	1,77	1,52	1,79	1,91	1,82
Estonia	1,72	1,61	1,74	1,68	1,57	1,57	1,82	1,68
Finland	2,08	1,65	1,81	1,82	1,87	1,69	1,79	1,85
France	2,42	2,06	1,88	1,98	2,43	2,12	1,91	2,01
Germany	1,92	1,43	1,28	1,38	1,98	1,43	1,26	1,38
Greece	1,85	1,50	1,48	1,45	2,16	1,62	1,52	1,46
Hungary	1,98	1,31	1,29	1,34	2,19	1,21	1,16	1,27
Iceland	2,50	1,64	2,14	2,17	2,45	1,81	2,09	2,15
Ireland	2,14	2,06	2,01	2,06	2,45	1,81	2,09	2,15
Italy	1,96	1,40	1,31	1,47	2,04	1,38	1,30	1,45
Latvia	1,69	1,45	1,41	1,40	1,84	1,32	1,39	1,38
Lithuania	1,87	1,79	1,42	1,54	1,99	1,74	1,35	1,52
Luxembourg	2,50	1,54	1,30	1,58	2,55	1,60	1,30	1,58
Netherlands	1,93	1,78	1,79	1,73	1,91	1,91	1,80	1,78
Norway	2,10	1,99	1,98	1,94	2,01	1,99	1,95	1,94
Poland	2,04	1,61	1,28	1,44	2,12	1,64	1,24	1,38
Portugal	1,78	1,28	1,01	1,32	1,87	1,27	1,06	1,36
Romania	2,05	1,60	1,35	1,59	2,22	1,66	1,51	1,57
Slovak Republic	1,68	1,61	1,37	1,46	2,02	1,55	1,37	1,44
Slovenia	1,75	1,50	1,69	1,58	1,84	1,38	1,72	1,55
Spain	1,46	1,36	1,30	1,35	1,50	1,38	1,26	1,36
Sweden	2,13	1,85	1,98	1,95	2,18	1,78	1,99	1,94
Switzerland	1,69	1,59	1,37	1,50	1,87	1,60	1,37	1,51
United Kingdom	2,31	2,20	1,63	1,88	2,42	2,17	1,63	1,91
Mean	2,01	1,62	1,56	1,63	2,09	1,61	1,57	1,63
Standard dev.	0,26	0,24	0,31	0,24	0,30	0,25	0,30	0,26
Minimum	1,46	1,28	1,01	1,32	1,50	1,21	1,06	1,27
Maximum	2,50	2,20	2,14	2,17	2,64	2,17	2,09	2,15
Range	1,04	0,91	1,13	0,85	1,13	0,95	1,03	0,88
Corr. with "All"	0,59	0,78	0,90	1	0,28	0,79	0,90	1

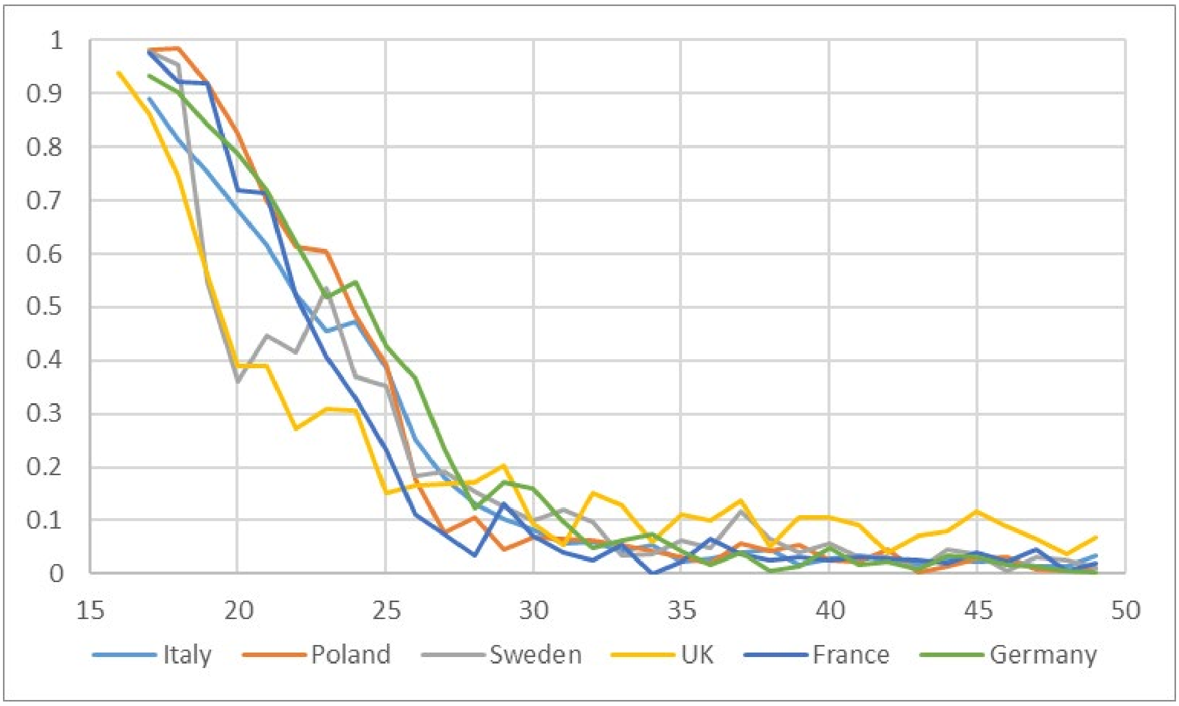
[1] Data source : EU-SILC. CS 2011-2013. Women aged 15-49. semi-retrospective approach. Education: Low: pre-primary. primary. lower secondary; Middle: upper secondary. post-secondary; High: tertiary

[2] Total fertility rates from the World Bank World Development Indicators (average TFR 2009. 2010. 2011). Note that these measures are the same than our *post-stratified* Total fertility rates from EU-SILC: semi-retrospective approach with two-year delay based on cross-sectional samples 2011, 2012 and 2013 (TFRs calculated for calendar years 2009, 2010 and 2011 – combined sample).

Note: the second part of the table presents the unweighted mean for each column, and some basic unweighted indicators of dispersion: standard deviation, minimum, maximum and range, as well as the correlation with the fertility index for the whole population.

Appendix A: Proportion of women still in education, by age

Figure A.1. Proportion of women in education, by age



Data source: EU-SILC – CS 2010.

Appendix B: Lexis-diagram of the observed universe to estimate synthetic fertility indices for 2010, based on EU-SILC 2012.

Figure B.1. Illustration of the semi-retrospective approach to observe education- and age-specific fertility, by mobilizing one wave of EU-SILC

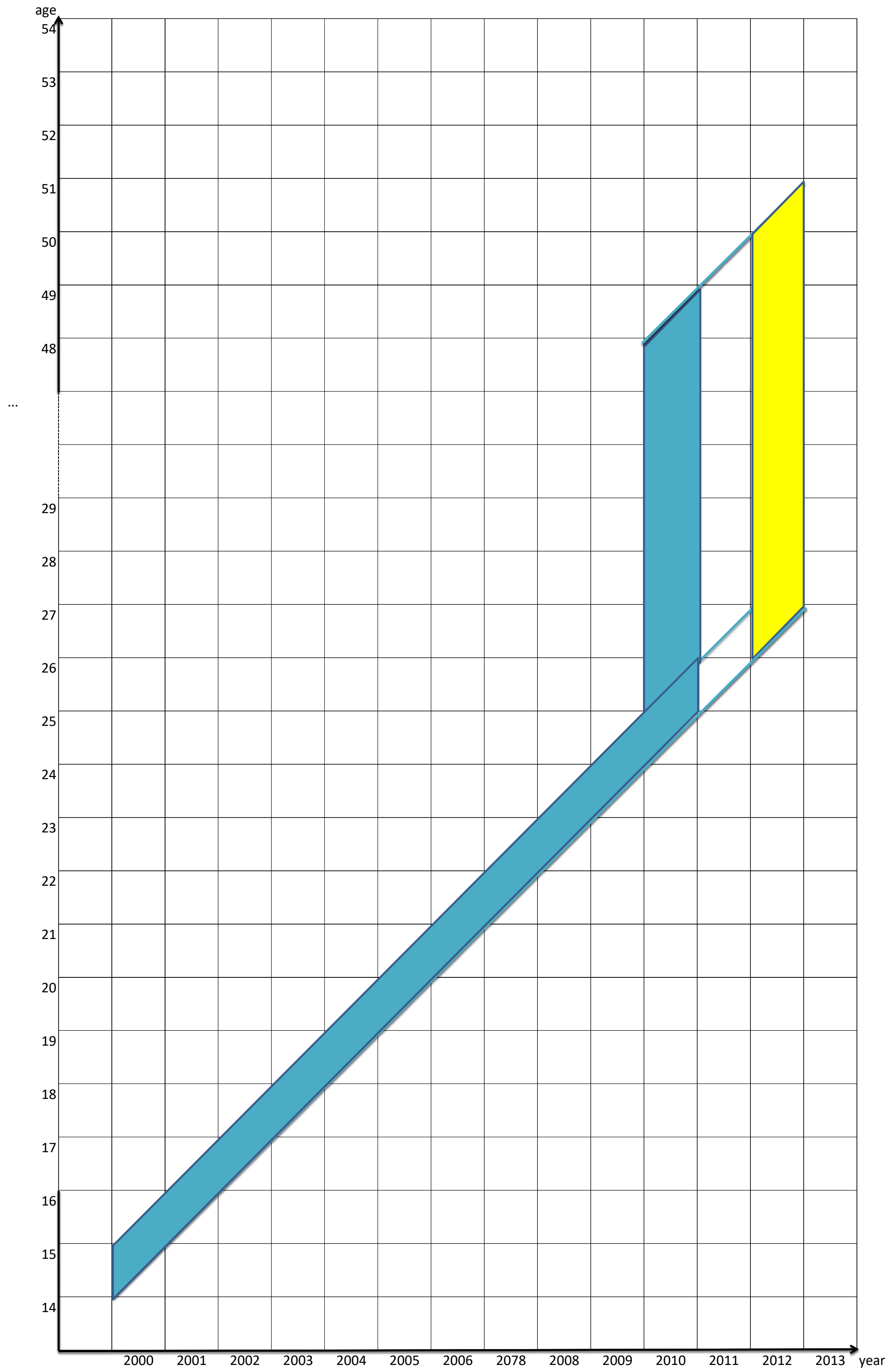
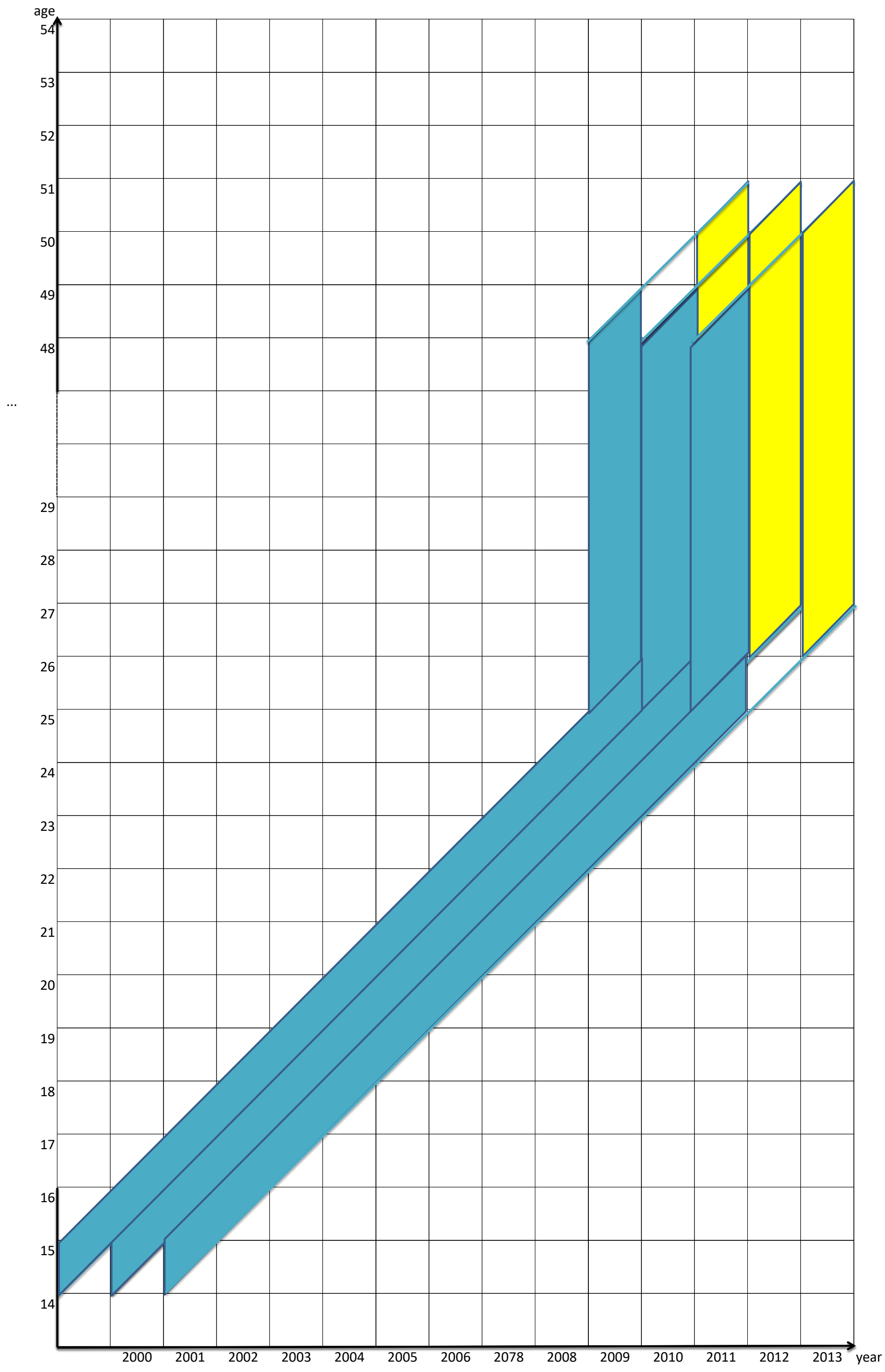


Figure B.2. Illustration of the semi-retrospective approach to observe education- and age-specific fertility, by combining three waves of EU-SILC (2011-2012-2013 to measure fertility in 2009, 2010, and 2011 respectively)



Source: creation by the authors

Appendix C: Posterior estimates and variances

C.a. Prior and posterior estimates of fertility rates

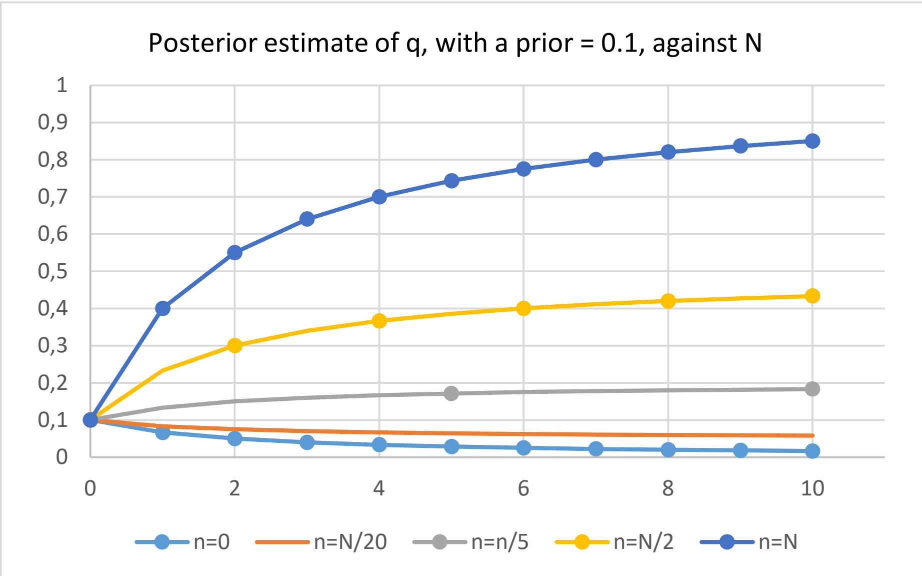
Consider a set of N respondents. Among them, n had a child. The final estimate (posterior) is a weighted mean of the prior estimate *prior* and the Bernouilli simple estimate (n/N), the weights being 2/(N+2) and N/(N+2):

$$Posterior = \frac{n + 2prior}{N + 2} = \frac{n}{N} \frac{1 + \frac{2\,prior}{n}}{1 + \frac{2}{N}} = \frac{2}{N + 2} prior + \frac{N}{N + 2} \frac{n}{N}$$

The curves in Figure C.1 show how the posterior diverges from the prior (if N=0) to converge to the limit n/N. As far as N>5, the estimates are very close to the usual ratio n/N. The dots indicate the possible observations in the absence of weights (e.g. with N=2, possible n are 0,1, and 2, so that Bernouilli estimates can only be 0, 0.5 and 1; the corresponding posterior estimates are 0.03, 0.37, and 0.70).

When N=10 or more, the posterior estimate is very close to the Bernouilli estimate n/N, the weight of the prior being only 2/12. With N=10 and n= 0, 2, 5 or 10, the final estimates are 0.02, 0.18, 0.43, and 0.85 respectively

Figure C.1



C.b. Variances of parity- and age-specific fertility rates considering the priors

Let us define the variances:

1. ***Age-specific fertility rates***

$$V1(x) = \frac{p(x, all, all)[1 - p(x, all, all)]}{N(x, all, all)}$$

2. Parity- and age-specific fertility rates

Instead of the simple variance

$$V(x,r) = \frac{p(x,r,all)[1 - p(x,r,all)]}{N(x,r,all)}$$

We use:

$$V2(x,r) = \left(\frac{N(x,r,all)}{N(x,r,all) + 2w(x,r,all)}\right)^2 V(x,r) + \left(\frac{2w(x,r,all)}{N(x,r,all) + 2w(x,r,all)}\right)^2 V1(x)$$

3. Parity- and age-specific fertility rates for each educational group

Instead of the simple variance

$$V(x,r,e) = \frac{p(x,r,e)[1 - p(x,r,e)]}{N(x,r,e)}$$

We use:

$$V2(x,r) = \left(\frac{N(x,r,e)}{N(x,r,e) + 2w(x,r,e)}\right)^2 V(x,r,e) + \left(\frac{2w(x,r,e)}{N(x,r,e) + 2w(x,r,e)}\right)^2 V2(x,r)$$

The variance of the cumulated probabilities are thus much lower when we use the priors, in case of very small numbers: we introduce a small downward bias in educational differences, but avoid large variance due to too small numbers.

4. *Cumulated age-specific rate*

We estimate the variances of the cumulated probabilities by a simple summation of the variance of age-specific rates:

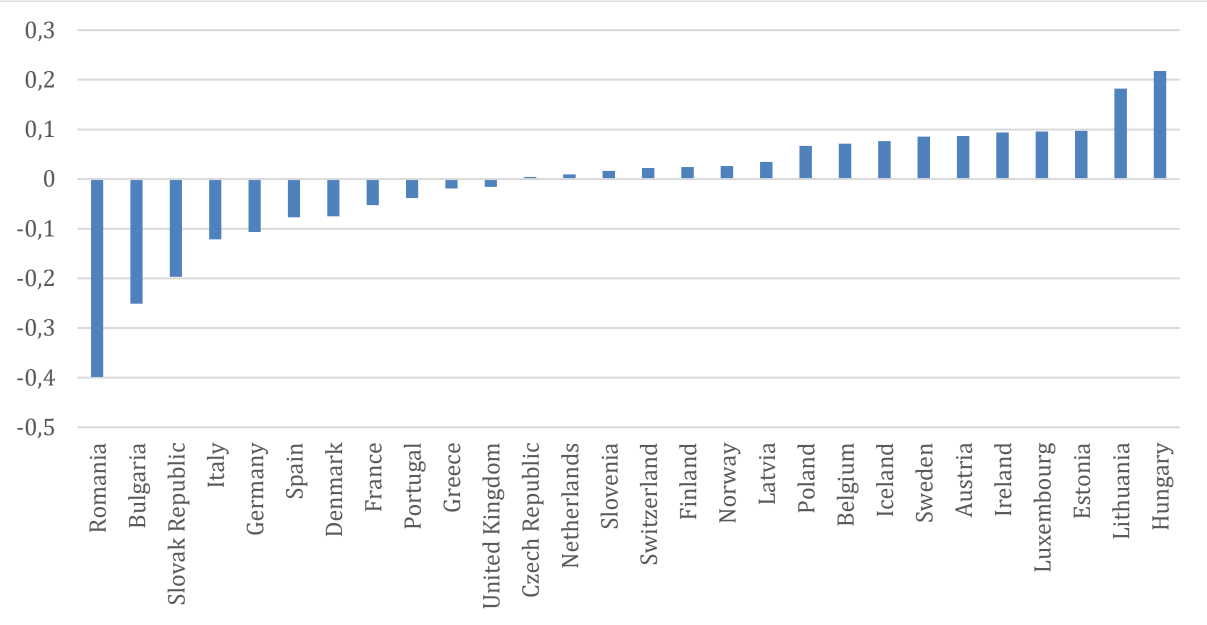
Let *TCum*(*x*) be the sum of the age-specific rates up to *x*, and *VCum*(*x*) its variance:

$$TCum(x) = \sum_{y=15}^{x} p(y, all, all)$$

$$VCum(x) = \sum_{y=15}^{x} V1(y)$$

Appendix D: Estimates of Total fertility rates

Figure D.1. Relative difference between total fertility rates from the WB WDI and those obtained with EU-SILC (in percent)



Total fertility rates from the World Bank World Development Indicators: average TFR 2009, 2010, 2011.

Total fertility rates from EU-SILC: semi-retrospective approach with two-year delay based on cross-sectional samples 2011, 2012 and 2013 (TFRSs calculated for calendar years 2009, 2010 and 2011 – combined sample).

Relative difference calculus: (SILC-WDI)/WDI

Appendix E: Post-stratification

Assuming that the answers regarding children in the household are accurate in the survey, and that all children are living with their mother, the overall bias in fertility in EU-SILC may come from different survey response rates among women who gave birth two years ago and those who did not. Under this assumption, the observed fertility rate is a simple function of the true fertility rate and the ratio of response rates in the two groups. More precisely, for any group in the population, let us call:

- *N* the observed number of women
- *n* the number of births
- *r*1 the response rate among women who gave birth
- *r*0 the overall response rate
- *p* the birth probability (the fertility rate, observed in absence of differential non response)
- *pr* the observed proportion (measured fertility rate)
- OR(*p*) the odds ratio of a proportion *p*

We have:

$$p = \frac{n}{N} \text{ ; } \mathrm{OR}(p) = \frac{n}{N-n}$$

$$pr = \frac{n\,r1}{(N-n)\,r0 + n\,r1} \text{ ; } \mathrm{OR}(pr) = \frac{n\,r1}{(N-n)\,r0} = \frac{r1}{r0}\ \mathrm{OR}(p)$$

As *pr* and *p* are typically lower than 0.2, we may assimilate the odds ratios to relative risks, so that:

$$pr \approx \frac{r1}{r0} p$$

In practice, the post-stratification based on a common factor *r* = *r*1/*r*0 for all population groups leads to the most careful post-stratification (with minimal changes from the raw data). It may lead to a relative change in our estimates slightly closer to 1 than *r*, because of the non-linearity of the multi-stage life table, but in practice the corrections are very similar.

More sophisticated post-stratification could be used, based on age- or parity-specific estimates of *r*. There may be some reasons to assume that childless women's response rate is different to the one of mothers. Under that assumption, only first birth probabilities would be affected – mothers responding in the same way if they had a child or not 2 years before the survey.

We compared the impact of such an assumption on the parity distribution, together with a direct adjustment on the odds ratios of cumulated probabilities. Elaborating on Devolder (2018)'s relation between the Total fertility *F* and the mean parity progression ratio *a* [the relation is simply *F*=OR(*a*) = *a*/(1-*a*)], we may use the series *F*1_i, (i=1; 5+) of the proportion of women having at least *i* children, *i*=1,5. We have: *F*1 = Sum(*F*1_*i*). We consider that the minimal change in the distribution of women by number of children ever born, from an initial series of *F*1_*i*, (*i*=1; 5+) to a final series of *F*2_i, (*i*=1; 5+), is given by a translation of *R* of the odds ratios:

$$\text{For all } i, \mathrm{OR}(F1\_i) = \frac{F1\_i}{1 - F1\_i} \text{ and } \mathrm{OR}(F2\_i) = \frac{F2\_i}{1 - F2\_i}$$

$$\text{For all } i, \mathrm{OR}(F1\_i) = \mathrm{OR}(F2\_i) + R$$

Taking the example of highly educated women in Austria (country arbitrarily chosen as the first one on the list), the Figure below shows the impact of a post-stratification of the TFR from 1.54 (EU-SILC measure) to 1.42 (WB WDI measure). When a ratio of 1.42/1.54=0.92 is applied to all age- and parity-specific fertility rates, the total birth intensity of highly educated women moves from 1.45 to 1.35 children per woman (a ratio of 0.93). Table E.1 shows that different methods of post-stratification all lead to the same estimate of 1.35, but that the final distribution by parity depends on the method.

Table E.1 distinguishes between three different post-stratification scenarios. Due to the multi-state life table logic, lower fertility rates at all ages all parities imply a larger decline in higher-birth-order births than in first births. The first-birth intensity moves from 0.74 to 0.71 first births per woman, a 4% decline only, because lower probabilities at young ages mean more women at risk at older ages, and then a lower decline (even an increase) in first births at old ages (see Table E.2). As lower first birth rates mean less first births occurring at later ages, the second birth intensity is reduced at a large pace, from 0.55 to 0.50 second births per woman (a 8% decline). The relative decrease is even more pronounced for higher birth orders.

When we change only first birth probabilities (line “First probabilities only” in tables E.1 and E.2), the relative decline is similar for first births and higher-order births (0.93): less and later first births lead to a decline in second births, even if the second birth probabilities are unchanged. Using lagged cumulative odds ratios of proportions (Lagged odds ratios, following Devolder 2018, see above) leads to an intermediate result.

Table E.1. Fertility by birth order (children per women). Austrian highly educated women

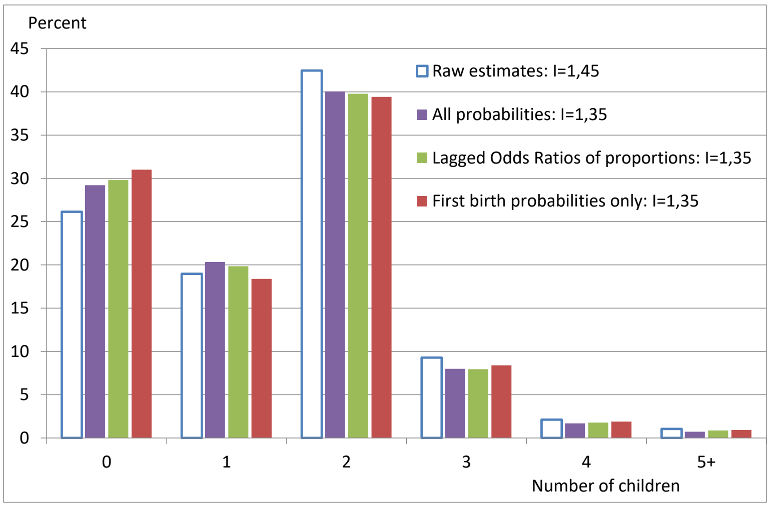
Birth order	1	2	3	4	5	All
Raw estimates	0,74	0,55	0,12	0,03	0,01	1,45
All probabilities	0,71	0,50	0,10	0,02	0,01	1,35
First birth probabilities only	0,69	0,51	0,11	0,03	0,01	1,35
Lagged odds ratios	0,70	0,50	0,11	0,03	0,01	1,35

Table E.2. Relative fertility by birth order (ref. = raw estimates). Austrian highly educated women

Birth order	1	2	3	4	5	All
Raw estimates (reference)	1	1	1	1	1	1
All probabilities	0,96	0,92	0,84	0,77	0,70	0,93
First birth probabilities only	0,93	0,92	0,90	0,89	0,89	0,93
Lagged odds ratios	0,95	0,92	0,85	0,84	0,84	0,93

According to these results, it could appear convenient to adjust only first birth probabilities, based on the assumption that non-response is larger among childless women - all the more that this adjustment leads to more or less proportional change in births intensities at all birth orders. But the consequence in terms of distribution by final parity is very different. When all probabilities are modified, the decline in first births is lower, and it is compensated by the decline is second birth rates, leading to a small increasing proportion of women with one child (Figure E.1). At higher parities, the change in the distribution is less pronounced when all rates are changed. Finally, adjusting all birth probabilities (at all ages, all parities), based on the simplest assumption on non-response (the participation in the survey is better for young mothers, irrespective of any other characteristics) appeared as the correction leading to the smallest changes in the final distribution.

Figure E.1. Distribution of Austrian highly educated women by final parity



We also tried to post-stratify age-specific rates in order to make them consistent with official figures (coming from the Human Fertility Data Base). However, this post-stratification led to unstable results when we compared groups by education, which were difficult to interpret due to the complex interaction between distribution by parity at each age and parity- and age-specific schedules by level of education in different countries.

We did not envision assuming differential response bias by level of education, in order not to introduce any artefact in our comparison by level of education.

Appendix F: Distribution of women aged 15-49 by education

Table F.1. Proportion of women aged 15-49 by education

country	low educated	middle educated	high educated
AT	15,79	63,82	20,39
BE	18,11	34,82	47,07
BG	19,40	46,96	33,65
CH	13,23	56,58	30,19
CY	15,79	37,87	46,34
CZ	5,11	67,71	27,17
DE	7,74	54,82	37,44
DK	13,31	40,35	46,33
EE	8,43	41,35	50,22
EL	17,67	44,77	37,56
ES	33,45	25,59	40,97
FI	6,20	44,53	49,28
FR	12,31	43,02	44,67
HR	13,60	60,46	25,94
HU	15,03	53,98	30,98
IE	14,49	36,03	49,48
IS	23,10	35,52	41,37
IT	30,17	47,83	22,00
LT	6,75	45,24	48,01
LU	29,00	35,53	35,46
LV	9,95	48,54	41,51
MT	54,11	22,21	23,69
NL	15,98	40,31	43,71
NO	15,45	32,16	52,39
PL	5,55	55,77	38,67
PT	46,90	27,42	25,68
RO	20,17	54,54	25,29
RS	14,58	60,31	25,11
SE	5,97	43,15	50,88
SI	10,10	54,55	35,35
SK	4,26	60,62	35,12
UK	8,39	44,15	47,46

Education: Low: pre-primary, primary, lower secondary; Middle: upper secondary, post-secondary; High: tertiary

Data source : EU-SILC, CS 2011-2013

Women aged 15-49, semi-retrospective approach

Abstract

This study is based on data from Eurostat, *EU Statistics on Income and Living Conditions* [2011,2012,2013]. The responsibility for all conclusions drawn from the data lies entirely with the authors.

This article provides new measures allowing comparing within-country differences in current fertility behavior in Europe. By mobilizing data from the European Union's Survey of Income and Living Conditions (EU-SILC), we measure the educational gradient of female period fertility for a large set of European countries. A semi-retrospective approach serves to observe fertility behavior of cohorts that are currently at childbearing age, while at the same time recording the educational level correctly. Bayesian statistics allow us to obtain credible intervals for the age, education- and parity specific birth probabilities for each country. These birth probabilities are then combined into a multi-state life table in order to obtain parity-specific and total birth intensities by education. A post-stratification of birth probabilities leads us to be consistent with national fertility estimates, enabling international comparisons for specific groups (e.g. highly educated women) or for particular dimensions of fertility behavior (e.g. childlessness). This analytical set-up allows us to reveal if there are significant differences between education groups in fertility behavior within each European country and in how far these differentials vary between European countries. More precisely, we answer the question if –all birth orders combined– heterogeneity in period fertility behavior is larger among the higher or the lower educated across Europe. In addition, we show for which parity the heterogeneity between education groups is the largest.

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