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Research Article

Measuring the educational gradient of period fertility in 28 European countries: A new approach based on parity-specific fertility estimates

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Measuring the educational gradient of period fertility in 28 European countries: A new approach based on parity-specific fertility estimates

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Abstract

BACKGROUND
Measures of fertility by level of female education are currently only available for cohorts that have already completed childbearing age. The focus on cohorts whose fertility decisions were made in the past is problematic when the objective is to better understand which specific groups within European countries are currently the most affected by low and/or declining fertility.

OBJECTIVE
In this article we provide more timely measures of the educational gradient of fertility for Europe by quantifying it for those cohorts that are currently of childbearing age (ages 15 to 49) for most European countries.

METHODS
To measure period fertility by education for 24 EU and 4 non-EU countries in Europe, we use data from the European Union's Survey of Income and Living Conditions, EU-SILC (Eurostat 2020). A semi-retrospective approach is used to observe the parity-specific fertility behavior of cohorts that are of 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 allows consistency with national fertility estimates, enabling international comparisons of specific groups (e.g., highly educated women) or of particular dimensions of fertility behavior (e.g., childlessness).

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RESULTS
Our analytical set-up reveals whether there are significant differences in fertility behavior between education groups in each European country and how these differentials vary between European countries. More precisely, we answer the question of whether, when all birth orders are combined, heterogeneity in period fertility behavior is greater among the higher- or the lower-educated across Europe. In addition, we show for which parity the heterogeneity between education groups is the largest.

CONCLUSIONS
Even if low-educated women have the highest period fertility levels in almost all covered European countries, the educational gradient is not always negative. In one-third of European countries, period fertility levels in 2010 exhibit a U-shaped pattern, with the middle-educated having the lowest fertility. The diversity in period fertility levels among highly educated women in Europe is due to the transitions to first and second childbirth of highly educated women being higher in some countries than in others, while higher-order childbirths exhibit a more negative educational gradient across Europe.

CONTRIBUTION
By delivering a new method for measuring the educational gradient of fertility for women who are of childbearing age rather than for women who have already completed their reproductive years, our research enables a timely analysis of within-country differentials of period fertility behavior.

1. Introduction

Although fertility increased in many European countries between 1990 and 2010, since 2010 fertility has been stagnating or decreasing in countries where previously fertility was close to 2 children per woman. The COVID-19 crisis certainly accelerated the trend of declining fertility, but did not trigger it (Sobotka et al. 2022). Fertility levels and trends in Europe – and thereby long-term population-aging trends – have important impacts on both economic and social outcomes, and need to be monitored in detail. While European cross-country differences in total fertility rates (TFR) are rather well-documented today (see for example the OECD Family Database: https://www.oecd.org/els/family/database.htm; or the 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, such as by educational level, that covers all European countries.

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

In this article we deliver a new methodological approach to measuring 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 dataset that has not yet been used for this kind of demographic analysis (European socioeconomic survey data: EU-SILC), we quantify the educational gradient of fertility for the cohorts that are currently of childbearing age (ages 15 to 49) for the large majority of European countries.

Our country-by-country analysis allows a timely insight into the educational composition of fertility levels in Europe and their components by birth order. Our measures of the educational gradient of period fertility reveal whether fertility differentials are important for those who are currently of childbearing age, within each European country. This is particularly relevant in a context where total fertility rates are below replacement level in all European countries, and are even re-decreasing in some: The EU average increased from 1.48 children per woman in 2005 to 1.60 in 2010, but then decreased to 1.50 in 2020 (Human Fertility Database 2023).[3] Fertility increased after 2010 in a few countries (e.g., Germany and Hungary), but since 2017 total fertility rates have been decreasing in most European countries.

Measuring the educational gradient of period fertility allows for a better understanding of which educational group has the lowest fertility, and whether the contrasts by education are larger for the entry into motherhood or for the progression from one birth to the next. Moreover, consistent measures for each European country allow for comprehensive international comparisons. By delivering measures of the educational gradient of fertility for women who are of childbearing age rather than for women who have already completed their reproductive years, our research enables a timely analysis of the within-country differentials of period fertility behavior. This article presents measures for 28 European countries for the year 2010, complemented by measures for 2005 and 2015 presented in online Appendices I (tables) and II (figures). A more precise analysis of fertility in 2010, focusing on six countries which are representative of different European regions (France, Germany, Italy, Poland, the United Kingdom, and Sweden), allows a clear understanding of fertility differentials by education in those countries. This analysis is based on indices such as period cumulated fertility by age, for all birth orders as well as for first, second, and third births, thus allowing a comparison of the timing and intensity of parity-specific fertility among

[3] In a few European countries, TFRs have increased to some extent over the last decade, starting from very low levels (in Germany and Hungary, for example).

different educational groups in each country. The analysis and the calculation method presented in this article lend themselves to producing annual data, enabling the empirical analysis of institutional determinants of educational gradients in period fertility behavior in Europe.

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

2. The state of play

To our knowledge, to date no study exists that delivers measures of the educational gradient of period fertility levels for a comprehensive set of European countries. The reason for this is that a series of technical barriers and data limitations make all-encompassing analyses difficult. Existing studies of the educational gradient of fertility often use a reduced analytical spectrum to bypass the methodological and data-related barriers: They focus on parity-specific period fertility, or on a certain country or a subset of European countries, and/or limit the analysis to women who have already completed their childbearing years. In this section we present the existing studies and describe the methodological barriers and data-related limitations, thus highlighting the challenges and potential contributions of our study.

2.1 Parity-specific analyses of fertility behavior by education in European countries

Since the pioneering work of Whelpton (1946), parity, i.e., the number of children ever born, has been used as a major covariate of fertility, in addition to age, in order to accurately measure period fertility. Empirical analyses of period fertility behavior by education are often limited to specific birth orders (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 (for example, Rondinelli, Aassve, and Billari 2010; Schmitt 2012; Pailhé and Solaz 2012; Jalovaara et al. 2019), which hinders modelling context dependency.

2.2 Limited availability of internationally comparable data

The focus on specific parities and single countries that prevails in demographic research analyzing period fertility behavior in Europe is due to a lack of harmonized international data that combines high quality demographics with comparable socioeconomic measures. Some European countries deliver survey data that combines demographic and socioeconomic measures, be it cross-sectional or longitudinal – for example, Germany (SOEP) and the United Kingdom (BHPS). However, as not all available panel surveys are harmonized (socioeconomic variables such as education and labor market participation are not always coded in 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 institutional determinants of demographic behavior.

An alternative to consider is census data, but census questionnaires are also not fully harmonized across European countries and censuses are not available on a yearly basis, making it impossible to observe yearly fluctuations of period fertility behavior. In addition, there is a risk of undercounting young children in census data (O'Hare 2017; Toulemon 2017; Tomkinson 2023). O'Hare (2017) shows that the risk exists worldwide, including in high income countries. By comparing French census data to the French demographic panel EDP (a 4% sample of French inhabitants combining information from census data, civil registration data, income tax files, and employment-related administrative files), Tomkinson (2023) shows that very young children (ages 0–2, before their enrollment in pre-school) tend to be under-declared in the French census, in particular for large and complex families, for higher-order children, and for households where the respondent may not be the mother.[4] One possible reason is that filling out an additional census form for a very young child does not seem useful to some parents, as not much information can be given other than purely demographic information.

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 GGS is engaged in the second round of data collection (GGS-II). Thus, it still has relatively limited country- and time-coverage. More socioeconomically oriented surveys with larger country- and time-coverage are possible alternatives. The European Union's Labour Force Survey (EU-LFS) could be used as a harmonized large-scale dataset to estimate fertility (see, for example, Bordone, Billari, and Dalla Zuanna 2009), but it comes with several technical shortcomings. First, fertility

[4] Among households participating in the French census, multi-generational households where the responding household head is not the parent of the young child are found to have a children omission rate of more than 17%, compared to only 3.5% for single-family households.

is not covered explicitly (there is no explicit question on the existence of children in the questionnaire), 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 put together different waves). Third, the released data do not include exact age but only 5-year age groups,[5] which makes it complicated to compute period fertility measures with the own-children method.

Combining different data sources (national censuses and surveys, GGS, etc.) might enable researchers to cover several countries, but would result in many variables not being harmonized. 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 now covers 32 European countries: 28 EU countries and 4 non-EU countries (United Kingdom, Iceland, Norway, Switzerland). Years are covered from 2004 on, for most countries. Besides annual cross-sectional waves (which we use in this article), EU-SILC comes with a short rotational panel (not used in this analysis) which follows up individuals and households for a period of four years. However, EU-SILC does not provide straight fertility measures. Like the EU-LFS, it has no explicit question on the number of children in and outside the household. This makes the use of EU-SILC rather inconvenient for the analysis of socioeconomic differentials of period fertility behavior, albeit not impossible, as children have their own register file in EU-SILC (see section 3 for more detailed information about the method applied to enable the observation of period fertility in EU-SILC). The number and age of household members, including children, are used to produce statistics on living standards, income distribution, and poverty, based on the "equivalized household size" and "equivalized disposable income" (Eurostat 2023).

Greulich and Dasré (2017) evaluate positively the accuracy of period fertility measures derived from the cross-sectional database in EU-SILC 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, Drefahl, and Vignoli (2014) use the Italian short EU-SILC panel to estimate group-specific fertility rates. They find that despite the absence of questions on fertility in EU-SILC, group-specific fertility estimates (by income level, for example) can be obtained that are not biased by memory or selection of respondents, and which can be made consistent with the TFR observed in that period for the entire population. Rendall and Greulich (2016) demonstrate the feasibility of using the Polish short panel in EU-SILC to incorporate labor-market-related predictor variables on both the woman and her

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[5] https://ec.europa.eu/eurostat/documents/1978984/6037342/EULFS-Database-UserGuide.pdf. More precise information on respondents' and children's age is available for some countries, but not for all and all time periods.

partner, which are observed sufficiently prior to a birth event to reduce the endogeneity problems that compromise studies of fertility using cross-sectional data. Using multiple imputations to increase statistical power, they show that relative to not being full-time employed, having been full-time employed for two or more years is a positive and statistically significant predictor of childbearing for partnered women. Rendall et al. (2014), Klesment et al. (2014), Greulich, Dasré, and Inan (2016), Greulich, Thévenon, and Guergoat-Larivière (2017), and Nitsche et al. (2018) model educational gradients of parity-specific transition probabilities (individual-level regressions). Nitsche et al. (2018) show that highly educated homogamous couples have relatively high second- and third-birth rates compared to more hypergamous couples (in terms of education distribution between spouses) in many European countries. However, aggregate levels of period fertility differentiated by education have not yet been modelled with EU-SILC for a large set of European countries and several time periods.

2.3 Focus on completed cohort fertility

Besides the difficulty of choosing the appropriate data source, the absence of measures of period fertility levels differentiated by socioeconomic characteristics is due to methodological problems: education, labor market status, and income evolve over the life cycle (and thus vary with age). Also, age at birth (also called the ‘timing’ of births) varies across socioeconomic groups. The evolution of socioeconomic 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 ‘low-educated’, including those women who will continue education and who are not likely to have children at very young ages. To avoid any distortions due to differences between groups in the timing of birth and the variation of socioeconomic 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 only taking into account cohorts that have already completed their childbearing years. For the latter reason, most fertility measures focus on women only, as their reproductive years are more restricted than those of men.

Tomas Sobotka has recently provided completed cohort fertility rates for a large set of developed countries, differentiated by level of female education (www.cfe-database.org). Completed fertility rates (CFR) have a negative educational gradient in most European countries (see Sobotka, Beaujouan, and Van Bavel 2017 for an overview), suggesting that 10 to 20 years ago (at the time of their fertility decisions) it was mainly higher-educated women who were limiting their fertility. Nisén et al. (2021) measure women's completed fertility (women born in the late 1960s and early 1970s) 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. Brzozowska, Beaujouan, and Zeman (2022) analyze trends in family size by education for cohorts born between the 1930s and 1960s and show an increasing polarization among the low-educated in 16 high-income, low-fertility countries. A recent study by Beaujouan, Zeman, and Nathan (2023) combines various data sources (micro census data, household panel survey data, GGS data) to study how changes in completed cohort fertility (women born in the late 1960s and early 1970s) relate to age at first birth in 10 high income countries. They show that increased fertility intensities of mothers at older ages are insufficient to offset the depressing effect of delayed first births on cohort fertility rates (1940–1969 birth cohorts) in 10 high-income countries.

The completed-cohort approach enables an accurate demographic analysis of fertility by age and birth order across cohorts, but comes with the inconvenience that it only covers women who have already completed their fertility. The focus on cohorts whose fertility decisions were affected by past – but not current – policies is 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.

2.4 Challenges and potential contributions of our study

So far no comparative study exists that goes beyond cohort- or parity-specific analysis and quantifies the demographic impact of current socioeconomic differentials on levels of period fertility. Consequently, we do not know exactly which specific groups currently have the lowest fertility levels in European countries, or to what extent these groups contribute to the relatively low total fertility rates. Recent studies analyzing determinants of the transition to a first or second child suggest that in several European countries, highly educated couples no longer have the lowest probability of starting and enlarging a family (Greulich, Thévenon, and Guergoat-Larivière 2017; d'Albis, Gobbi, and Grelich 2017; d'Albis, Greulich, and Ponthière 2017; Nitsche et al. 2018). However, without combining all birth orders it is unclear whether these higher first and second birth transition ratios for highly educated women result in higher overall period fertility levels for this group. Thus, a broader analytical spectrum is necessary in order to determine socioeconomic differentials in current fertility levels. 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 a large 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 selected European countries, applying a series of precautionary measures to reduce measurement bias in fertility. For example, to reduce attrition bias, we apply the own-children method to the cross-sectional database rather than the rotational panel and use a two-year 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 the fertility behavior of cohorts which are of 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 results in consistency 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 determine whether there are significant differences in fertility behavior between education groups in each European country and how far these differentials differ across European countries. More precisely, we will answer the question of whether, combining all birth orders, heterogeneity in period fertility behavior is greater among the higher- or the lower-educated across Europe. In addition, we will see which parity has the greatest heterogeneity between education groups.

3. Methodology

3.1 Measuring period fertility

We use the European Union Statistics of Income and Living Conditions (EU-SILC) to obtain period fertility measures. 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. 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. However, in this mainly methodological paper 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. Such comparisons are beyond the scope of this paper, but providing our SILC-based measures of period fertility by education as well as a detailed data compilation protocol enables the research community to pursue work in this direction. Measures for 2005 and 2015 can be found in online Appendix I. Computing period fertility levels around the year 2010 means that we observe childbirths in three calendar years: 2009, 2010, and 2011. We group together 3 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 own register file containing their basic demographic information (age, sex…) as well as a mother and father id. This allows assessing fertility using the 'own children method'[6] by merging parents with their children. However, there are potential biases for period fertility measures calculated with EU-SILC. First, fertility might be underestimated and birth orders not correctly attributed due to unobserved children living outside the household. Second, as the annual cross-sectional data in EU-SILC is produced from the longitudinal panel (integrated design[7]),

[6] 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).
[7] 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

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, leading 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 the majority of covered countries (between –10% and –20% depending on the country). This particularly concerns fertility rates for ages 20 and 25. 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 as unbiased fertility measures coming from the Human Fertility Database 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 have recently moved due to childbirth re-enter the probability sample. For the analysis proposed in this study, a time delay of 2 years emerges as the best compromise to meet two different goals when measuring period fertility using EU-SILC: reducing the attrition-linked measurement bias in period fertility while at the same maintaining information that is as up to date as possible in a cross-sectional setting.

Thus, we allow for a time delay of 2 years when calculating our period fertility measures using 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 to observe births during the year 2009, and the 2013 wave for births during the year 2011. Using survey waves 2011, 2012, and 2013 of the cross-sectional EU-SILC sample allows us to cover 28 European countries.[8]

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.

[8] Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland (non-EU), Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway (non-EU) Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland (non-EU), United Kingdom (non-EU). Cyprus and Malta are excluded due to small sample size. Serbia and Croatia are excluded as they joined the EU-SILC later than 2011.

3.2 Recording education-specific period fertility behavior

To obtain education-specific period fertility measures, we apply a semi-retrospective approach. This approach serves to observe the fertility behavior of cohorts which are currently of childbearing age, while at the same time recording the educational level correctly. For the variable measuring education we use the UNESCO ISCED classification available in EU-SILC (cross-sectional waves 2011, 2012, and 2013) to distinguish three levels (uniform categories across all countries): 'low education' for pre-primary, primary, and lower secondary education (ISCED values 0, 1, and 2); 'medium education' for upper secondary and post-secondary non-tertiary education (ISCED values 3 and 4); 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) (ISCED value 5).

The objective is to observe the age-specific fertility behavior of women of different education levels, by recording their completed educational level at the same time. The problem is that when we apply a purely cross-sectional perspective to observe the fertility behavior of women who have not yet completed education we risk underestimating the 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 age 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 age 20 for women with low- and middle-education. To avoid this underestimation, we follow Greulich, Thévenon, and Guergoat-Larivière (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 whom 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 2-year delay mentioned in the section above.

For education-specific fertility observed for ages 15 to 25, 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%.[9] When considering the European countries in 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 thus emerges 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.[10] 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. There are certainly national differences in the length of primary, secondary, and tertiary education. However, as in all 28 countries in our sample educational enrolment is below 20% from age 27 on, we use age 27 uniformly in all countries to observe education for the retrospective approach. For education-specific fertility observed for ages 26+, 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 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. Note that for period fertility observed at ages above 35, adult children moving out of the parental home are not likely to greatly disturb our period fertility measures obtained with EU-SILC, as age gaps of more than 15 years between children are not very common. Greulich and Dasré (2017, 2018) show that the departure of children risks biasing fertility measures obtained with EU-SILC much more for completed cohort than for period fertility.

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 of childbearing age at the time of the survey.[11] The figures in Appendix B illustrate with a Lexis diagram the logic of our semi-retrospective approach, including the 2-year delay based on one wave (2012; Figure B-1), respectively on three cross-sectional waves (2011, 2012, and 2013; Figure B-2).

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[9] These six countries (France, Germany, Poland, Italy, Sweden, and the United Kingdom) 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 of a specific region in Europe.

[10] 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.

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

3.3 Combining tempo and quantum information

To see if and to what extent 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, differentiating by age, education level, and parity. We use order-specific birth probabilities (quotients) and not order-specific birth rates (incidence rates). Thereby, 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:

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

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

As mentioned in the section above, 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 $W(x,r–1,e)$ 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 $W(x,r–1,e)$ 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 by 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).

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:

$\mathrm{CB}(x,r,e) = \Sigma\, \mathrm{B}(y,r,e)$ over y, $y<x$
$\mathrm{CB}(x,\mathrm{all},e) = \Sigma\, \mathrm{B}(y,r,e)$ over r and y, $y<x = \Sigma\, \mathrm{CB}(x,r,e)$ 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 in 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.[12] We cumulate the age-specific birth intensities up to age 49 for each parity and sum up the different parity-specific birth intensities. Thus, 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 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 so that our country-, age-, parity-, and education-specific estimations are sometimes based on relatively small sample sizes[13] (which implies some additional cleansing; see next section). As we consider the level of education as fixed after age 27, and use education at age 27 to classify women for ages 15–25, we run separate multi-state life

[12] This hypothesis may be simplistic, 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.
[13] This is particularly the case for low-educated women at young ages at risk of higher parity-births: for example, in Germany in 2010 there are only 28 low-educated women below the age of 25 who are at risk of a second birth in our sample (and only 3 below the age of 21).

tables for each educational group, allowing us to compare three different groups of women in each country each year, consistently over the age range.

Note that we could have adjusted for tempo changes, 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 here we consider that life table estimates need not to be adjusted for tempo change (Ní 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 explicitly aiming to represent cohort fertility (Van Imhoff 2001), and without any assumption regarding 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.

3.4 Obtaining credible estimates and intervals for birth probabilities

For some of the countries we obtain relatively high values for some of our education-, age-, and order-specific birth probabilities. This is notably the case for some of the probabilities of higher-order birth 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 caused not only by the relatively small sample sizes in some countries, but also by the fact that fertility behavior can be very specific when it comes to the higher order births of very young mothers (Bongaarts and Feeney 1998). For example, 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).

Whether the reasons for these high birth probabilities at young ages are substantial or technical, 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). We then estimate age- and parity-specific probabilities based on events and exposures, by using priors n°1 to limit large random variations when 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 to random variations caused by specific outliers than Bernouilli estimates. This is especially 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 do not vary 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 weight, 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*,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*,all,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*,all) for age *x* and parity *r*-1, based on the age-specific priors *p*(*x*,all,all)

We first average the mean weights *w*(*x*,*r*,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 the 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 the 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 the 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 computation 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) and 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 proceed 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).

3.5 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, as a first step, the relative difference between total fertility rates coming from official statistics (the World Bank World Development Indicators – WB WDI, World Bank Group 2018) 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 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 2-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 the bias is between 10% and 20% for only four countries. The 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 exceeds the total fertility rate 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 2-year delay between the survey year and the calendar year for which childbirth is observed (which allowed reducing attrition-linked fertility bias, but did not 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 2-year delay), the relative differences between the EU-SILC measure and the WB WDI measure barely change from those illustrated in Figure D-1. This suggests that the main reason for differences between our EU-SILC measures and the total fertility rates from the WB WDI is the over/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 leads 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 together 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 appears to be 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 both the TFRs and the fertility intensities by birth order for each educational group.

4. Results

4.1 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), and Total Fertility Rates (TFRs), by education and overall, for each of the 28 countries covered in our sample, for the year 2010 (see online Appendix I for years 2005 and 2015).

Table 1 shows that in 2010, TFRs vary between 1.27 and 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 children per woman for highly educated women, 0.24 for middle-educated women, and 0.26 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 with the fertility levels of the highly educated than the low-educated (unweighted correlation coefficients R = 0.90 for highly educated, 0.78 for middle-educated, and 0.59 for low-educated).

Table 1: Overview of results by country, 2010

	Total birth intensity, by education (children per woman)				Total fertility rate, by education (children per woman)			
	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

Data source: EU-SILC.
Semi-retrospective approach with 2-year delay based on cross-sectional samples 2011, 2012, and 2013. Women aged 15–49.
Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary.
EU-SILC measures post-stratified based on total fertility rates from World Bank World Development Indicators (average calculated from calendar years 2009, 2010, and 2011).
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.

In comparison to Total Fertility Rates, our index of total fertility intensity at age 49 reduces the bias due to the delay in childbearing and leads to higher fertility estimates for the high- and middle-educated relative to the low-educated and thus to lower fertility differentials in most countries, with less extreme values, and more consistent estimates. Our total birth intensities at age 49 by education and country show that in almost all countries, low-educated women have the highest fertility. However, the educational gradient is not negative in all countries. In almost one-third of our covered European countries (8 out of 28), period fertility levels in 2010 exhibit a U-shaped pattern, with the middle-educated having the lowest fertility. Highly educated women have a considerably higher fertility level than middle-educated women, particularly in the Nordic countries (Iceland and Denmark, followed by Sweden and Finland) but also in Belgium, the Czech Republic, and Slovenia. Conversely, the educational gradient is particularly negative in Portugal, Bulgaria, Luxembourg, Poland, and Romania.

To go into more detail, Figures 1 to 6 present the age- and education-specific birth intensities for birth orders one, two, and three, as well as all birth orders combined. As the focus of this paper is methodological, age- and parity-specific results are not presented here for all of the selected European countries. In the following we focus on six countries, illustrating the diversity of European period fertility in 2010: France, Germany, Italy, Poland, the United Kingdom, and Sweden. Each of these countries is taken as representative of a specific European region: Germany for the German-speaking countries including Austria and Switzerland, France for the continental countries including Belgium, the Netherlands, and Luxembourg, the United Kingdom 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.

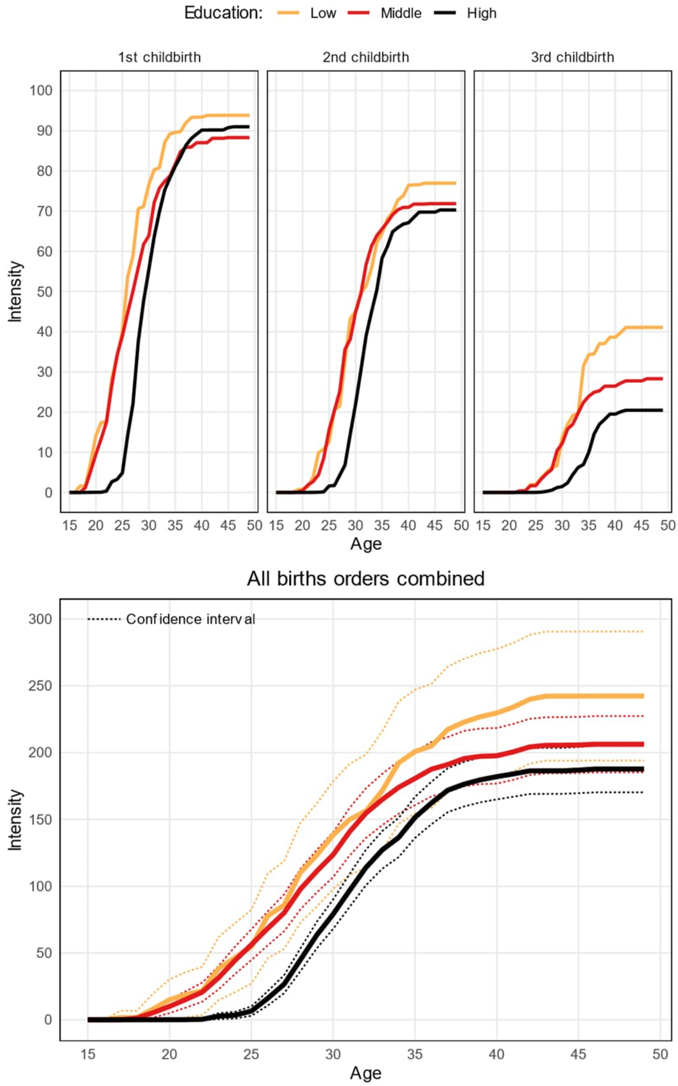
A table with all age-, education-, and parity-specific birth intensities for our six selected countries can be found as supplementary material in online Appendix I. The supplementary material also contains tables with total birth intensities (cumulated at age 49 from fertility life tables), as well as Total Fertility Rates (TFRs), by education and overall, for each of the 28 countries in our sample, for years 2005 and 2015 (in addition to year 2010 presented in Table 1), making it possible to analyze evolution over time. We furthermore illustrate, in online Appendix II, total birth intensities by education for 2005, 2010, and 2015 covering all countries available in EU-SILC, and use the example of Germany and Sweden for an annotated comparison of 2010 and 2015. Finally, the supplementary material contains two STATA do files (one for the data compilation, one for the data output) as well as an Excel file and a readme file documenting in detail our data compilation and calculation procedure (“datacompil.do”, “dataoutputDE.do”; Excel: example for Germany 2010 “Germany2010.xls”, “readme.txt”).[14]

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 age 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 they catch up quite rapidly with middle-educated women in terms of first childbirth. Their intensity of first childbirth catches up with that of middle-educated women at age 32 and even exceeds it from age 36 on. At age 49, 91% of highly educated women have at least one child in France. Therefore, in France the intensity of first childbirth is higher for highly educated women than for the middle-educated (88%).

However, the picture changes for higher-order births in France. For second childbirths, we still observe a relatively high birth intensity for high-educated women (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 again there are no striking differences between low- and middle-educated women in the timing of second childbirths 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 child before age 35, whereas highly educated women tend to have them between ages 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, compared with 2.06 children for the middle-educated 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 age 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+ than middle- and low-educated women.

[14] Yearly measures from 2005 on: work in progress.

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



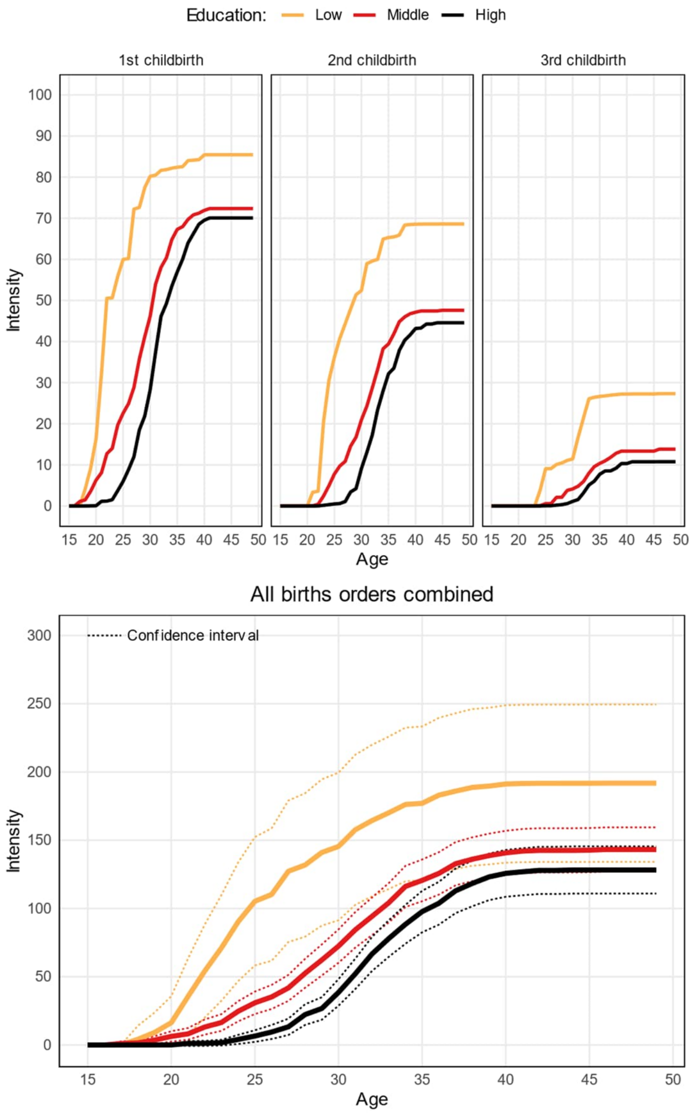
Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Note: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary. Women aged 15–49, semi-retrospective approach. CI (–) and CI (+) = lower and upper limits of confidence intervals.

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

Another striking difference between Germany and France is that in Germany, middle-educated women are much more similar to highly educated women in terms 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 of 27% is close to that of highly educated women in Germany. The difference we observe in Germany in the intensity of first childbirth for low-educated women on the one hand and middle- and high-educated women on the other translates into important differences for higher-order births: over 50% of middle- and high-educated women with one child do not have a higher-order child 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 big difference in the total birth intensity of 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).

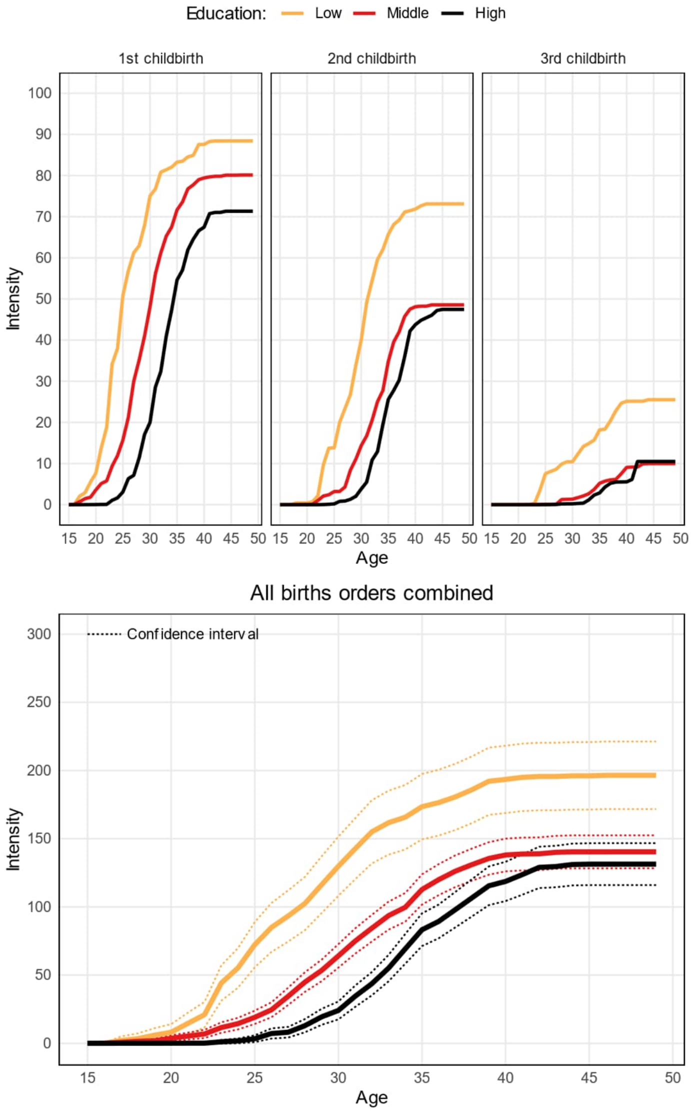
Figure 3 illustrates the birth intensities for Italy. The fertility patterns of highly educated women in Italy are very similar to those of highly educated German women. Middle-educated women in Italy fall in-between their counterparts in Germany and France when it comes to first childbirth, but the intensity of their higher-order births is at similarly low levels to that of the highly educated in Italy and Germany.

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



Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Note: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary. Women aged 15–49, semi-retrospective approach. CI (-) and CI (+) = lower and upper limits of confidence intervals.

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



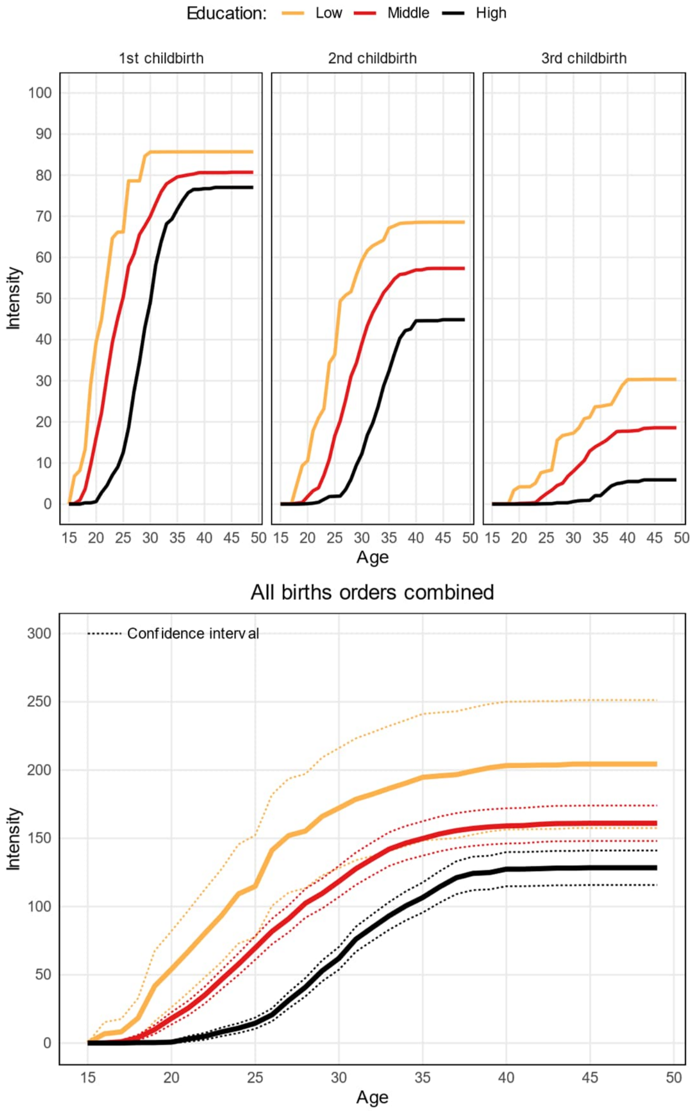
Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Note: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary. Women aged 15–49, semi-retrospective approach. CI (–) and CI (+) = lower and upper limits of confidence intervals.

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 women and 80% of middle-educated women have at least one child by age 49, the percentage is only 71% for highly educated women. Therefore, the proportion of childless women among the highly educated in Italy, 29% at age 49, is as high as in Germany. Highly educated women in Italy start childbearing even later than in Germany: only 20% have at least one child at age 30, against 28% in Germany. Only around 48% of middle- and highly educated women with one child go on to have at least two children, and below 10% of higher-educated women have at least three 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-educated and 1.31 for the high-educated, while the number is 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). However, in contrast to Germany and Italy, childlessness among highly educated women in Poland is relatively low (23% in Poland against 29% in Italy and 30% in Germany).

Highly educated women in Poland start childbearing later than middle- and low-educated women, but they catch up with the middle- and low-educated 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 for 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). However, big differences emerge between education groups from the second childbirth on: Less than 1 in 2 highly educated women with one child have a second child, and less than 6% of highly educated women in Poland have at least three children by the age of 49. The birth intensity of middle-educated women in Poland falls in-between that of high- and low-educated women, and this holds for all birth orders. Fifty-seven percent 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 therefore follow 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-educated, and 1.28 for the high-educated.

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

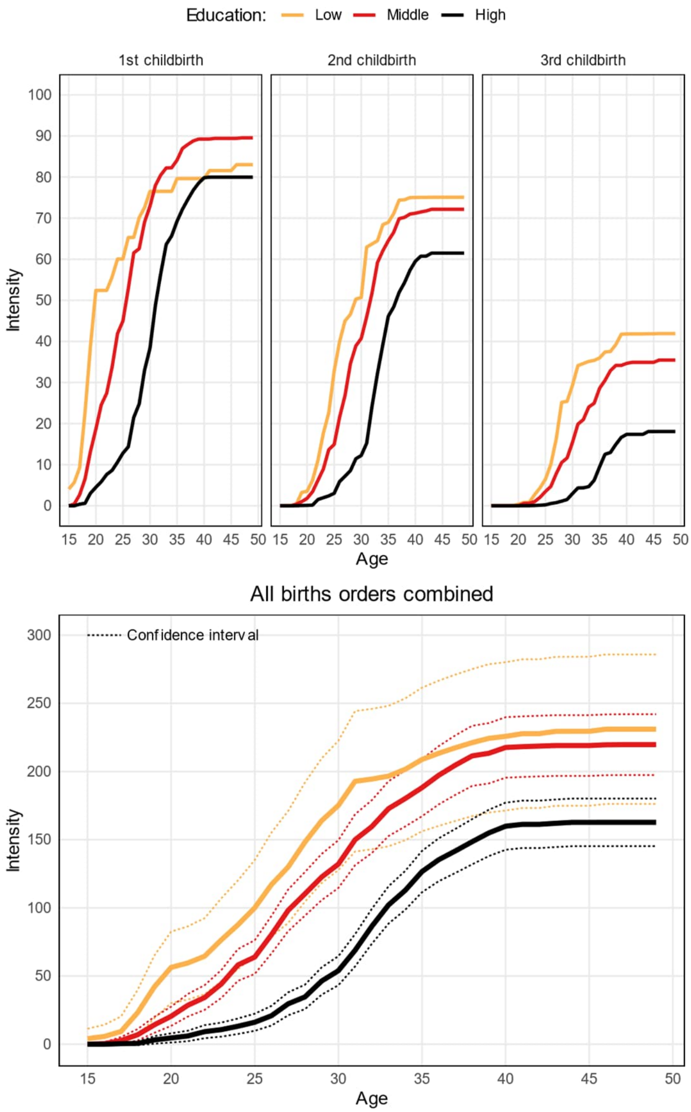


Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Note: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary.
Women aged 15–49, semi-retrospective approach. CI (–) and CI (+) = lower and upper limits of confidence intervals.

Figure 5 presents the birth intensities for the United Kingdom. The United Kingdom has relatively high birth intensities for first childbirth among young low-educated women, but middle-educated women exceed the low-educated women in terms of first birth intensities from age 29 on. Highly educated women almost completely catch up with low-educated women in terms of first birth intensities at age 38. Twenty percent 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 United Kingdom. At the same time, highly educated women have strikingly lower higher-order birth intensities than low- and middle-educated women, resulting in the fact that when all birth orders are combined, birth intensities for women at age 49, with 1.62 children per woman on average, are much lower for highly educated women than for middle- and low-educated women (2.19 and 2.31 children per woman respectively).

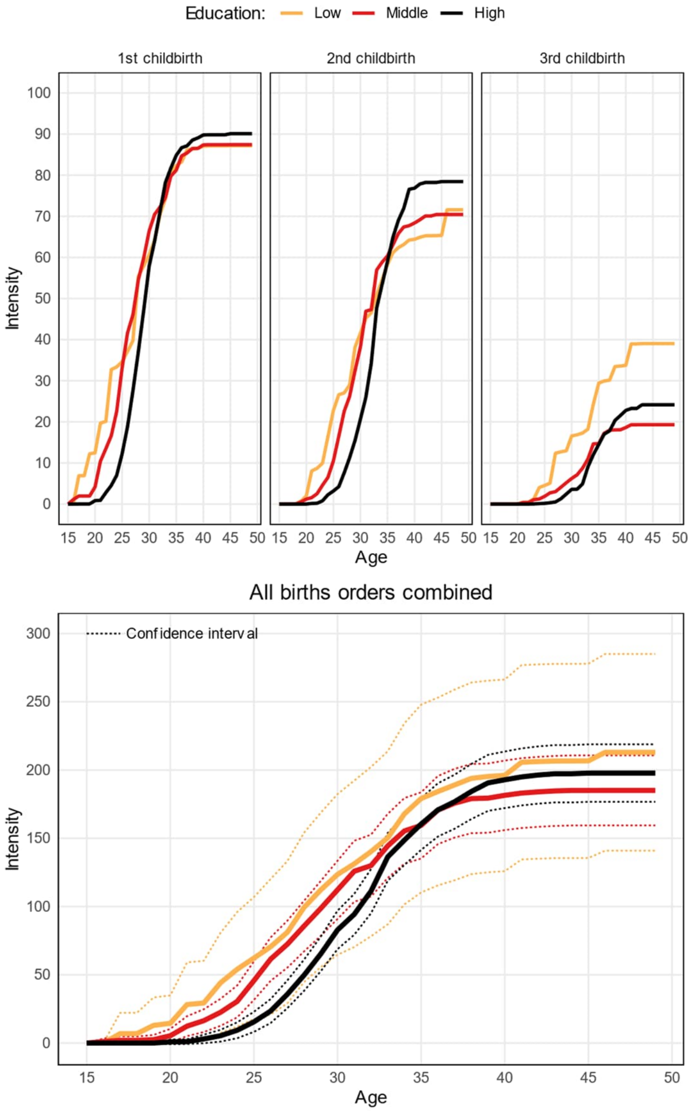
Figure 6 illustrates the birth intensities for Sweden. In comparison to the other five countries illustrated above, Sweden is the country with the lowest educational gradient in fertility – and this is valid for the timing as well as the quantum of births.

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



Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Notes: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary. Women aged 15–49, semi-retrospective approach. CI (–) and CI (+) = lower and upper limits of confidence intervals.

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



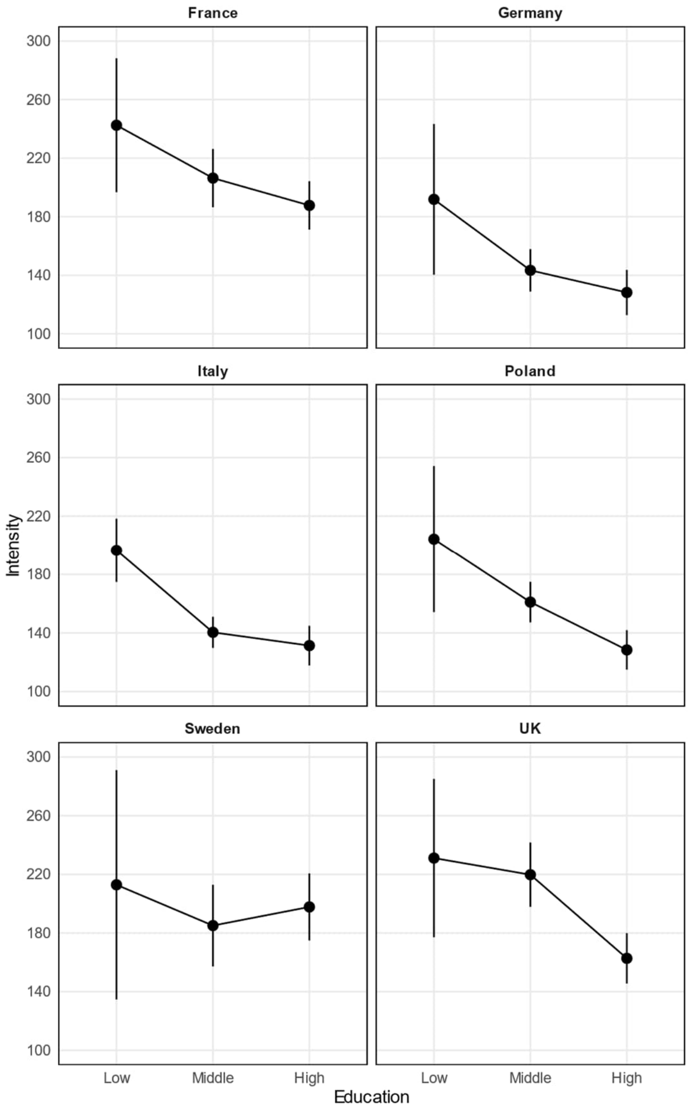
Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Notes: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary. Women aged 15–49, semi-retrospective approach. CI (–) and CI (+) = lower and upper limits of confidence intervals.

When it comes to first childbirth, there is almost no difference in the fertility patterns of 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 first childbirth intensities of the three education groups has already converged by around age 30. 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 their early 30s. From age 35 on their intensity of second childbirth exceeds even that of the lower-educated. 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. Nevertheless, it is important to note that in comparison to the other four countries presented above, higher-educated Swedish 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 third childbirth is below 20% for highly educated women in Poland, Italy, Germany, and France. When all birth orders are combined, differences in the total birth intensity are strikingly low in Sweden, while the birth intensities are all relatively high compared 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 age 49 compared with low- and high-educated women: 1.98 children per woman for highly educated women, 1.85 for middle-educated women, and 2.13 for low-educated women.

4.2 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: Total birth intensities (cumulated at age 49) by education and country (births per 100 women)



Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Notes: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary. Women aged 15–49, semi-retrospective approach. CI (–) and CI (+) = lower and upper limits of confidence intervals.

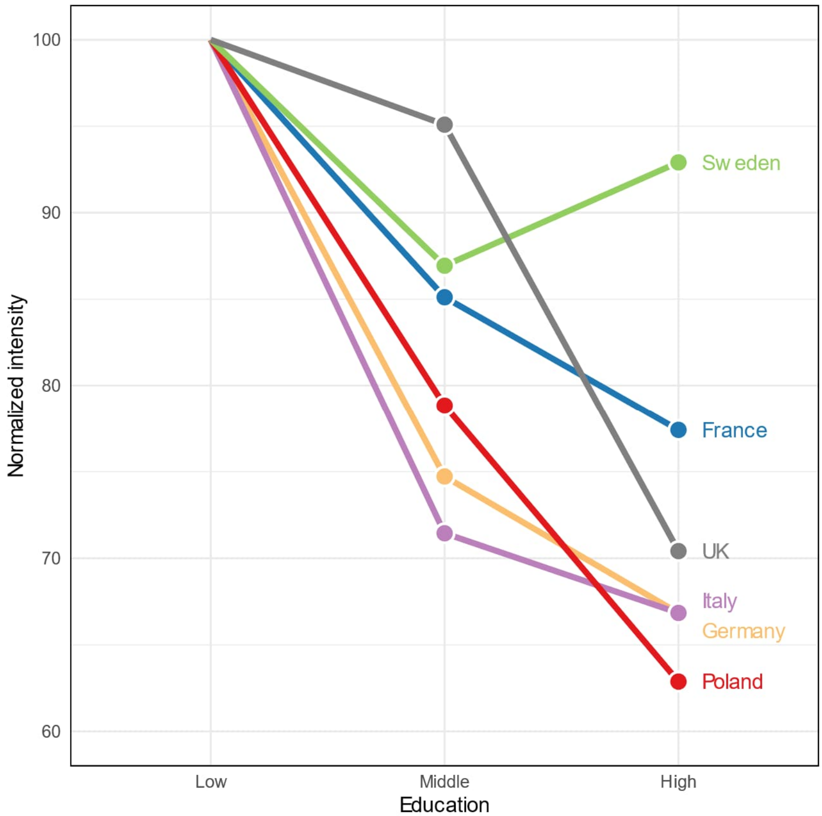
In all six countries, total birth intensities are the highest for the low-educated, and total birth intensities for low-educated women are at similar high levels for all six countries. Germany, Italy, and Poland, countries with relatively low overall fertility levels (TFR < 1.5), show a strong negative educational gradient: middle- and high-educated women have a much lower fertility level than low-educated women, while the fertility levels of middle- and highly educated women are similarly low. Confidence intervals are larger for low-educated women than for middle- and highly educated women in all countries. This is 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 in our sample. France, the United Kingdom, and Sweden have higher fertility levels for middle- and highly educated women than Germany, Poland, and Italy. France and the United Kingdom still show a negative educational fertility gradient, but the fertility levels of the middle- and highly educated are relatively high. This is particularly the case for the high-educated in France and for the middle-educated in the United Kingdom. In Sweden there is no clear educational gradient, and the differences between education groups in fertility levels are not significant. Figure 7 suggests that in Sweden the middle-educated have the lowest fertility level compared to the low- and high-educated.

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

Combining information from Table F-1 and Table 1, Figures G-1 and G-2 in Appendix G show that for our 28 covered countries there is a positive correlation between the percentage of highly educated women and the period fertility levels of highly educated women, as well as between the percentage of highly educated women and overall levels of period fertility. Countries with high overall fertility levels thus seem to combine higher fertility for highly educated women and higher proportions of highly educated women.

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

Figure 8: Normalized total birth intensities (cumulated at age 49) by education



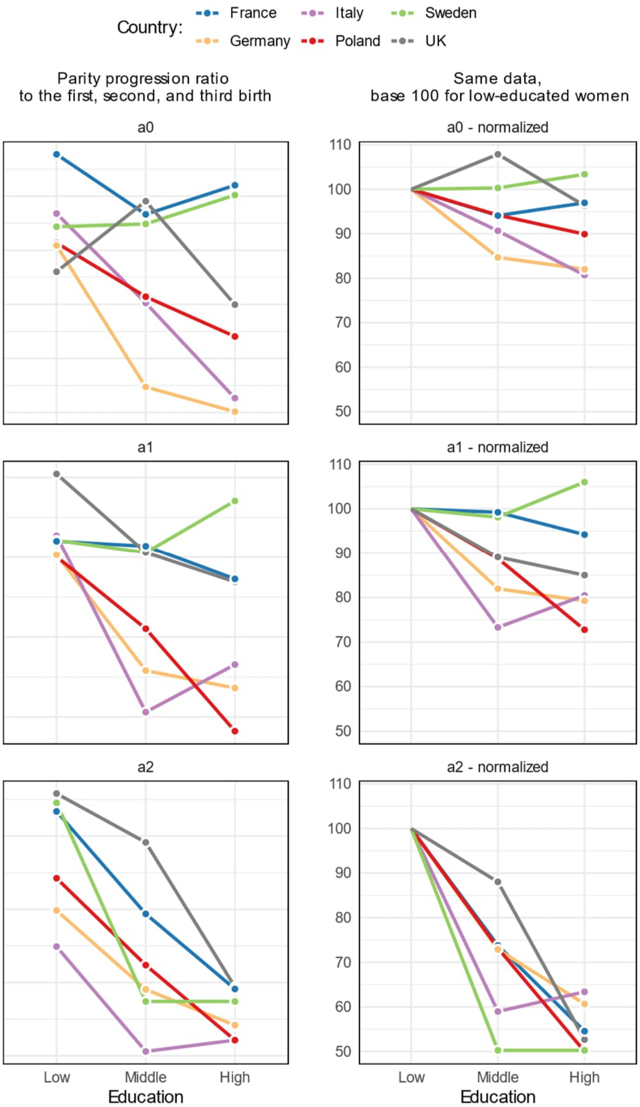
Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Note: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary. Women aged 15–49, semi-retrospective approach.

Figure 8 confirms that the educational gradient of fertility is negative for all countries except Sweden. Fertility differences between the low-educated on the one hand and the middle- and high-educated on the other are most important in Italy, followed by Germany and Poland. France and the United Kingdom also show a negative educational gradient in fertility, but the gradient is much more mitigated. In the United Kingdom the difference between the fertility levels of low- and middle-educated women is lower than in the other five countries, and the difference between the fertility levels of middle- and highly educated women is higher. In Sweden the fertility levels of highly educated women are higher than those of 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. Furthermore, Table 1 shows that total birth intensities are higher for highly educated women than for middle-educated women in five additional countries: Belgium, the Czech Republic, Estonia, the Netherlands, and Slovenia. Therefore, the educational gradient of period fertility levels is not strictly negative for 9 out of 28 European countries in 2010, or one-third of the countries in our sample.

Finally, Figure 9 illustrates for which birth order the heterogeneity is lowest by showing parity progression ratios for each country and education group (left panel = standard, right panel = normalized). The left panel of Figure 9 shows that transitions to first (a_0) and second (a_1) childbirth are quite uniformly situated at relatively high levels for low-educated women in the six countries, while they differ strongly for higher-educated women: Higher-educated women in France, Sweden, and the United Kingdom are much more likely to have at least one and at least two children than higher-educated women in Germany, Poland, and Italy. For transitions to a third child (a_2) the picture is somewhat different. Transition ratios are uniformly situated at 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 United Kingdom, 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 in particular are less likely to stay childless in the United Kingdom and more likely to stay childless in Germany. The educational gradient between low- and highly educated women in terms of transition to first childbirth is negative in Poland, Italy, and Germany (and similarly strong in Germany and Italy), while there is no important gradient between low- and high-educated women in Sweden, France, and the United Kingdom. However, in France and the United Kingdom the gradient between low- and highly educated women is much stronger 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 United Kingdom, 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 of having a second child than low-educated women. For third childbirths the educational gradient is strictly negative for the United Kingdom, Germany, France, and Poland. In Italy and Sweden, however, middle- and highly educated women have similar transitions to third childbirth, albeit much lower than those for low-educated woman. Altogether, transition to third childbirth is similarly low for highly educated women compared to low-educated women in all six countries.

Figure 9: Parity progression ratios (percent) of total birth intensities (cumulated at age 49)



Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Note: Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary.
Women aged 15–49, semi-retrospective approach.

Table 2: Parity progression ratios (percent) to the first (a0), second (a1), and third (a2) birth, by country, 2010

	Low-educated			Middle-educated			High-educated		
	a_0	a_1	a_2	a_0	a_1	a_2	a_0	a_1	a_2
Austria	85,29	83,34	53,81	78,16	62,32	19,78	70,70	71,19	20,57
Belgium	83,60	74,79	61,76	83,48	55,59	40,15	82,36	79,44	43,41
Bulgaria	94,05	95,38	41,09	86,84	50,92	14,54	59,75	74,86	1,79
Czech Republic	77,90	79,57	57,85	85,74	63,67	18,35	83,63	78,04	21,11
Denmark	88,90	69,92	62,41	74,45	78,88	36,70	88,16	82,40	33,94
Estonia	88,52	62,03	35,50	88,63	60,20	28,11	91,82	65,79	27,91
Finland	75,12	85,78	54,52	74,77	71,95	41,61	81,26	83,12	34,54
France	93,88	82,00	53,37	88,33	81,38	39,38	91,02	77,25	29,12
Germany	85,44	80,29	39,84	72,36	65,80	29,04	70,08	63,62	24,17
Greece	89,89	89,07	15,28	76,80	87,58	7,86	80,24	75,47	10,64
Hungary	86,98	74,50	43,10	80,25	50,25	20,97	75,67	60,67	12,14
Iceland	91,06	83,06	65,00	78,70	74,31	36,03	90,49	83,94	47,24
Ireland	93,79	75,83	46,64	93,67	72,97	48,25	92,01	73,39	49,74
Italy	88,40	82,70	34,91	80,13	60,61	20,58	71,33	66,55	22,13
Latvia	81,61	71,81	29,92	82,32	59,56	20,83	84,95	51,99	22,04
Lithuania	93,74	64,75	34,45	86,53	72,02	39,29	83,90	60,88	11,29
Luxembourg	96,61	89,68	60,64	78,36	65,78	37,71	68,26	64,07	37,35
Netherlands	81,05	79,93	49,53	78,93	85,57	35,66	82,78	78,55	40,05
Norway	86,49	81,67	61,70	89,48	82,73	36,36	90,35	80,43	36,21
Poland	85,68	80,03	44,25	80,71	71,03	32,38	77,03	58,23	13,12
Portugal	90,76	73,13	25,98	68,84	64,58	20,17	62,46	55,70	8,38
Romania	85,59	83,44	53,29	88,44	63,45	22,91	66,43	80,75	15,22
Slovak Republic	56,69	81,91	63,47	80,23	71,53	28,17	70,58	69,36	27,47
Slovenia	81,74	71,46	40,72	83,91	62,91	20,87	82,72	77,11	25,06
Spain	76,06	69,16	26,38	76,25	69,37	11,45	71,05	65,72	18,95
Sweden	87,18	82,11	54,54	87,44	80,58	27,41	90,10	87,07	30,79
Switzerland	71,76	84,89	42,42	79,65	74,79	26,77	71,37	74,65	20,64
United Kingdom	83,02	90,45	55,82	89,54	80,58	49,14	79,98	76,89	29,40
Mean	85,03	79,38	46,72	81,89	69,32	28,94	78,95	72,04	25,52
Standard dev.	8,26	7,84	13,14	5,99	10,01	10,75	9,44	9,32	12,05
Minimum	56,69	62,03	15,28	68,84	50,25	7,86	59,75	51,99	1,79
Maximum	96,61	95,38	65,00	93,67	87,58	49,14	92,01	87,07	49,74

Data source: EU-SILC.
Notes: Parity progression ratios calculated based on birth-order-specific birth intensities (cumulated) at age 49 (semi-retrospective approach with 2-year delay based on cross-sectional samples 2011, 2012, and 2013. Women aged 15–49).
Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary.

Table 2 presents parity progression ratios for all 28 countries and the year 2010. Table 2 confirms that transitions to first (a_0) and second (a_1) childbirth are at relatively similar and relatively high levels for low-educated women in most European countries, ranging between 96% and 72% for a_0 (except for the Slovak Republic: 57% only for a_0) and between 95% and 62% for a_1. Transitions to a first and second child are lower among the middle- and high-educated in Europe, on average, in comparison to the low-educated. The lowest transition to a first child is found in Bulgaria for highly educated women (60% only), and the lowest transition to a second child is found in Hungary for middle-educated women (50% only). The most striking difference between countries is for the transition to a third child (a_2) as compared to transitions to first and second childbirth, in all three education groups. Interestingly, a_2-differences between countries are the highest among low-educated women, for whom a_2 ranges between 15% (Greece) and 65% (Iceland). However, the lowest transition ratio to a third child is found among the high-educated the in Bulgaria: only 2%.

Focusing on the educational gradient within countries, Table 2 shows that in 2010, in almost half of the covered countries (13 out of 28), middle- and/or high-educated women have higher transitions to first childbirth (a_0) than low-educated women.[15] Middle- and high-educated women have particularly higher transitions (relative difference) to a first child in comparison to low-educated women in the Slovak Republic and the Czech Republic. The educational gradient for a_0 is strictly negative for only 9 out of 28 countries (one-third) and most negative in Bulgaria (in relative terms). Highly educated women have higher transitions to first childbirth (i.e., lower levels of childlessness) than middle-educated women in 10 out of 28 European countries – in particular in the Nordic countries but also in Greece, the Netherlands, France, Estonia, and Latvia. In one-third of the covered countries (9 out of 28) in 2010, middle- and/or high-educated women have higher transitions to second childbirth (a_1) than low-educated women[16] and the educational gradient of a_1 is strictly negative in only 8 countries. In 13 out of 28 European countries, highly educated women have higher transitions to second childbirth than middle-educated women, which is the case in several Nordic countries but also in Bulgaria, Belgium, Hungary, Slovenia, Romania, the Czech Republic, and Estonia. For the transition to third childbirth (a_2) the picture is quite different. In 2010), middle- and/or high-educated women have higher transitions to third childbirth than low-educated women in only 2 out of 28 countries (Ireland, Lithuania. However, the educational gradient for a_2 is strictly negative in only 10 countries. In the remaining 16 countries, highly educated women have similar or even somewhat higher transitions to third childbirth than middle-educated women. A U-shaped educational gradient for transitions to third childbirth, implying a considerably higher transition for highly and low-educated women in comparison to middle-educated women, can be found in particular in Spain, Greece, and Iceland, but also in Slovenia and the Netherlands.

Table 1 has shown that the educational gradient of period fertility levels is not strictly negative in one-third of countries in our sample in 2010 and that there is more

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[15] Czech Republic, Estonia, Finland, Latvia, Netherlands, Norway, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and United Kingdom.

[16] Belgium, Denmark, Iceland, Lithuania, Netherlands, Norway, Slovenia, Spain, and Sweden.

diversity between European countries among highly educated women than among low-educated women. Table 2 completes this information by highlighting that in countries with relatively high overall period fertility levels for highly educated women, highly educated women have relatively high transitions to first childbirth (i.e., childlessness is less common), followed by relatively high transitions to second childbirth. Higher-order childbirths (three or more) exhibit a more negative educational gradient across European countries overall, with middle- and highly educated women having lower transitions to third childbirth than low-educated women in most countries. However, in half of the covered European countries, middle-educated women do not have higher transitions to third childbirth than highly educated women.

5. Conclusion

In this study, we used harmonized socioeconomic 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 in this article for six countries: France, Germany, Italy, Poland, the United Kingdom, 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 women than 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 the middle-educated having the lowest fertility.

Our focus on six selected countries confirmed that total birth intensities are at similar levels for the low-educated, but differ significantly between education groups in 5 out of 6 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 than low-educated women. In France and the United Kingdom, middle- and highly educated women also have lower intensities, but they are at much higher levels than in Poland, Italy, and Germany. This is particularly the case for the middle-educated. Thus, that the overall levels of period fertility in Poland, Italy, and Germany are quite low in comparison to the other three countries is due to lower birth intensities for the 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 at a similarly high level to that of low-educated women, with middle-educated women having a lower level than low- and highly educated women. Our focus on six countries also allowed us to analyze age- and parity-specific fertility behavior in more detail. While the transitions to first and second childbirth are quite uniformly situated at 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 United Kingdom compared to Germany, Poland, and Italy. The difference between countries is most striking for middle-educated women: in particular, in comparison to low-educated women they are less likely to stay childless in the United Kingdom and more likely to stay childless in Germany. 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 thus seems that the higher overall period fertility levels in Sweden, the United Kingdom, 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 educated women but also for the middle-educated. 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, in France and Sweden they catch up with lower-educated women around the age of 30.

The novelty of our analytical approach is that it can analyze a large majority of European countries (28 in our sample). As in Sweden, we find that total birth intensities (at age 49) are also lower for middle-educated women than for the highly educated in Iceland, Denmark, Finland, Belgium, the Czech Republic, Estonia, the Netherlands, and Slovenia. Therefore, the educational gradient of period fertility is not strictly negative for 9 out of 28 European countries, which constitutes one-third of European countries. This finding contrasts with the main current of the existing empirical literature, which finds that the educational gradient of completed cohort fertility is negative for the large majority of European countries (Sobotka, Beaujouan, and Van Bavel 2017; Nisén et al. 2021; and Skirbekk 2022 for an overview of findings). Our focus on period fertility levels thus represents a major update of the present state of knowledge regarding the association between education and fertility in Europe.

In most countries the share of highly educated women has increased over recent decades, and we have shown that higher shares of highly educated women come hand in hand with higher period fertility levels. Further analyses based on our rich dataset will reveal whether, how far, and under which institutional circumstances the educational expansion among women also comes hand in hand with an eventual reversal of the educational gradient of period fertility.

At this stage the presented research results are purely descriptive, as this paper focuses mainly on methodological advances for measuring the educational gradient of fertility for women of childbearing age. However, we would like to highlight at this point that existing studies on determinants of educational differences in fertility outcomes have shown that the causes of fertility changes in high-income countries are diverse and differ between individuals and countries (Kohler, Billari, and Ortega 2006; Balbo, Billari, and Mills 2013). The social mechanisms leading to changes in fertility are different for individuals with different levels of education, so that the overall social trends are likely to have an impact not only on the overall level of period fertility but also on differentials by level of education. Cohorts represent actual people followed over the years, but social mechanisms act mostly on a period basis. Postponement may or may not be followed by recuperation, depending on whether a decline in fertility among young adults is followed by an increase at later ages. Furthermore, international comparisons show that the correlation between fertility and female labor force participation in European countries reversed around the year 2000 (Engelhardt and Prskawetz 2004). The same holds for the correlation with age at first marriage, marriage intensity, the proportion of births out of marriage, and total divorce rates, which have reversed or vanished (Sobotka and Toulemon 2008), showing that fertility determinants have changed recently, and that these changes may not only be country-specific but may also vary with educational level. This calls for an up-to-date analysis of macro-level trends, by differentiating impacts between education groups and their time trends on a period basis. Analyses of social stratification in parity-specific cohort fertility using education reveal a larger and increasing polarization among the low-educated (Brzozowska, Beaujouan, and Zeman 2022), while among women with a high level of education, postponement of first births may lead to lower opportunity costs and better secured income, and therewith stronger and more persistent positive income effects (Balbo, Billari, and Mills 2013). Besides these micro-mechanisms, differences between countries in terms of public institutions facilitating parental employment in terms of gender and family norms, as well as in terms of employment protection and income opportunities, might contribute to explaining why period fertility levels differ between European countries especially among the highly educated (see for example Bastianelli, Guetto, and Vignoli 2023 or Hsu 2023 for most recent studies on this topic).

However, to enable a holistic understanding of the driving patterns of educational gradients in period fertility behavior in Europe, we still need data on age- and parity-specific period fertility by education that covers not only as many countries as possible, but also as many time periods. In this paper we have presented a method that allows producing such information for a large set of European countries, on a year-by-year basis from 2005 on. Thus, in a next step, it becomes possible to empirically model the institutional determinants of heterogeneities in the educational gradient of period fertility levels between countries, based on panel data estimation methods (fixed effects modelling, multi-level analysis, etc.). This kind of analysis has the potential to reveal how far the educational gradient of period fertility behavior is sensitive to region- and country-specific contexts such as economic development, labor market conditions, family policy settings, gender and family norms, etc. With the measure of the educational gradient having been available on a yearly basis for almost two decades now, it is also possible to identify time trends and discover, for example, which educational group contributed the most to the fertility decline that has recently occurred in several European countries, while taking into account potential structural 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 and a considerable time period contains the potential to improve fertility forecasts and micro-simulation models.

A major condition for the realization of these research paths is the reassurance 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 and post-stratification. Providing access to these measures and to the detailed compilation protocol allows the research community to now retrace our compilation of measures and to pursue and improve data quality checks. In this article we presented data for the year 2010 to allow for comparison with census data. Our priority is now to provide a systematic data quality check. We therefore will compare EU-SILC-based measures of the educational gradients of period fertility to those that will be calculated with alternative, more demographic datasets, for as many countries and years as possible. The focus will be on the identification of education-specific biases. Besides census data, we will use national register data, GGS data, national survey datasets (German SOEP, Swiss Household Panel, Polish Social Diagnosis, Italian Multipurpose Survey on Households, British Household Panel Survey, etc.) as well as newly available national administrative datasets such as the *Échantillon Démographique Permanent* in France, which consists of a linked-census subsample merged with tax returns data.

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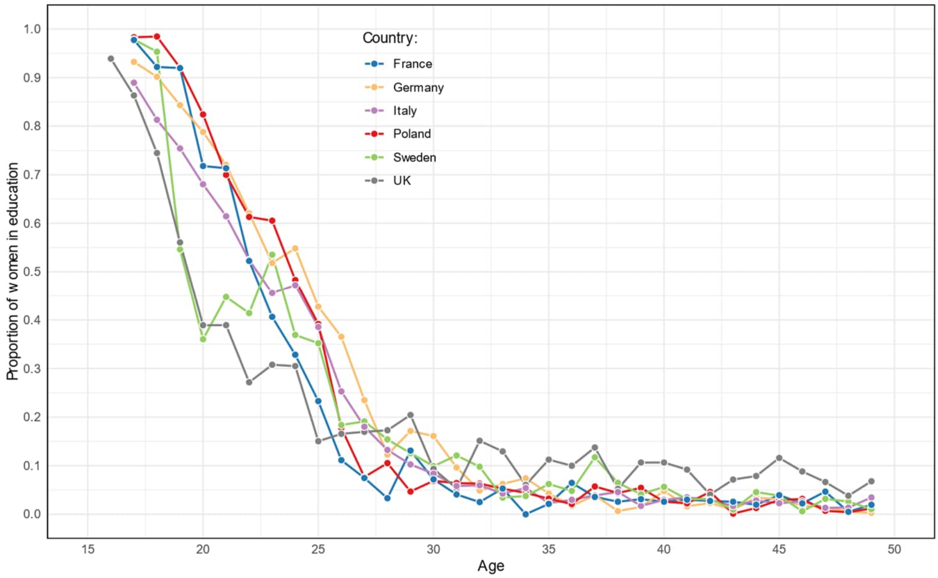
Appendix A: Proportion of women still in education, by age

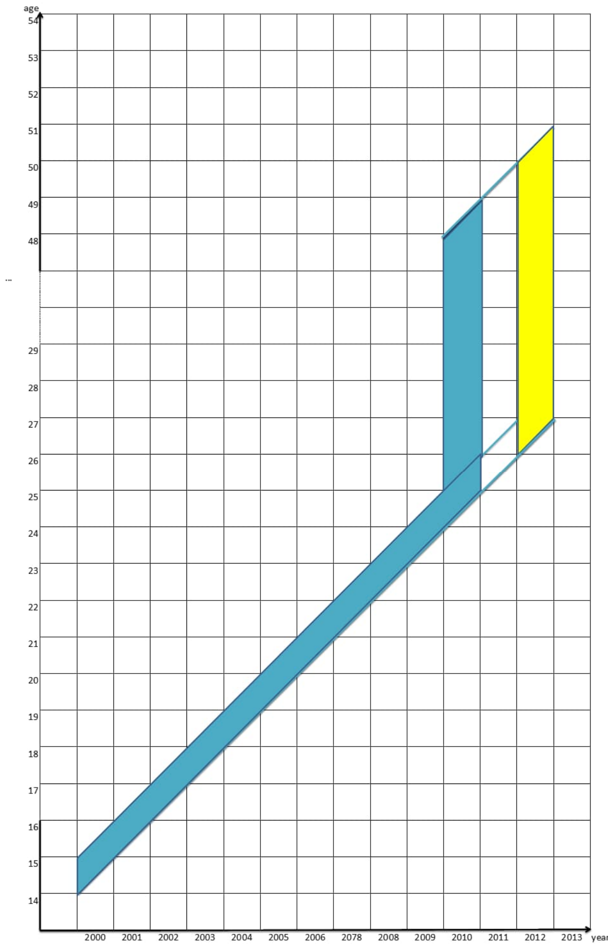
Figure A-1: Proportion of women in education, by age



Data source: EU-SILC – CS 2010.

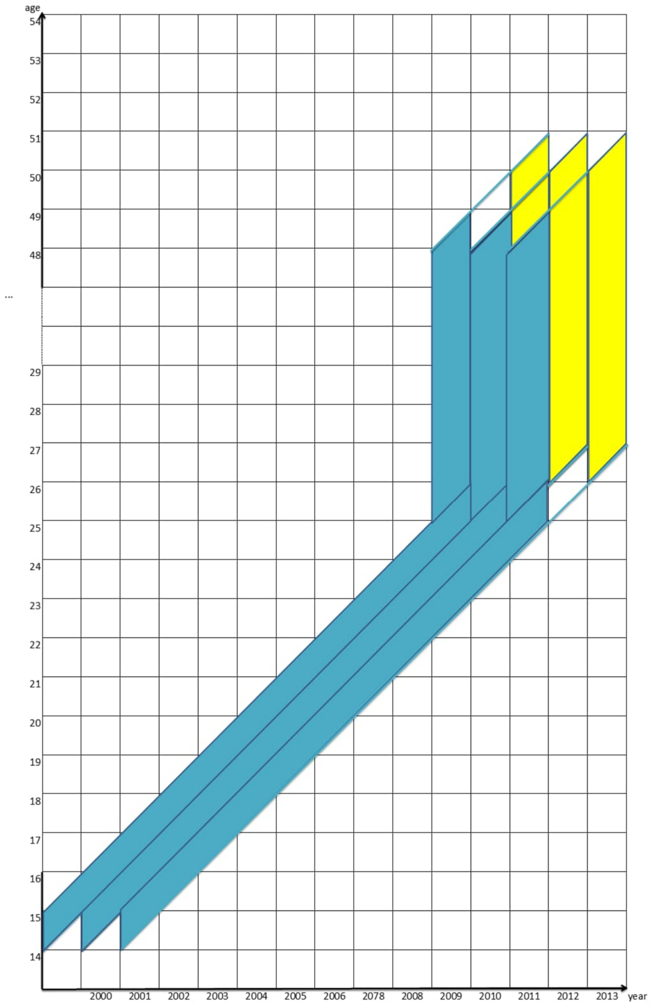
Appendix B: Lexis diagram of the observed universe to estimate synthetic fertility indices for 2010, based on EU-SILC 2012.

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



Source: Created by the authors.
Notes: The EU-SILC cross-sectional wave of 2012 (ages 27–51) (illustrated in yellow) is used to observe age-specific fertility for ages 15 to 49 in 2010 (illustrated in blue).
Synthetic cohort for ages 25+: age 25 in 2010 = age 27 in 2012: education completed; births observed in 2010. Retrospective approach for ages 15–24 (i.e., education is observed at age 27; only 1 cohort: 1985): births observed between 2000 and 2009).

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: Created by the authors.
Notes: The EU-SILC cross-sectional waves of 2011, 2012, and 2013 (ages 27–51) (illustrated in yellow) are used to observe age-specific fertility for ages 15 to 49 in 2009, 2010, and 2011 (illustrated in blue).

Appendix C: Posterior estimates and variances

C.a. Prior and posterior estimates of fertility rates

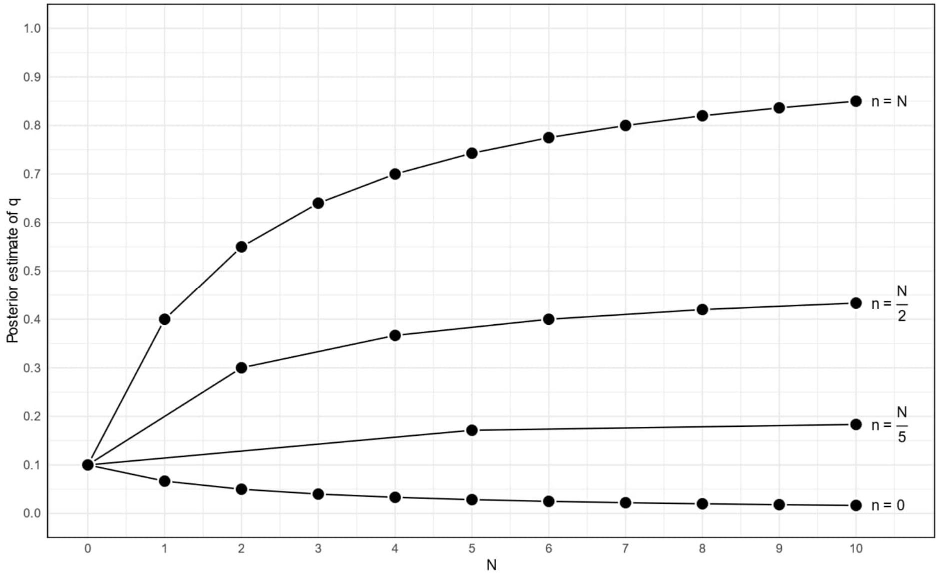
Consider a set of N respondents. Among them, n had a child. The final estimate (posterior) is a weighted mean of the prior estimate *prior* and the Bernouilli simple estimate (n/N), the weights being 2/(N+2) and N/(N+2):

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

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: Posterior/prior divergence: Posterior estimate of q, with a prior=0.1, against N



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 is thus much lower when we use the priors, in the 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:

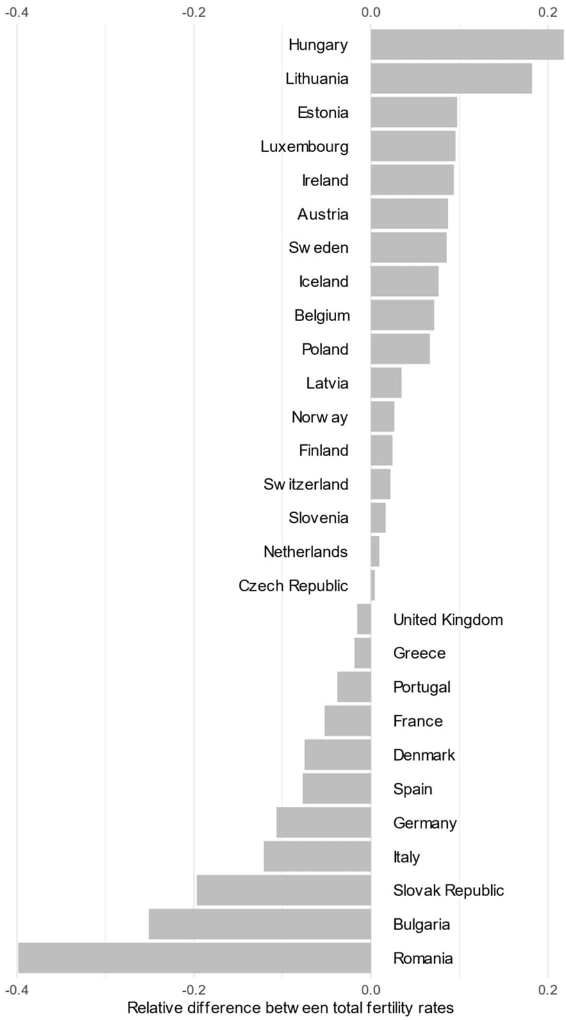
Let *TCum*(x) be the sum of the age-specific rates up to x, and *VCum*(x) its variance:

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

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

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 2-year delay based on cross-sectional samples 2011, 2012, and 2013 (i.e., TFRs calculated for calendar years 2009, 2010, and 2011 – combined sample).
Calculation of the relative difference: (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 2 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
- $r1$ the response rate among women who gave birth
- $r0$ 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 $r = r1/r0$ 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 reasons to assume that childless women's response rate differs from that of mothers. Under that assumption, only first birth probabilities would be affected – mothers responding in the same way whether or not they had a child 2 years before the survey.

We compared the impact of such an assumption on the parity distribution, together with a direct adjustment of the odds ratios of cumulated probabilities. Elaborating on Devolder's (2018) relation between Total fertility F and mean parity progression ratio a [the relation is simply $F = \mathrm{OR}(a) = a/(1–a)$], we may use the series $F1\_i$, (i = 1; 5+) of the proportion of women having at least i children, $i = 1,5$. We have: $F1 = \mathrm{Sum}(F1\_i)$. We consider that the minimal change in the distribution of women by number of children ever born, from an initial series of $F1\_i$, (i = 1; 5+) to a final series of $F2\_i$, (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, only a 4% decline, 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 fewer first births occurring at later ages, the second birth intensity is reduced at a fast pace, from 0.55 to 0.50 second births per woman (an 8% decline). The relative decrease is even more pronounced for higher birth orders.

When we change only first-birth probabilities (line 'First birth probabilities only' in Tables E-1 and E-2), the relative decline is similar for first births and higher-order births (0.93): fewer 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

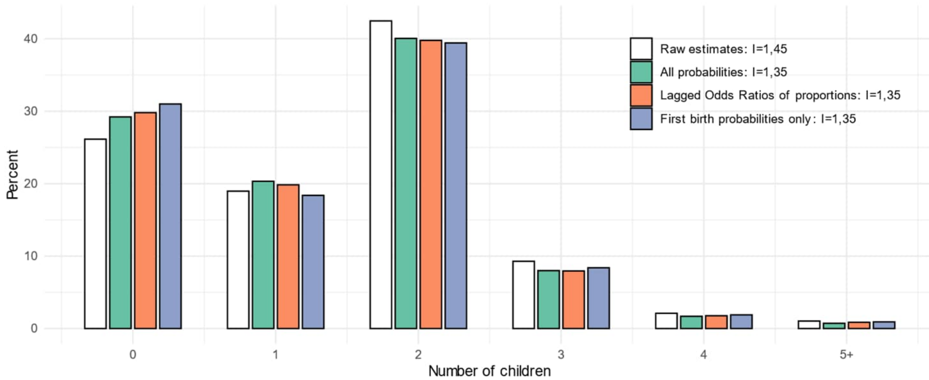
Birth order	1	2	3	4	5	All
Raw estimates	0,74	0,55	0,12	0,03	0,01	1,45
All probabilities	0,71	0,50	0,10	0,02	0,01	1,35
First birth probabilities only	0,69	0,51	0,11	0,03	0,01	1,35
Lagged odds ratios	0,70	0,50	0,11	0,03	0,01	1,35

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 a rather 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 of non-response (participation in the survey is better for young mothers, irrespective of any other characteristics) appeared to be 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 (from the Human Fertility Data Base). However, when we compared groups by education this post-stratification led to unstable results, 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

	Low	Middle	High
Austria	15,79	63,82	20,39
Belgium	18,11	34,82	47,07
Bulgaria	19,40	46,96	33,65
Czech Republic	5,11	67,71	27,17
Denmark	13,31	40,35	46,33
Estonia	8,43	41,35	50,22
Finland	6,20	44,53	49,28
France	12,31	43,02	44,67
Germany	7,74	54,82	37,44
Greece	17,67	44,77	37,56
Hungary	15,03	53,98	30,98
Iceland	23,10	35,52	41,37
Ireland	14,49	36,03	49,48
Italy	30,17	47,83	22,00
Latvia	9,95	48,54	41,51
Lithuania	6,75	45,24	48,01
Luxembourg	29,00	35,53	35,46
Netherlands	15,98	40,31	43,71
Norway	15,45	32,16	52,39
Poland	5,55	55,77	38,67
Portugal	46,90	27,42	25,68
Romania	20,17	54,54	25,29
Slovak Republic	4,26	60,62	35,12
Slovenia	10,10	54,55	35,35
Spain	33,45	25,59	40,97
Sweden	5,97	43,15	50,88
Switzerland	13,23	56,58	30,19
United Kingdom	8,39	44,15	47,46
Mean	15,43	45,70	38,87
Standard dev.	9,89	10,57	9,35
Minimum	4,26	25,59	20,39
Maximum	46,90	67,71	52,39

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

Appendix G: Total birth intensities at age 49 against the share of highly educated women in the population

Figure G-1: Total birth intensities at age 49 for highly educated women against the share of highly educated women in the population

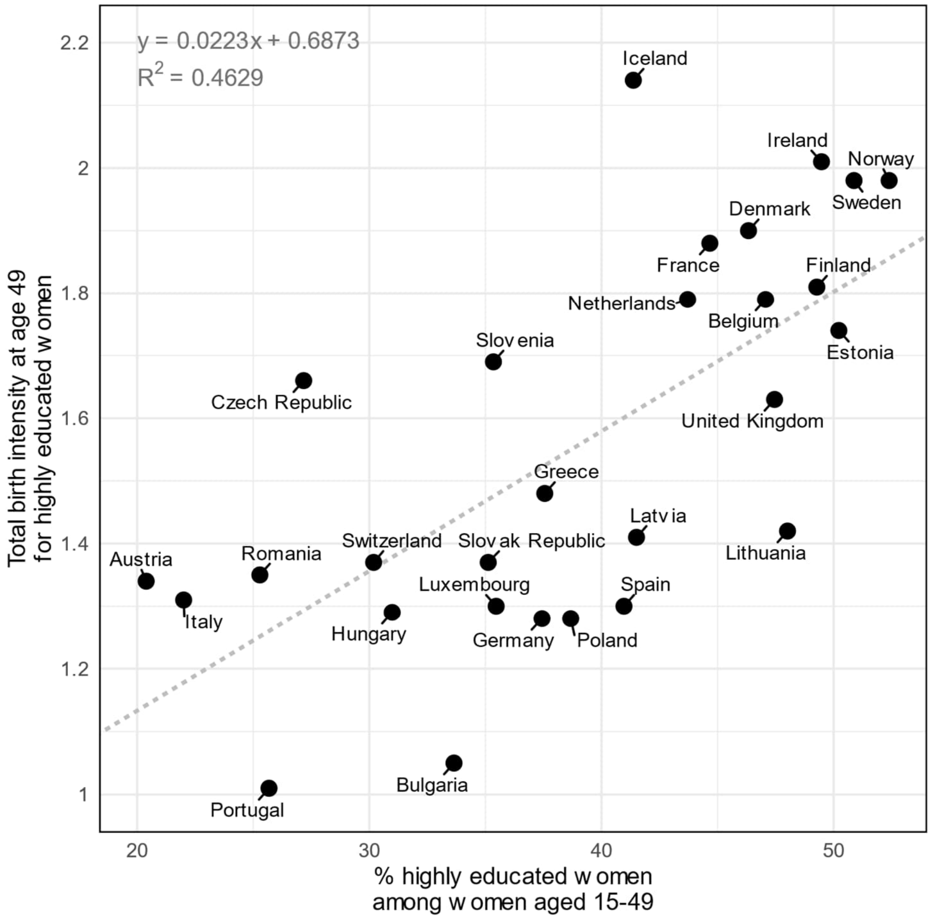
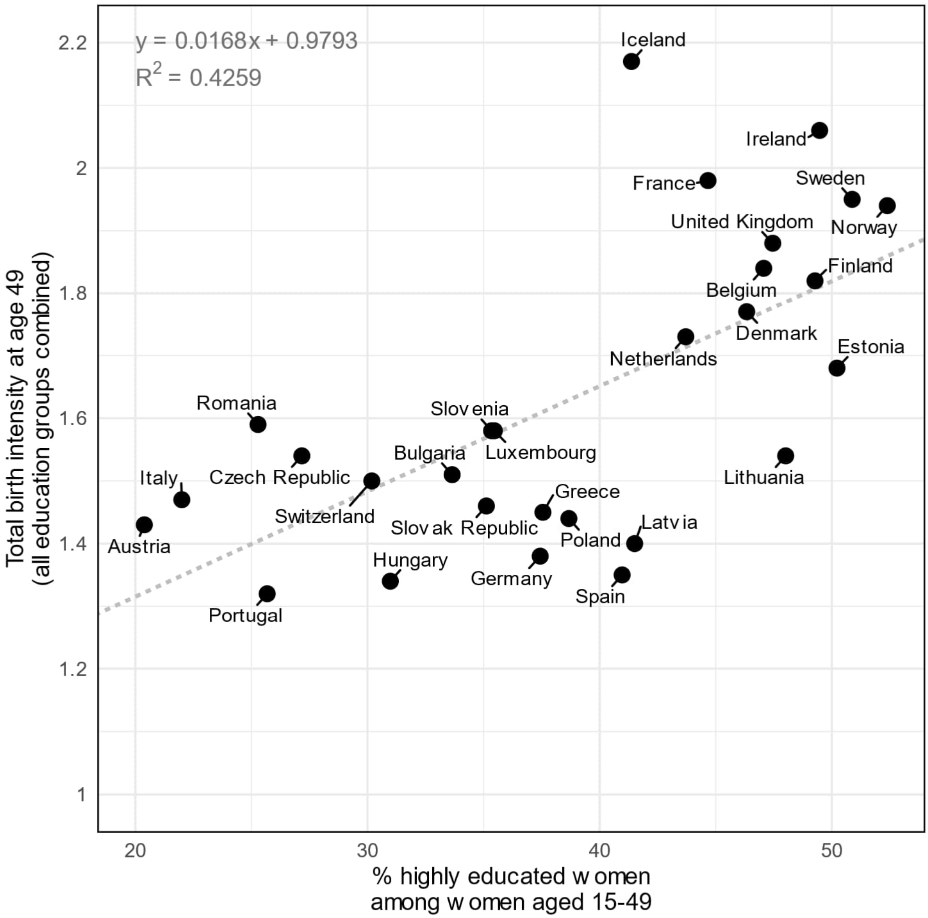


Figure G-2: Total birth intensities at age 49 (all education groups combined) against the share of highly educated women in the population



Data source: EU-SILC, CS 2011–2013: childbirths observed in 2009, 2010, and 2011.
Notes: Birth intensity: see Table 1; Education: see Table F1.
Education: Low = pre-primary, primary, lower secondary; Middle = upper secondary, post-secondary; High = tertiary.
Women aged 15–49, semi-retrospective approach.