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Educational differences in cohort fertility across sub-national regions in Europe

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Educational differences in female cohort fertility have been shown to vary across high-income countries and over time, but knowledge about how educational fertility differentials play out at the sub-national regional level is limited. Examining these sub-national regional patterns might improve our understanding of national patterns, as regionally varying contextual conditions may affect fertility. This study provides for the first time for a large number of European countries a comprehensive account of educational differences in the cohort fertility rate (CFR) at the sub-national regional level. We harmonise data from population registers, censuses, and large-sample surveys for 15 countries in order to measure women's completed fertility by educational level and region of residence at the end of the reproductive lifespan. In order to explore associations between educational differences in CFRs and levels of economic development, we link our data to regional estimates of GDP per capita. Empirical Bayesian estimation is used to reduce uncertainty in the regional fertility estimates. Our results document an overall negative gradient between the CFR and level of education, and notable variation in the gradient across regions. The gradient varies systematically by the level of economic development: moving from less to more developed regions, we observe smaller gradients both across countries and within countries. However, the within-country patterns of countries differ. Our findings underline the variability of educational gradients in women's fertility, suggest that higher levels of development may be associated with less negative gradients, and call for more in-depth fertility analyses by education at the sub-national level.

Introduction

Research on variation in fertility in contemporary societies often focuses on the relationship between education and fertility (Gustafsson & Kalwij, 2006; Kreyenfeld & Konietzka, 2017; Sobotka, Beaujouan, & Van Bavel, 2017). There is evidence that the typically negative relationship between education and fertility has varied across place (Beaujouan, Brzozowska, & Zeman, 2016; Klesment, Puur, Rahnu, & Sakkeus, 2014; Van Bavel et al., 2018; Wood, Neels, & Kil, 2014) and time (Andersson et al., 2009; Jalovaara et al., 2019; Kravdal & Rindfuss, 2008; Neels & De Wachter, 2010). However, most previous analyses on this relationship have been conducted at the country level, while paying little attention to potential variation in this relationship across regions within countries. National patterns are, however, composites of sub-national regional patterns. As regionally varying contextual conditions may affect fertility outcomes (Basten, Huinink, & Klüsener, 2012; de Beer & Deerenberg, 2007; Kulu, 2013), exploring this dimension might improve our understanding of observed national-level patterns in educational gradients in fertility (Snyder, 2001). A perspective beyond the national level also has value in light of globalisation theories predicting that affluent, developed sub-national regions across countries will become more similar to each other over time, even as regional differences in living conditions within countries are increasing (Veltz, 2014).

From a macro perspective, socio-economic development is among the central determinants of fertility levels (Bryant, 2007; Lee, 2003). While in the past countries with higher levels of socio-economic development tended to have lower fertility levels, among contemporary high-income countries, this long-standing negative relationship has reversed (Luci-Greulich & Thévenon, 2013; Myrskylä, Kohler, & Billari, 2009). A similar tendency is observed within European countries, as the association of fertility with the level of economic development across sub-national regions has, in recent decades, become less negative, or even positive (Fox, Klüsener, & Myrskylä, 2019). Our study is motivated by these recent changes. It is possible that changes in the fertility-education relationship at the regional level have contributed to the changing regional patterns of development and fertility, as, for example, the high-educated are particularly concentrated in highly developed areas (Eurostat 2019). Our study aims to make a novel contribution by investigating for the first time for a large number of European countries the educational patterning of cohort fertility rates (CFRs) at the sub-national regional level. We seek to bridge previous studies on the relationships between education and fertility and development and fertility by exploring whether regional variation in CFRs by educational attainment is systematically associated with regional variation in economic development.

Existing research on educational differences in cohort fertility shows that higher-educated women have had lower CFRs at least since the early 20th century (Skirbekk, 2008). However, in the cohorts born up to the mid-1940s, there was convergence towards a two-child family model across educational groups, which in some countries led to a decrease in the educational gradient in CFR (Van Bavel et al., 2018). Moreover, the gap in childlessness between low- and middle-educated women, which has been an important factor in CFR differentials, declined among the mid-20th-century cohorts (Beaujouan et al., 2016). Further deviations from the well-known pattern of a negative educational gradient in CFRs have been reported for female cohorts born between the 1940s and the mid-1970s in Northern and North-Western Europe, where gradients have narrowed, and are often no longer observable (Andersson et al., 2009; Jalovaara et al., 2019; Kravdal & Rindfuss, 2008; Neels & De Wachter, 2010). So far, however, there has been no overall convergence in cohort fertility among educational groups across high-income countries (Sobotka, Beaujouan, & Brzozowska, 2018), and the magnitude of fertility gradients continues to vary greatly across countries (Beaujouan et al., 2016; Klesment et al., 2014; Neyer & Hoem, 2008; Wood et al., 2014).

Women's cohort fertility results from consecutive decisions and events in the life course that are shaped by contextual factors (Huinink & Kohli, 2014; Thomson, Winkler-Dworak, & Kennedy, 2013). Thus, at the sub-national level, cohort fertility is subject to regional contextual conditions across the reproductive lifespan (Kulu, 2013; Kulu, Vikat, & Andersson, 2007). As we will discuss in this section, regionally-varying contextual conditions might affect childbearing opportunity structures differently depending on women's educational levels, and can lead to variation between regions in the educational gradient in fertility. For example, while high regional living costs due to factors like expensive housing are likely to depress childbearing by contributing to high direct costs of children (Dettling & Kearney, 2014; Flynn, 2017; Mulder, 2013), the childbearing of high-educated women might be less sensitive to such mechanisms because they are more likely to have high household income levels (Esping-Andersen, 2009; Konietzka & Kreyenfeld, 2010). Employment has recently become an important prerequisite for childbearing in most European countries (Matysiak & Vignoli, 2008), particularly among high-educated women (Kreyenfeld & Andersson, 2014; Wood & Neels, 2017). We can therefore hypothesise that regional employment prospects (Bujard & Scheller, 2017; Kravdal, 2002) are particularly important for these women. Furthermore, the availability of flexible working arrangements that support work-family reconciliation, such as working remotely from home, is likely to vary regionally (Fox et al., 2019), and might be more prevalent among high-educated employees (Golden, 2001). The positive effect on fertility of the regional availability of childcare services (Rindfuss, Guilkey, Morgan, &

Kravdal, 2010) has been shown to be particularly strong for high-educated women, most likely because of the high opportunity costs they face when having children (Wood, Klüsener, Neels, & Myrskylä, 2017).

We can therefore hypothesise that higher living costs, better employment opportunities, and better access to flexible work arrangements and childcare services are among the factors that could lead to relatively high fertility among high-educated women – and, thus, to a less negative regional educational gradient in fertility. Moreover, these contextual factors could bring about systematic variation in the educational gradient depending on the regional level of economic development, given their association with the latter (Dunford, 1996; Fox et al., 2019; Kosfeld, Eckey, & Lauridsen, 2007; Kurre, 2003). Living costs, employment rates, and access to flexible working practices are typically higher in more developed regions. If higher living costs have fewer negative effects and good employment prospects and access to flexible work arrangements have more positive effects on childbearing among the high-educated, these factors may contribute to less negative educational gradients within more developed regions. It is also plausible that higher concentrations of the high-educated (Eurostat, 2019) and dual-earner couples (de Meester & Van Ham, 2009) in more developed regions contribute to more demand for and better availability of childcare services in these regions, which could in turn lead to a less negative regional educational gradient. Obviously, in addition to living costs, employment rates, and access to services, normative and cultural factors (Kulu, 2013; Mulder, 2013) may be relevant in this context. Thus, alternative hypotheses might also help to explain regional variation in fertility by educational attainment.[1]

This study aims to describe the educational gradient of the female cohort fertility rate (CFR) at the regional level in contemporary Europe. We assess 1) whether there is sub-national regional variation in the educational gradient in CFRs; and 2) whether this variation is systematic by regional level of development. Based on our theoretical considerations, we expect to find that negative educational fertility gradients are more common among women living in less economically developed regions, and that these gradients might be low or even positive in more developed regions. This study investigates the cohort fertility of women born in the late 1960s and early 1970s in 15 European countries. These cohorts are of interest because they recently completed their childbearing, and because in some European countries, their educational gradients in fertility have undergone marked changes. For these

[1] For instance, in developed regions, labour markets may also provide more opportunities and be more competitive, both of which could depress fertility, particularly among the high-educated (Kulu, 2013; Kulu & Washbrook, 2014).

women, we are able to measure number of children, level of education, and region of residence at the end of the reproductive career.

Women may move across regions over their life course – before, during, and after having (any) children. While sub-national migration and family formation are often closely interrelated life course steps, long-distance moves are less common at higher parities and higher reproductive ages (Dommermuth & Klüsener, 2019; Kulu, 2008; Michielin, 2004). The higher-educated have a greater propensity to migrate, and their reasons for migration are often related to further education and employment. Thus, they typically move to economically developed regions and cities (Berry & Glaeser, 2005). This pattern likely contributes to higher concentrations of the high-educated in the more developed regions.[2] For the low-educated, family-related reasons, such as proximity to kin, are more relevant for moving decisions. Thus, their moves seem to be less dependent on the economic development level of the destination region (Dawkins, 2006; Thomas, 2019). Taken together, a woman's region of residence at the end of her reproductive life, as measured in this study, may differ from the region where she lived during her prime childbearing years, possibly even in systematic ways. This can bias attempts to investigate hypothesised effects of regional contextual factors on our measured fertility outcomes. The aim of this study is, therefore, not to validate a causal link between contextual factors and fertility, but to describe educational patterning of cohort fertility among women by the region of residence at the end of the reproductive lifespan.

Data and methods

The datasets utilised in this study are described in Table 1. The study is based on register, census, and large-scale survey data. We cover 15 countries: Austria, Belarus, Belgium, Finland, France, Germany, Greece, Hungary, Ireland, Lithuania, the Netherlands, Norway, Romania, Spain, and Sweden. The study analyses native-born women born between 1964 and 1970. Cohort fertility, highest educational attainment, region of residence, and level of economic development are measured at the end of the reproductive career. In most countries, the data reflect the achieved fertility as of 2011. All women were aged 40 or older at the time of the measurement.

[2] Across Europe in 2018, 49% of women aged 30-34 had tertiary education and 15% had primary education; while in the capital regions, the respective shares were 58% and 13% (Eurostat, 2019). In the cohorts under study, the educational levels were generally lower.

[TABLE 1 ABOUT HERE]

The regional classification is based on the Nomenclature of Territorial Units for Statistics (NUTS) classification by Eurostat (Eurostat, 2011), a sub-regional categorisation of territorial units in the European Union. For most countries, we use the NUTS 2 level of classification, which covers regions and smaller countries with between 800,000 and three million inhabitants. Appendix 1 provides detailed information on the regional categorisation.

In register data, information on the region of residence is derived from registers on the place of dwelling. In survey data, it is self-reported. In census data, it is either self-reported or obtained from registers and corrected, where necessary, based on self-reports. We measure regional development using GDP (purchasing power standardised gross domestic product per capita) in 2011 extracted from the Eurostat database (Eurostat, 2018). We also considered other development measures, such as employee compensation, which focuses on household income. But as employee compensation is highly correlated with GDP across European regions and is not available for all regions in our dataset, we decided to use GDP.[3] See Appendix 2 for GDP per capita across regions.

The measurement of education is based on registers in the register data and self-reports in other data. We distinguish between low, medium, and high educational attainment following the International Standard Classification of Education (ISCED) (UNESCO, 1999). High refers to education at the tertiary level (ISCED 1997 levels 5-6), including short-cycle tertiary level education. Medium refers to education at the higher secondary or post-secondary non-tertiary level (ISCED 1997 levels 3-4). Low refers to education at the lower secondary level or lower (ISCED 1997 levels 1-2)[4]. In Belarus, Greece, Ireland, and Romania, the classification is based on the standards used by IPUMS international (IPUMS, 2018).[5] See Appendix 2 for the distribution of the educational attainment by region.

Fertility is measured as the mean total number of children per woman, corresponding to the cohort fertility rate. This number includes all children women have ever given birth to, and is derived from self-reports in census or survey data and information on registered births in register data. In France, the

[3] Based on own calculations of the European Regional Dataset (Cambridge Econometrics, 2018), the correlation between GDP per capita and employee compensation was 0.97 across NUTS 2 levels in 2011.
[4] In the Nordic countries, the small shares of women with missing information on educational attainment are classified as low-educated (<3% in Norway, <1% in Sweden and Finland).
[5] In order to follow the ISCED as closely as possible, we classify technical education college degrees (Greece), third-level non-degree qualifications (Ireland), and short-term post-secondary (associate) degrees (Romania) as tertiary (see also OECD, 2015).

Netherlands, and Norway, children given for adoption are linked to their adoptive parents instead of their biological parents. The country-specific mean age at the measurement of fertility was at least 42 in all cases except Belgium, where it was 41. Thus, completed fertility is slightly underestimated, particularly in Belgium. Prior research indicates, however, that changes in the educational gradient of women are very small past this age (Andersson et al., 2009; Berrington, Stone, & Beaujouan, 2015). In census-based data, women reporting unknown parity may cause errors in the parity estimates (Sobotka, 2017). Among the countries in this study for which census or survey data are used, the small numbers of women with unknown parity are redistributed in Belarus, Germany, and Lithuania.

Fertility rates of women by education and region are subject to sampling variation in the 9 out of the 15 countries for which full population data are not available (see Table 1). In order to document variation that reflects true heterogeneity rather than sampling noise, we use a standard method of small area estimation: the empirical Bayesian (EB) estimation (Assunção, Schmertmann, Potter, & Cavenaghi, 2005; Longford, 1999; Rao, 2014). In this method, statistical power is borrowed from other educational groups and regions in an attempt to limit noise in the fertility rate estimates. We assume that the number of children follows a Poisson distribution, and borrow strength for each educational group (1) from other educational groups within the region, (2) from the same educational groups in other regions within the country, and (3) from regularities in education-specific fertility schedules within the country. Shrinkage of an estimate is stronger when the estimate is based on a smaller sample size and is stronger towards another estimate based on a larger sample size. Additionally, given a correlation between fertility rates and GDP within countries (cross-country mean of correlation coefficient between regional fertility rate and regional logged GDP -0.6), larger weight is given in the estimation to regions that are more similar in terms of their GDP. See Appendix 3 for the details of the method, and Appendixes 4-6 for the comparison between unadjusted CFRs and our preferred EB-adjusted CFRs. Appendixes 9-11 show our main results based on unadjusted CFRs. These findings are stronger than those based on EB adjustment. We consider that the more conservative EB-based results are more likely to reflect reality than the unadjusted measures.

Results

A comparison at the country level

We first situate the sub-national analysis within the broader cross-country context in Europe. National CFRs independent of education range from 1.50 in Germany to 2.09 in Ireland (Table 2). Turning to the CFRs by education, it is relevant to note that the cross-country average of the share of women in each educational category is 32% for tertiary (range 16-53%), 53% for medium (36-73%), and 16% for low (2-29%) (Appendix 2). The medium-educated are the largest group in all but two countries (Finland and Norway), while the low-educated are the smallest group in all but one country (Greece). The educational gradient in CFRs is negative in almost all countries, but the magnitude of the gradient varies across countries and educational comparisons. Notably, high- and medium-educated women are, on average, more similar in their CFRs than medium- and low-educated women. The high-educated have, on average, fewer children than the medium-educated in all but one country, with the difference ranging from -0.42 in Romania, to almost zero in Norway and Sweden, to 0.10 in Belgium. The medium-educated have fewer children than the low-educated, with the difference ranging from close to zero in Finland and Norway to -0.68 in Romania and -0.59 in Hungary. In all countries, our derived rates for the high-educated are below those for the low-educated, with the difference ranging from -0.03 (Norway) and -0.01 (Belgium) to -0.69 (Hungary) and -1.10 (Romania).

[TABLE 2 ABOUT HERE]

Variation between and within countries by GDP

Figure 1 plots for our complete set of regions the CFR difference between the high- and medium-educated (Figure 1A), the medium- and-low educated (Figure 1B), and the high- and low-educated (Figure 1C) by log-transformed GDP[6]. The overall pattern that emerges is that of a negative educational gradient that declines as the level of regional economic development increases, and that has considerable variation at any level of GDP. The regions with low GDP tend to display larger educational differences in CFRs. In a number of regions, the difference is reversed; i.e., the high-educated have a higher CFR than the low-educated, particularly among the more developed regions. See Appendix 7 for CFR by education for all regions.

[6] See Appendix 2 for within-country variation in educational attainment. In all but four countries (Belgium, Germany, Netherlands, Spain), the share of high-educated women was largest in the region with the highest GDP.

[FIGURE 1A-C ABOUT HERE]

A pattern of the fertility differentials between educational groups becoming smaller as we move from regions with lower GDP to regions with higher GDP is observed both across all countries and within countries. The regression lines superimposed on the graphs show a strong and significant correlation between higher levels of economic development and decreasing differences in fertility between educational groups for all three educational comparisons. Whether this pattern is attributable to variation between or within countries can be tested by regressing the educational fertility difference on GDP while controlling for country fixed effects. The coefficients of these regressions are shown in the bottom-right corner of each of the figures. In each instance, the coefficients suggest that within countries, educational differences in fertility also tend to be smaller as the level of economic development of a region increases. The evidence for the within-country pattern is stronger in the high-medium comparison than in the medium-low comparison. As the figures illustrate, there are exceptions to the general pattern of a smaller gradient, as in some countries the educational fertility gradient is not associated or positively associated with the level of GDP of a region. However, averaged across all countries, the evidence suggests that within countries, a higher level of economic development is also associated with smaller differences in fertility between educational groups. Additional analyses show that countries in Eastern and Central Europe strongly contribute to the within-country pattern; when these countries are excluded, the cross-country association between the educational gradient and GDP persists, but the within-country association becomes flat (Appendix 8).

Regions with the highest GDP and other regions

In order to better understand within-country patterns, we additionally analyse educational gradients by comparing the economically most developed region to all other regions within each country (Figure 2). There is a general tendency towards smaller educational differences in the most developed regions within countries: in all educational group comparisons, the educational difference averaged across countries is smaller in the region with the highest GDP. However, there is large variation across countries around this average tendency. The three panels shown in Figure 2 indicate that the differences in the magnitudes of the educational gradient between the highest GDP region and other regions are particularly large in Eastern European countries, where the country-level magnitudes of the gradient are also large. In Norway, Sweden, Spain, and Greece, the differences are also smaller in the highest GDP region, but the differences relative to other regions are not as large. In Finland, France, the Netherlands, and Ireland, the differences between the highest GDP region and other regions are small; and in

Belgium, Austria, and Germany, there are indications that the educational gradient is larger in the highest GDP regions than in other regions.

[FIGURE 2 ABOUT HERE]

Conclusion

Previous studies have shown that educational differences in women's completed fertility vary between countries and over time. We show that educational gradients also vary across sub-national regions within countries in Europe, and that this variation is notable and quite systematic. Women educated to high and medium levels are, on average, more similar in their completed fertility than women educated to medium and low levels; and the gradient between the high- and low-educated in completed fertility narrows with increasing levels of economic development between and within countries. However, the variation between countries in the within-country pattern is noteworthy. For example, in Hungary, high-educated women have only 0.04 fewer children than medium-educated women in the most developed region, compared to 0.13 fewer children in other areas. Meanwhile, in Belgium, high-educated women have 0.06 fewer children than medium-educated women in the most developed region, but 0.11 more children in other areas.

We expected to find weaker negative gradients in cohort fertility in the more developed regions based on our hypothesis that the contextual conditions in such regions could lead to more similar childbearing patterns among women in different educational groups. For example, the fertility of the low-educated might be particularly depressed in these regions due to higher living costs, while the high-educated might benefit more from better access to employment, childcare services, and flexible work. In line with our expectations, we find that well-developed regions have smaller differentials in fertility by education. In this descriptive analysis, however, we were not able to test the importance of the hypothesised mechanisms. Further studies could validate the role of regional contextual factors for educational gradients in fertility by linking individual-level data to such factors at the time when childbearing decisions are made (see Hank, 2002; Kulu, 2013). The role of sub-national migration over the life course for the educational patterning of cohort fertility at the regional level also requires investigation. Given the sequential nature of childbearing and the evidence that cohort fertility masks parity-specific variation (Zeman, Beaujouan, Brzozowska, & Sobotka, 2018), parity-specific analysis (see Fiori, Graham,

& Feng, 2014; Kulu & Washbrook, 2014) may help to disentangle the mechanisms behind the observed patterns.

The environment women born in the late 1960s experienced during their prime childbearing years differed substantially across countries. An elaborated analysis of such between-country differences is beyond our focus, but we note that women in the former communist countries – Belarus, former East Germany (classified here as part of Germany[7]), Hungary, Lithuania, and Romania – experienced a very particular childbearing context (Billingsley, 2010; Sobotka, 2011). The female cohorts of the late 1960s were in their early twenties at the onset of the crisis of the Soviet Union in 1989. By then, many of those who had not entered university had already become mothers, while many of those who were students finished their education after the onset of the crisis, and were thus more likely to postpone childbearing. These circumstances contributed to strong variation in fertility in the cohorts studied (Kreyenfeld, 2006). The timing of the crisis may have also contributed to some of the strong regional patterns we observe in the Central and Eastern European countries. Moreover, the high levels of regional inequality in these countries (Petrakos, 2001) may have further contributed to regional variation in educational gradients.

Our data sources vary by country. Measurement is likely to be more accurate in register than in census or survey data. Quality assessment of the small-sample data sources used in the study in Austria (Neuwirth, 2015; Statistics Austria, 2018; Verwiebe, Troger, & Riederer, 2014), France (INSEE, 2013, 2014), and Germany (Federal Statistical Office and Statistical Offices of the Federal States, 2018) showed relatively high overall response rates (78-95%), but lower rates among the low-educated and varying rates by region, with the rates being lower in capital regions. We cannot rule out the possibility that measurement error affected the results of this study, but it is unlikely that it would have led to the main results, because the error would need to be differently selective by educational attainment across regions. We were also unable to assess the sensitivity of our results to regional categorisation ("modifiable areal unit problem") (Openshaw, 1984). Given the changes observed over time in educational gradients at the country level, as well as the changes in the association between the level of development and fertility at the sub-national regional level, future studies should investigate whether the regional patterning of educational gradients is subject to change over time by including a wider selection of birth cohorts.

[7] The following regions belonged to the German Democratic Republic until 1990: Berlin and Brandenburg, Saxony and Thuringia, and Mecklenburg-Western Pomerania and Saxony-Anhalt.

This study underlines the variability of the educational gradient in fertility. We document an overall negative gradient between CFRs and level of education, and notable variation in the magnitude of the gradient across sub-national regions. While smaller negative gradients are generally found in more economically developed regions, notable differences can be observed between countries in the within-country patterning of the gradient. The high fertility of high-educated women relative to medium- (or low-) educated women in more developed regions suggests that in Europe, negative educational gradients in cohort fertility at the country level are more strongly driven by women living in less economically prosperous sub-national regions (at the end of their reproductive careers). Furthermore, given that the shares of women with high educational attainment are particularly large in well-developed regions, these findings may help to explain why overall fertility has been relatively high in these European regions in recent years. To conclude, this study suggests that using a sub-national regional approach can advance our understanding of the dynamics of educational differentials in fertility, and that more in-depth (comparative) fertility analyses are needed on the relationship between education and fertility at the level of sub-national regions.

Additional material: an interactive map showing women's cohort fertility rate by level of education at the sub-national regional level in 15 European countries: https://fertility.shinyapps.io/cfr_edu_region/; the cohort fertility rates in digital format and the code used to generate the interactive map: https://github.com/DemogrFertility/cfr_edu_region.

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Table 1 Data sources of the study in 15 European countries

Country	Cohorts	Sample (%)	Data type	Measurement date	Age at measurement
Austria	1965-1970	>1	Microcensus+survey	2012-2013/2016[1]	42-46
Belarus	1965-1968	10	Census	14.-24.10.2009	41-45
Belgium	1964-1966	100	Register	31.12.2006[2]	40-42
Finland	1966-1970	10	Register	31.12.2012[3]	42-46
France	1965-1970	1	Survey	26.2.2011	40-45
Germany	1964-1970	1	Microcensus	2008/2012/2016[4]	41-48
Greece	1965-1970	10	Census	10.-20.5.2011	40-46
Hungary	1966-1970	100	Census	1.10.2011	41-45
Ireland	1965-1970	10	Census	10.4.2011	41-45
Lithuania	1966-1970	100	Census	1.3.2011	41-45
Netherlands	1966-1970	100	Register	31.12.2011	41-43
Norway	1966-1970	100	Register	31.12.2011	41-45
Romania	1965-1970	10	Census	20.-31.10.2011	40-45
Spain	1966-1970	9	Census	11.1.2011	41-45
Sweden	1966-1970	100	Register	31.12.2012	40-44

[1] Data sources in Austria are microcensuses in 2012 (4th quarter) and 2016 (4th quarter), Austrian Gender and Generations Survey gathered from September 2012 to March 2013, and Basic Social Science Research for Vienna Survey gathered from October 2012 to July 2013. [2] In Belgium, education is measured in the census conducted on 1 October 2001 when women were aged 34 to 37. [3] In Finland, education and region were measured on 31 December 2007 when women were aged 37 to 41. [4] Data sources for Germany are microcensuses in 2008, 2012, and 2016 gathered throughout the year.

Table 2 Cohort fertility rate of women by educational attainment in 15 European countries.

COUNTRY	High	Medium	Low	Total	Δ High-Medium	Δ Medium-Low	Δ High-Low
Austria	1.38	1.62	1.98	1.61	-0.19	-0.33	-0.52
Belarus	1.43	1.76	1.96	1.68	-0.29	-0.14	-0.44
Belgium	1.74	1.65	1.78	1.72	0.10	-0.11	-0.01
Finland	1.81	1.99	1.97	1.90	-0.15	-0.01	-0.16
France	1.76	1.87	2.10	1.87	-0.09	-0.22	-0.31
Germany	1.40	1.51	1.67	1.50	-0.11	-0.16	-0.27
Greece	1.54	1.69	2.09	1.76	-0.14	-0.33	-0.48
Hungary	1.66	1.77	2.42	1.86	-0.10	-0.59	-0.69
Ireland	1.88	2.10	2.38	2.09	-0.22	-0.28	-0.50
Lithuania	1.56	1.90	2.06	1.80	-0.29	-0.14	-0.43
Netherlands	1.71	1.82	1.89	1.81	-0.10	-0.03	-0.12
Norway	1.99	2.04	2.05	2.02	-0.01	-0.02	-0.03
Romania	1.12	1.57	2.28	1.65	-0.42	-0.68	-1.10
Spain	1.34	1.48	1.71	1.46	-0.14	-0.14	-0.28
Sweden	1.93	1.94	2.04	1.94	0.00	-0.10	-0.10
	1.62	1.78	2.03	1.78	-0.14	-0.22	-0.36

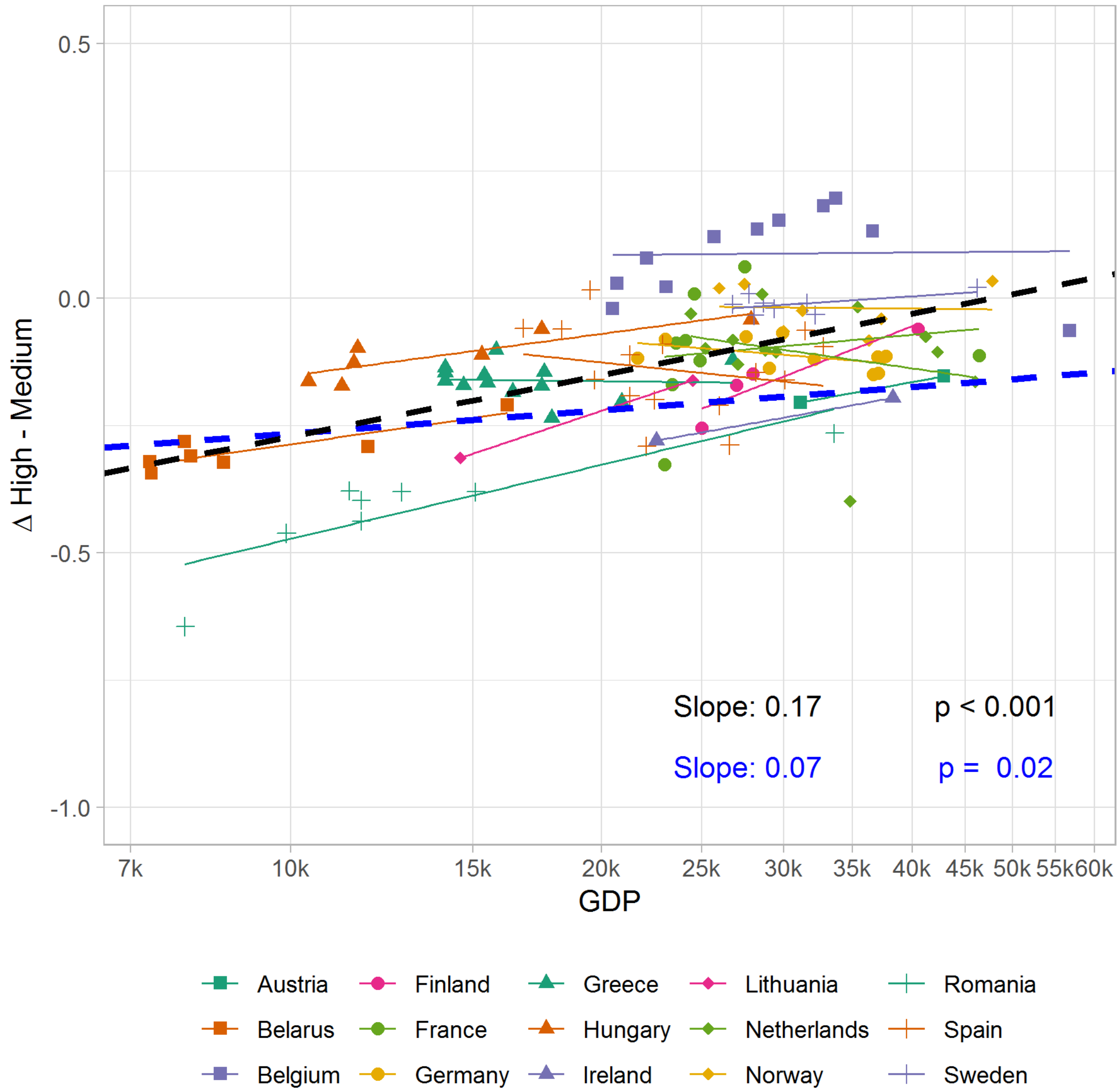


Figure 1A The difference in cohort fertility rate between high- and medium-educated women according to the GDP per capita level of the region in 15 European countries. Regression lines are fitted for the global trend without (black dashed line) and with (blue dashed line) country fixed effects, and for the within-country trends for each country separately (solid lines).

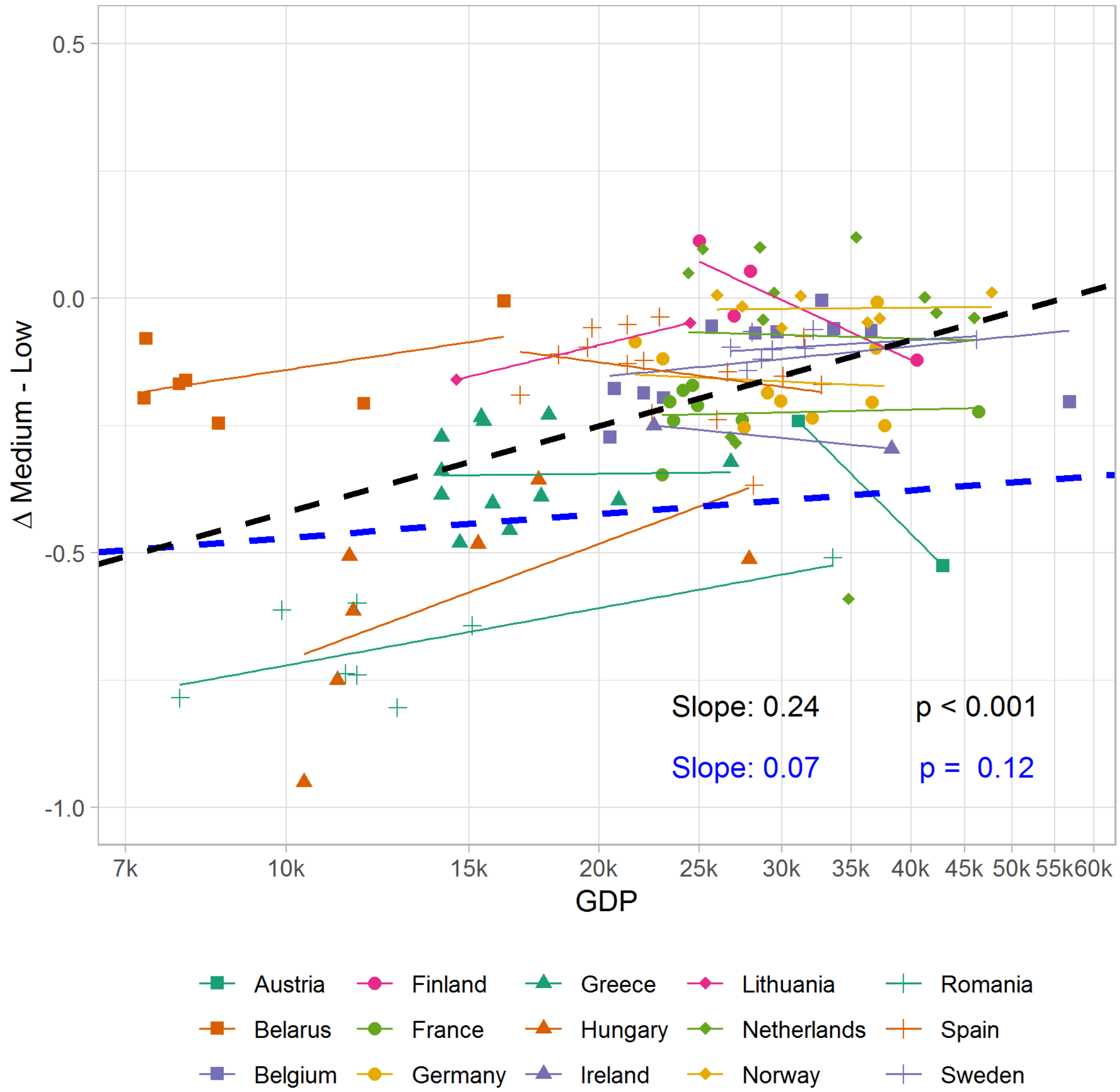


Figure 1B The difference in cohort fertility rate between medium- and low-educated women according to the GDP per capita level of the region in 15 European countries. Regression lines are fitted for the global trend without (black dashed line) and with (blue dashed line) country fixed effects, and for the within-country trends for each country separately (solid lines).

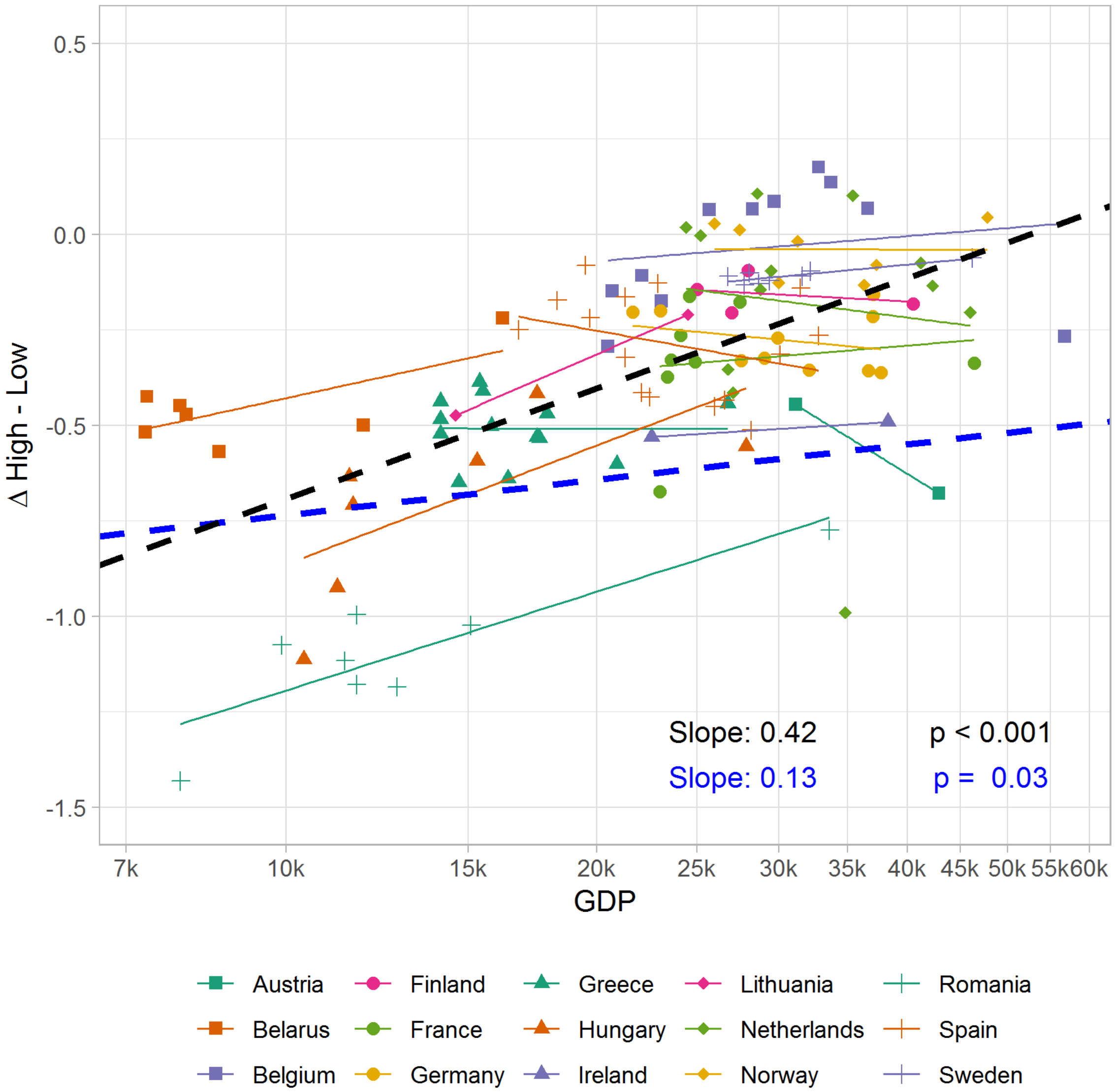


Figure 1C The difference in cohort fertility rate between high- and low-educated women according to the GDP per capita level of the region of the 15 European countries. Regression lines are fitted for the global trend without (black dashed line) and with (blue dashed line) country fixed effects, and for the within-country trends for each country separately (solid lines).

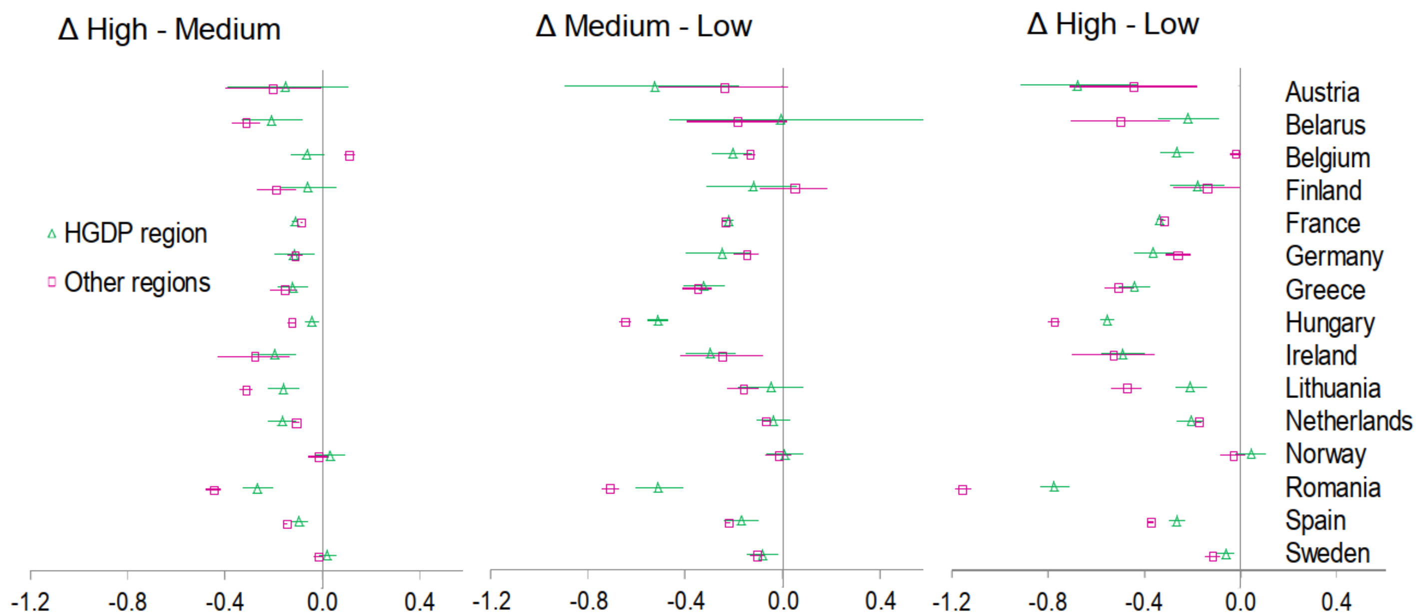


Figure 2 The difference in cohort fertility rate between two educational groups of women by country: the region with the highest GDP per capita value (HGDP region) and other regions of a country in 15 European countries. Figures also display 95% credible intervals of the point estimates with horizontal lines.

Appendix 1 Description of the sub-national regional categorisation in 15 European countries

The NUTS categorisation is strongly linked to existing administrative divisions in a country, and also considers the general character and population size of the region. This categorisation has three levels, and we generally aimed to use the NUTS 2 level, which covers regions with between 800,000 and three million inhabitants. At the NUTS 1 level, on the other hand, many smaller countries would consist of one region only. NUTS 2-level data were analysed for Belarus, Belgium, Finland, Greece, Hungary, Ireland, the Netherlands, Norway, Romania, Spain, and Sweden. These regions generally have populations between 800,000 and three million inhabitants. In Austria, France, and Germany, limited sample sizes forced us to conduct the analysis at a higher level of geographic detail. In Austria, the capital city of Vienna (NUTS 2) was compared with the rest of the country. For France, we excluded overseas territories, and used the NUTS 1 level. For Germany, a modified version of the NUTS 1 level was used to compensate for the small numbers in some regions due to the sample used. For Finland, we excluded the Åland islands; and for Spain, we excluded the Canary Islands and the Balearic Islands, Ceuta and Melilia, due to their small population sizes and distinct cultures. For Lithuania, which back in 2011 consisted of just one NUTS 2 region, we separated out the capital city of Vilnius (a LAU1 level unit in the classification of Eurostat) from the rest of Lithuania. Belarus is not an EU country, but a corresponding classification has been developed for it; please see http://riate.cnrs.fr/wp-content/uploads/2015/03/M4D_20121220_TR_russia.pdf.

Appendix 2 Descriptive characteristics of the study population by sub-national region in 15 European countries

Country	Region	High, %	Medium, %	Low, %	N	GDP per capita
Austria	Vienna	32	62	7	813	42,900
	Rest of Austria	19	65	16	1,893	31,147
	Total	23	64	13	2,706	37,023
Belarus	Minsk city	40	60	0	3,922	16,209
	Minsk	20	78	3	3,533	11,879
	Gomel	21	76	3	3,474	8,604
	Brest	23	76	2	3,411	7,329
	Vitebsk	24	75	2	2,996	7,886
	Grodno	24	75	1	2,904	8,003
	Mogilev	21	77	2	2,664	7,300
	Total	25	73	2	22,904	9,601
Belgium	Brussels	49	25	26	9,753	56,800
	Antwerp	36	41	23	33,484	36,600
	Brabant Walonne	50	28	22	6,910	33,700
	Vlaams Brabant	46	36	18	22,053	32,800
	West Flanders	32	39	29	24,065	29,700
	East Flanders	36	38	27	29,704	28,300
	Limburg	33	40	27	16,818	25,700
	Liège	33	34	34	18,787	23,100
	Namur	35	35	31	8,980	22,100
	Luxembourg	35	35	30	4,884	20,700
	Hainaut	29	34	37	23,647	20,500
	Total	36	36	27	199,085	30,000
Finland	Helsinki-Uusimaa	58	32	10	5,118	40,500
	West Finland	50	42	9	3,848	28,000
	South Finland	48	42	10	3,317	27,000
	North and East Finland	50	42	8	3,419	25,000
	Total	52	39	9	15,702	30,125
France	Parisian region	49	36	15	352,428	46,400
	Central East France	35	49	16	270,447	27,500
	Mediterranean France	35	48	18	291,688	24,900
	South West France	37	48	15	246,325	24,600
	West France	34	50	16	321,986	24,100
	Paris Basin	28	50	22	400,242	23,600
	East France	30	51	19	194,127	23,400
	North France	31	45	24	148,062	23,000
	Total	35	47	18	2,225,305	27,188
Germany	Hesse	26	65	9	4,565	37,672
	Bavaria	23	68	9	10,408	37,050
	Baden-Wuerttemberg	25	66	9	7,844	36,987
	Schleswig-Holstein and Hamburg	25	65	9	3,844	36,640
	North Rhine-Westphalia	22	67	12	13,423	32,095
	Lower Saxony and Bremen	19	69	12	6,972	29,919
	Rhineland Palatinate and Saarland	20	68	12	3,928	29,070
	Berlin and Brandenburg	37	58	5	4,752	27,583
	Saxony and Thuringia	33	65	2	5,208	23,044
	Mecklenburg-Western Pomerania	28	67	5	3,351	21,676
	Total	25	66	9	64,295	31,174

Appendix 2 continues

Country	Region	High, %	Medium, %	Low, %	N	GDP per capita
Greece	Attiki	34	49	18	14726	26,800
	Notio Aigaio	17	40	43	1075	20,900
	Dytiki Makedonia	25	37	39	1111	17,900
	Ionia Nisia	22	42	36	766	17,600
	Sterea Ellada	22	42	37	2048	17,500
	Kriti	25	41	33	2248	16,400
	Peloponnisos	22	42	36	1964	15,800
	Voreio Aigaio	26	38	36	673	15,500
	Kentriki Makedonia	30	41	29	6990	15,400
	Dytiki Ellada	22	39	39	2600	14,700
	Anatoliki Makedonia, Thraki	22	34	44	2112	14,100
	Ipeiros	31	34	35	1140	14,100
	Thessalia	28	36	36	2731	14,100
	Total	29	43	29	40184	16,985
Hungary	Central Hungary	31	58	11	97,031	27,900
	Western Transdanubia	20	64	17	33,439	17,500
	Central Transdanubia	19	62	20	36,369	15,300
	Southern Great Plain	19	59	22	31,485	11,600
	Southern Transdanubia	20	61	19	43,003	11,500
	Northern Great Plain	19	57	25	50,040	11,200
	Northern Hungary	19	59	22	40,142	10,400
	Total	23	59	18	331,509	15,057
Ireland	Southern and Eastern	35	41	24	10,475	38,300
	Border, Midland and Western	33	42	25	3,772	22,600
	Total	34	41	24	14,247	30,450
Lithuania	Vilnius	52	45	2	17,445	24,500
	Rest of Lithuania	28	67	5	89,592	14,592
	Total	32	64	5	107,037	19,546
Netherlands	Groningen	28	51	21	18,462	46,000
	Noord-Holland	37	45	18	81,843	42,300
	Utrecht	42	41	17	40,787	41,200
	Noord-Brabant	27	50	23	82,607	35,400
	Zuid-Holland	21	34	45	30,974	34,800
	Gelderland	29	49	23	68,838	29,500
	Overijssel	25	53	21	37,527	28,800
	Limburg	24	51	25	36,124	28,600
	Zeeland	20	56	24	12,173	27,100
	Flevoland	26	50	24	12,087	26,800
	Friesland	26	54	20	22,576	25,200
	Drenthe	26	53	21	17,589	24,400
	Total	29	48	23	461,587	32,508
Norway	Oslo and Akershus	52	34	14	19,290	47,800
	Agder and Rogaland	39	43	19	9,689	37,300
	Western Norway	43	42	16	11,474	36,300
	Trøndelag	44	41	15	6,389	31,300
	Northern Norway	45	39	16	7,024	30,000
	South Eastern Norway	36	43	20	15,211	27,500
	Hedmark and Oppland	34	45	21	6,107	26,000
	Total	43	40	17	75,184	33,743

Appendix 2 continues

Country	Region	High, %	Medium, %	Low, %	N	GDP per capita
Romania	Bucharest - Ilfov	37	50	13	11,206	33,600
	West	20	55	25	8,658	15,100
	Center	19	60	22	10,154	12,800
	Northwest	19	56	26	11,214	11,700
	South - Muntenia	16	58	27	14,805	11,700
	South East	19	55	26	11,485	11,400
	South-West Oltenia	16	62	22	9,657	9,900
	Northeast	16	56	28	13,626	7,900
	Total	20	56	24	90,805	14,263
Spain	Madrid	29	66	6	2,744	32,800
	Basque Community	29	65	6	21,332	31,500
	Navarre	23	67	10	13,219	30,100
	Catalonia	25	66	8	1,345	28,200
	Aragon	22	64	14	3,749	26,600
	La Rioja	20	62	18	24,744	26,000
	Castile-Leon	24	70	7	2,027	22,900
	Cantabria	17	67	16	5,326	22,500
	Principality of Asturias	17	68	16	8,905	22,100
	Galicia	25	65	9	7,613	21,300
	Valencian Community	27	67	6	5,595	21,300
	Murcia	25	67	9	13,179	19,700
	Castille-La Mancha	35	60	5	7,460	19,500
	Andalucia	40	55	5	17,579	18,300
	Extremadura	31	64	6	3,013	16,800
	Total	28	62	10	137,830	23,973
Sweden	Stockholm	43	49	8	54,235	46,200
	Upper Norrland	41	51	9	14,216	32,200
	West Sweden	37	53	9	52,153	31,600
	Middle Norrland	35	55	10	10,780	29,400
	East Middle Sweden	36	54	10	42,457	28,700
	Småland and the islands	34	57	9	22,080	28,100
	South Sweden	39	52	9	36,575	27,800
	North Sweden	33	56	11	23,241	26,800
	Total	38	53	9	255,737	31,350

Note: Results for Austria, France, and Spain are shown as weighted. Sub-national regions within a country are ranked by the GDP per capita of the region, from highest to lowest. Population-weighted average GDP per capita was used for regions containing more than one NUTS region. In Lithuania, the GDP per capita value was not available for the chosen regional classification, and the value for Vilnius county, a larger area that also covers the surrounding areas of Vilnius city (NUTS 3 level region), had to be used as a proximate estimate. The total rows show for the GDP per capita the non-weighted country averages of the regional values.

Appendix 3 Empirical Bayesian estimation

We use a vector-based empirical Bayesian approach to estimate region- and education-specific cohort fertility rates and their credible intervals (Assunção et al., 2005; Longford, 1999). The vector-based approach borrows strength not only from other regions in the same country based on the sample sizes of these regions and their similarity to the GDP of the region in question, but from other educational groups in the same region and from regularities in educational fertility schedules across regions. The estimation method can be described as follows. Suppose the total number of women from selected cohorts observed from country c $(c = 1, \ldots, C)$, region r $(r = 1, \ldots, R_c)$ with education level e $(e = 1,2,3)$ is denoted as $NWomen_{c,r,e}$and the number of children is denoted by $NChild_{c,r,e}$. The crude cohort fertility rate is denoted by $\hat{\lambda}_{c,r,e} = NChild_{c,r,e}/NWomen_{c,r,e}$ and $\hat{\lambda}_{c,r} = NChild_{c,r}/NWomen_{c,r}$, where

$NWomen_{c,r} = \left(NWomen_{c,r,1}, NWomen_{c,r,2}, NWomen_{c,r,3}\right)$, and

$NChild_{c,r} = \left(NChild_{c,r,1}, NChild_{c,r,2}, NChild_{c,r,3}\right)$.

Suppose the *real* cohort fertility rate $\lambda_{c,r,e}$follows:

$$NChild_{c,r,e}|\lambda_{c,r,e} \sim Poisson(NWomen_{c,r,e} \times \lambda_{c,r,e})$$

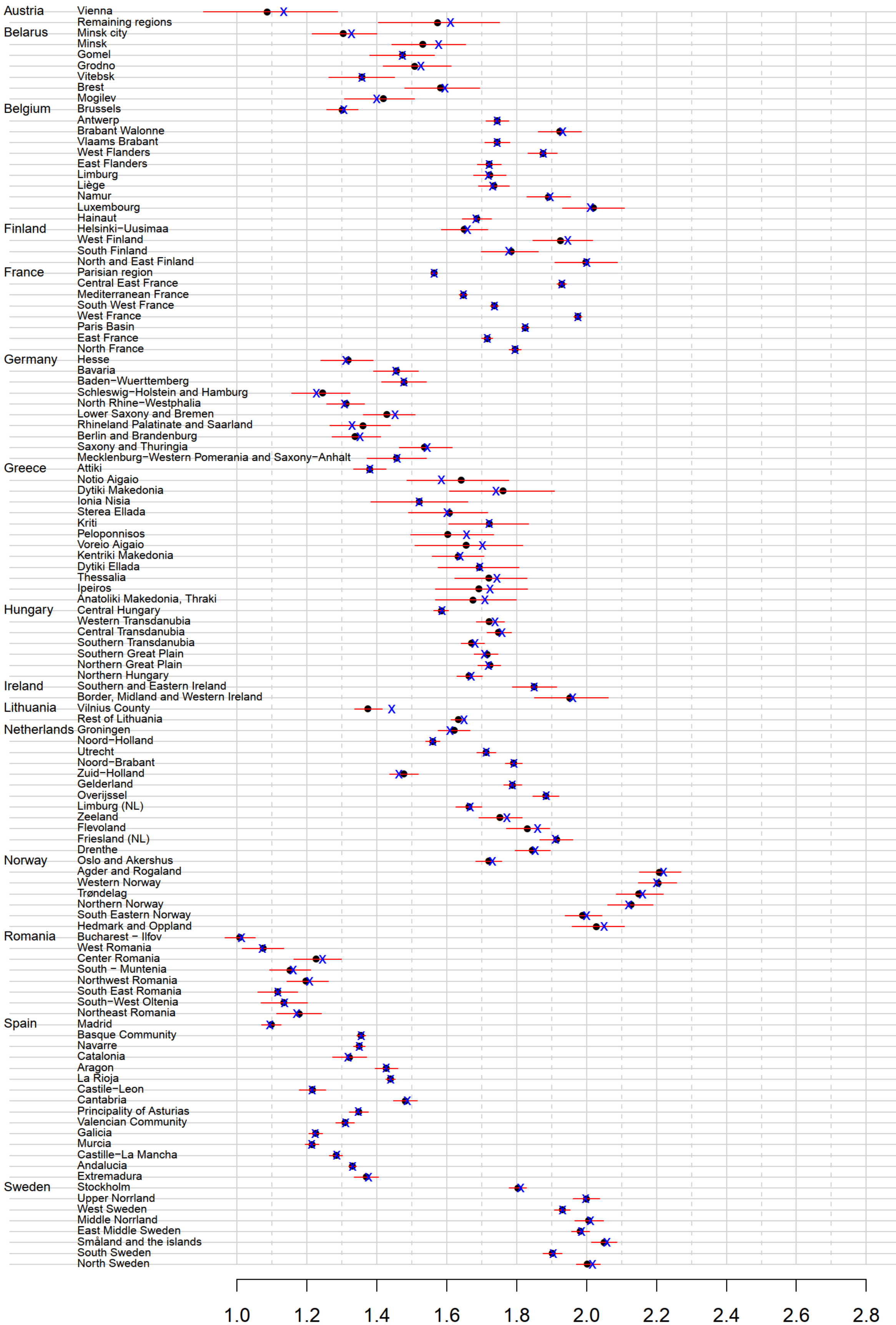
The distance in GDP between region $r_1$of country $c_1$and region r_2 of country c_2 is defined as

$$d_{c_1,c_2;r_1,r_2} = \begin{cases} \left|GDP_{c_1,r_1} - GDP_{c_2,r_2}\right|/range_{1\le c\le C, 1\le r\le R_c}\left(GDP_{c,r}\right) & if\ c_1 = c_2 \\ 1 & if\ c_1 \neq c_2 \end{cases}$$

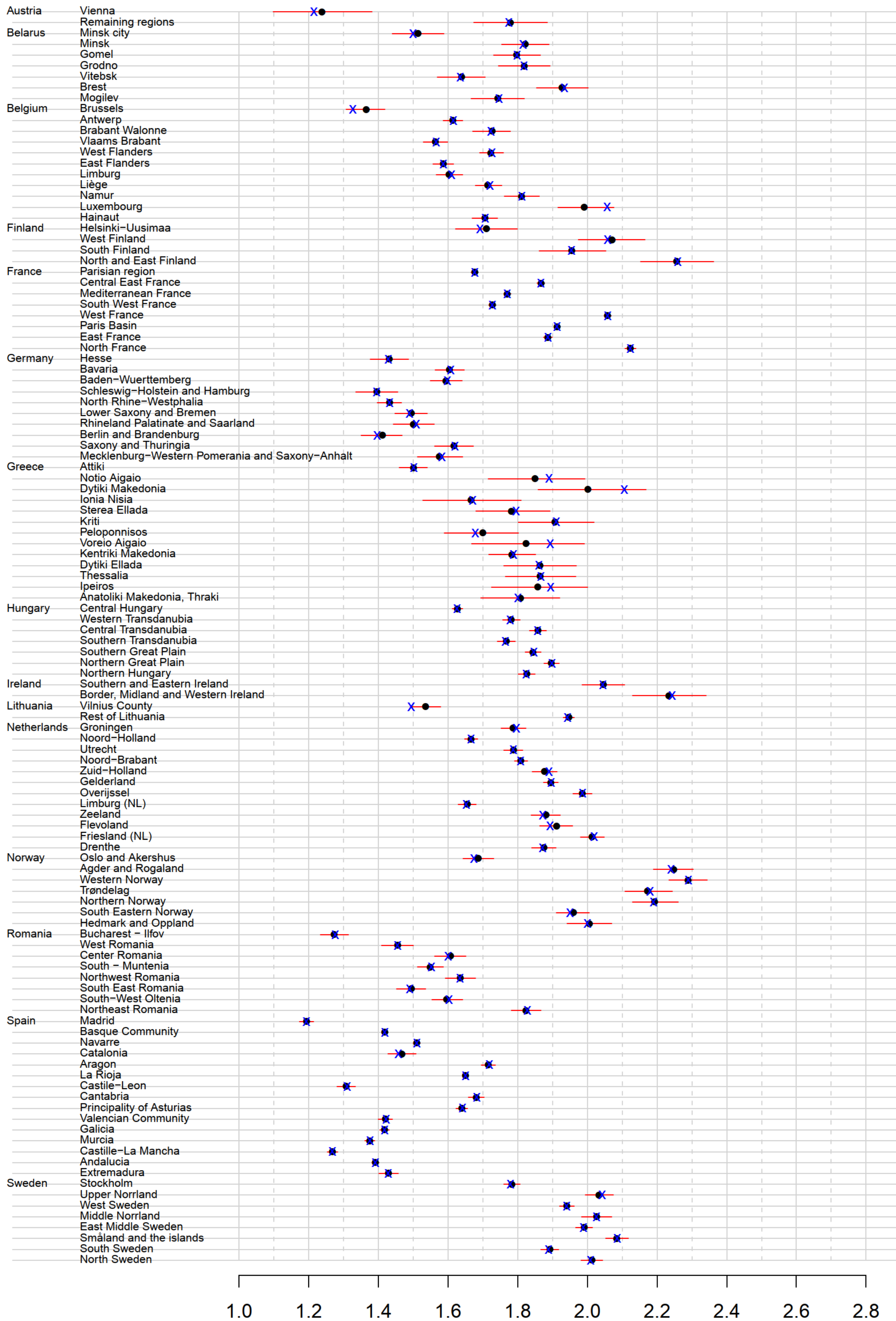
The vectorial regional shrinkage estimator for the cohort fertility rate is denoted as:

$\lambda^*_{c,r} = \hat{\lambda}_{c,r} + \tau_{c,r}\left(E(\lambda_{c,r}) - \hat{\lambda}_{c,r}\right)$, where $E\left(\lambda_{c,r}\right)$ is the cohort fertility rate of region r and $\tau_{c,r}$ shrinking factor. $E\left(\lambda_{c,r}\right)$ is estimated as $\hat{E}\left(\lambda_{c,r}\right) = \sum_{r_i=1}^{Rc}\left[\left(1 - d_{c,c;r,r_i}\right) \times \hat{\lambda}_{c,r_2}\right]$ by borrowing information from other regions in country c according to their distances in GDP. The vectorial shrinkage estimator $\lambda^*_{c,r}$ shrinks a vector of regional cohort fertility rate estimates towards a more typical pattern of regional fertility estimates within a country, with more shrinkage when the distance in GDP is smaller. The shrinking factor $\tau_{c,r}$ is estimated using moments estimation, as proposed by Assunção et al., 2005, which gives larger values (i.e., more shrinkage) when the sampling noise of a regional estimate is expected to be large relative to the variability of the estimates across regions within a country. It follows that shrinkage is larger for regions with smaller sample sizes. Sensitivity analysis showed that the results were robust when different distance matrixes were defined based on the GDP. All CIs (credible intervals) were estimated based on 10,000 bootstrapping replications. The analysis was performed using R version 3.4.1.

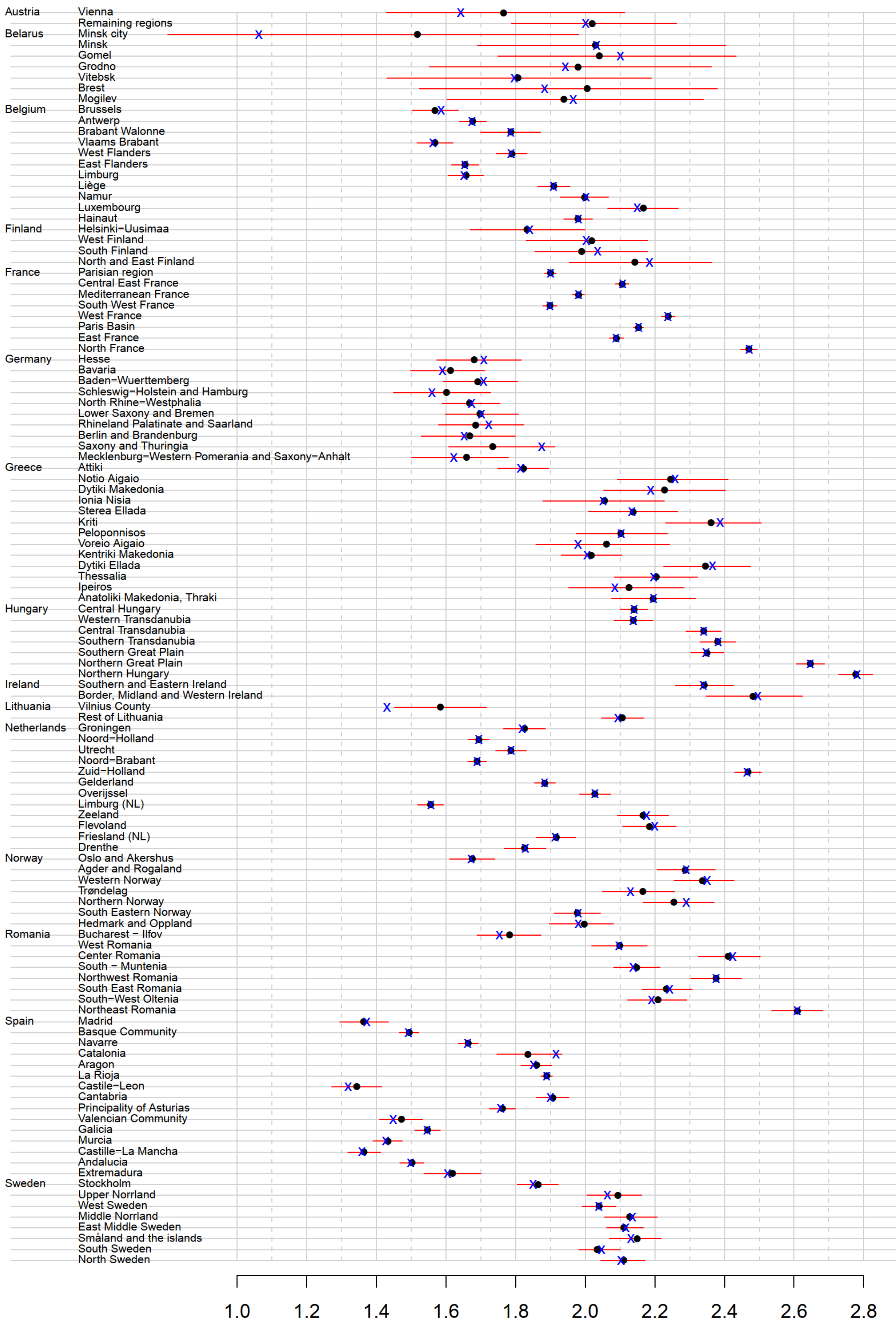
Appendix 4 Empirical Bayesian cohort fertility rate (black), 95% credible interval (red), and observed cohort fertility rate (blue) for the high-educated by sub-national region in 15 European countries



Appendix 5 Empirical Bayesian cohort fertility rate (black), 95% credible interval (red), and observed cohort fertility rate (blue) for the medium-educated by sub-national region in 15 European countries



Appendix 6 Empirical Bayesian cohort fertility rate (black), 95% credible interval (red), and observed cohort fertility rate (blue) for the low-educated by sub-national region in 15 European countries



Appendix 7 Cohort fertility rate of women by educational attainment and sub-national region in 15 European countries. Empirical Bayesian cohort fertility rates.

Country	Region	High	Med	Low	Δ High - Med (95% CI)		Δ Med - Low (95% CI)		Δ High - Low (95% CI)	
Austria	Vienna	1.09	1.24	1.77	-0.15	(-0.39,0.10)	-0.53	(-0.90,-0.18)	-0.68	(-1.07,-0.29)
	Rest of Austria	1.57	1.78	2.02	-0.20	(-0.40,-0.01)	-0.24	(-0.51,0.02)	-0.45	(-0.74,-0.15)
	Total	1.37	1.62	1.98	-0.19	(-0.35,-0.03)	-0.33	(-0.55,-0.11)	-0.52	(-0.77,-0.27)
Belarus	Minsk city	1.28	1.53	1.72	-0.21	(-0.33,-0.08)	-0.01	(-0.46,0.71)	-0.22	(-0.68,0.52)
	Minsk	1.50	1.83	2.01	-0.29	(-0.39,-0.15)	-0.21	(-0.59,0.13)	-0.50	(-0.87,-0.13)
	Gomel	1.48	1.80	1.98	-0.32	(-0.43,-0.22)	-0.25	(-0.64,0.05)	-0.57	(-0.97,-0.27)
	Brest	1.50	1.82	2.00	-0.31	(-0.41,-0.19)	-0.16	(-0.53,0.27)	-0.47	(-0.84,-0.03)
	Vitebsk	1.36	1.64	1.84	-0.28	(-0.38,-0.18)	-0.17	(-0.55,0.20)	-0.45	(-0.84,-0.07)
	Grodno	1.58	1.93	2.08	-0.34	(-0.46,-0.22)	-0.08	(-0.45,0.41)	-0.42	(-0.80,0.08)
	Mogilev	1.44	1.74	1.93	-0.32	(-0.45,-0.23)	-0.20	(-0.59,0.14)	-0.52	(-0.94,-0.19)
	Total	1.43	1.76	1.96	-0.29	(-0.35,-0.24)	-0.14	(-0.35,0.07)	-0.44	(-0.65,-0.22)
Belgium	Brussels	1.30	1.38	1.56	-0.06	(-0.13,0.01)	-0.20	(-0.29,-0.12)	-0.27	(-0.35,-0.19)
	Antwerp	1.75	1.61	1.68	0.13	(0.09,0.17)	-0.06	(-0.11,-0.02)	0.07	(0.02,0.12)
	Brabant Walonne	1.92	1.73	1.78	0.20	(0.13,0.27)	-0.06	(-0.14,0.02)	0.14	(0.03,0.25)
	Vlaams Brabant	1.75	1.56	1.57	0.18	(0.13,0.23)	0.00	(-0.06,0.05)	0.18	(0.11,0.24)
	West Flanders	1.88	1.72	1.79	0.15	(0.10,0.20)	-0.07	(-0.12,-0.01)	0.09	(0.02,0.15)
	East Flanders	1.72	1.59	1.66	0.14	(0.09,0.18)	-0.07	(-0.11,-0.02)	0.07	(0.01,0.12)
	Limburg	1.73	1.60	1.66	0.12	(0.06,0.17)	-0.06	(-0.11,0.01)	0.07	(0.00,0.14)
	Liège	1.74	1.71	1.91	0.02	(-0.03,0.07)	-0.20	(-0.25,-0.14)	-0.17	(-0.24,-0.11)
	Namur	1.89	1.81	2.00	0.08	(0.01,0.15)	-0.19	(-0.26,-0.12)	-0.11	(-0.20,-0.01)
	Luxembourg	2.03	1.98	2.18	0.03	(-0.08,0.13)	-0.18	(-0.28,-0.05)	-0.15	(-0.29,-0.01)
	Hainaut	1.69	1.71	1.98	-0.02	(-0.07,0.03)	-0.27	(-0.33,-0.22)	-0.29	(-0.35,-0.23)
	Total	1.74	1.65	1.78	0.10	(0.08,0.12)	-0.11	(-0.13,-0.09)	-0.01	(-0.03,0.01)
Finland	Helsinki-Uusimaa	1.65	1.71	1.84	-0.06	(-0.17,0.05)	-0.12	(-0.31,0.06)	-0.18	(-0.36,-0.01)
	West Finland	1.91	2.09	2.04	-0.15	(-0.25,-0.01)	0.05	(-0.13,0.25)	-0.09	(-0.26,0.13)
	South Finland	1.80	1.95	1.97	-0.17	(-0.29,-0.07)	-0.03	(-0.24,0.11)	-0.20	(-0.42,-0.06)
	North and East Finland	2.00	2.25	2.14	-0.26	(-0.39,-0.13)	0.11	(-0.12,0.32)	-0.14	(-0.38,0.06)
	Total	1.81	1.99	1.97	-0.15	(-0.21,-0.08)	-0.01	(-0.13,0.10)	-0.16	(-0.27,-0.05)
France	Parisian region	1.56	1.68	1.90	-0.11	(-0.13,-0.10)	-0.22	(-0.24,-0.20)	-0.34	(-0.35,-0.32)
	Central East France	1.93	1.87	2.11	0.06	(0.05,0.08)	-0.24	(-0.26,-0.22)	-0.18	(-0.20,-0.15)
	Mediterranean France	1.65	1.77	1.98	-0.12	(-0.14,-0.11)	-0.21	(-0.23,-0.19)	-0.33	(-0.35,-0.31)
	South West France	1.74	1.73	1.90	0.01	(-0.01,0.02)	-0.17	(-0.19,-0.15)	-0.16	(-0.19,-0.14)
	West France	1.98	2.06	2.24	-0.08	(-0.10,-0.07)	-0.18	(-0.20,-0.16)	-0.26	(-0.29,-0.24)
	Paris Basin	1.82	1.91	2.15	-0.09	(-0.10,-0.07)	-0.24	(-0.26,-0.22)	-0.33	(-0.35,-0.31)
	East France	1.72	1.89	2.09	-0.17	(-0.19,-0.15)	-0.20	(-0.23,-0.18)	-0.37	(-0.40,-0.35)
	North France	1.80	2.12	2.47	-0.33	(-0.35,-0.30)	-0.35	(-0.37,-0.32)	-0.67	(-0.70,-0.65)
	Total	1.76	1.87	2.10	-0.09	(-0.10,-0.08)	-0.22	(-0.23,-0.21)	-0.31	(-0.32,-0.30)
Germany	Hesse	1.32	1.43	1.66	-0.11	(-0.20,-0.03)	-0.25	(-0.40,-0.13)	-0.36	(-0.51,-0.25)
	Bavaria	1.45	1.60	1.65	-0.15	(-0.22,-0.08)	-0.01	(-0.12,0.11)	-0.16	(-0.27,-0.03)
	Baden-Wuerttemberg	1.48	1.59	1.68	-0.12	(-0.19,-0.04)	-0.10	(-0.22,0.01)	-0.21	(-0.34,-0.10)
	Schleswig-Holstein and Hamburg	1.25	1.39	1.63	-0.15	(-0.25,-0.07)	-0.20	(-0.35,-0.04)	-0.36	(-0.50,-0.20)
	North Rhine-Westphalia	1.32	1.43	1.66	-0.12	(-0.18,-0.06)	-0.24	(-0.33,-0.15)	-0.36	(-0.46,-0.27)
	Lower Saxony and Bremen	1.42	1.50	1.70	-0.07	(-0.13,0.03)	-0.20	(-0.32,-0.09)	-0.27	(-0.38,-0.14)
	Rhineland Palatinate and Saarland	1.37	1.50	1.66	-0.14	(-0.24,-0.07)	-0.19	(-0.33,-0.06)	-0.32	(-0.50,-0.21)
	Berlin and Brandenburg	1.33	1.41	1.68	-0.08	(-0.15,0.02)	-0.25	(-0.41,-0.11)	-0.33	(-0.47,-0.18)
	Saxony and Thuringia	1.53	1.62	1.71	-0.08	(-0.16,0.01)	-0.12	(-0.31,0.02)	-0.20	(-0.37,-0.06)
	Meckl.-West. Pom. and Sax.-Anh.	1.46	1.58	1.68	-0.12	(-0.21,-0.03)	-0.09	(-0.22,0.09)	-0.20	(-0.33,-0.04)
	Total	1.40	1.51	1.67	-0.11	(-0.15,-0.08)	-0.16	(-0.21,-0.11)	-0.27	(-0.33,-0.22)

Appendix 7 continues

Country	Region	High	Med	Low	Δ High - Med (95% CI)		Δ Med - Low (95% CI)		Δ High - Low (95% CI)	
Greece	Attiki	1.38	1.50	1.82	-0.12	(-0.18,-0.06)	-0.32	(-0.40,-0.24)	-0.44	(-0.53,-0.36)
	Notio Aigaio	1.67	1.84	2.24	-0.20	(-0.37,-0.10)	-0.40	(-0.57,-0.22)	-0.60	(-0.82,-0.44)
	Dytiki Makedonia	1.79	1.97	2.25	-0.24	(-0.43,-0.10)	-0.23	(-0.41,0.00)	-0.47	(-0.67,-0.25)
	Ionia Nisia	1.53	1.67	2.06	-0.14	(-0.27,-0.03)	-0.39	(-0.57,-0.21)	-0.53	(-0.72,-0.35)
	Sterea Ellada	1.62	1.78	2.14	-0.17	(-0.31,-0.06)	-0.36	(-0.50,-0.20)	-0.53	(-0.69,-0.38)
	Kriti	1.73	1.91	2.36	-0.18	(-0.32,-0.06)	-0.46	(-0.63,-0.30)	-0.64	(-0.82,-0.48)
	Peloponnisos	1.57	1.72	2.10	-0.10	(-0.20,0.06)	-0.40	(-0.57,-0.25)	-0.50	(-0.66,-0.32)
	Voreio Aigaio	1.65	1.81	2.09	-0.17	(-0.32,-0.03)	-0.24	(-0.41,0.00)	-0.41	(-0.58,-0.17)
	Kentriki Makedonia	1.63	1.78	2.02	-0.15	(-0.25,-0.05)	-0.23	(-0.34,-0.12)	-0.39	(-0.50,-0.27)
	Dytiki Ellada	1.70	1.87	2.34	-0.17	(-0.30,-0.04)	-0.48	(-0.64,-0.33)	-0.65	(-0.82,-0.50)
	Anatoliki Makedonia, Thraki	1.66	1.82	2.20	-0.14	(-0.24,0.01)	-0.39	(-0.54,-0.24)	-0.52	(-0.67,-0.36)
	Ipeiros	1.69	1.85	2.14	-0.16	(-0.30,-0.03)	-0.27	(-0.43,-0.07)	-0.44	(-0.60,-0.22)
	Thessalia	1.71	1.88	2.21	-0.15	(-0.26,-0.01)	-0.34	(-0.48,-0.19)	-0.48	(-0.63,-0.32)
	Total	1.54	1.69	2.09	-0.14	(-0.19,-0.10)	-0.33	(-0.38,-0.28)	-0.48	(-0.53,-0.43)
Hungary	Central Hungary	1.58	1.63	2.14	-0.04	(-0.07,-0.02)	-0.51	(-0.56,-0.47)	-0.56	(-0.60,-0.51)
	Western Transdanubia	1.71	1.78	2.14	-0.06	(-0.10,-0.01)	-0.36	(-0.42,-0.30)	-0.42	(-0.49,-0.35)
	Central Transdanubia	1.74	1.86	2.34	-0.11	(-0.15,-0.07)	-0.48	(-0.54,-0.43)	-0.59	(-0.65,-0.53)
	Southern Great Plain	1.67	1.77	2.38	-0.10	(-0.12,-0.05)	-0.61	(-0.67,-0.56)	-0.71	(-0.77,-0.64)
	Southern Transdanubia	1.72	1.84	2.35	-0.13	(-0.17,-0.09)	-0.51	(-0.56,-0.45)	-0.63	(-0.69,-0.58)
	Northern Great Plain	1.73	1.90	2.65	-0.17	(-0.21,-0.14)	-0.75	(-0.80,-0.71)	-0.92	(-0.98,-0.87)
	Northern Hungary	1.66	1.83	2.78	-0.16	(-0.20,-0.12)	-0.95	(-1.00,-0.90)	-1.11	(-1.17,-1.05)
	Total	1.66	1.77	2.42	-0.10	(-0.12,-0.09)	-0.59	(-0.61,-0.57)	-0.69	(-0.72,-0.67)
Ireland	Southern and Eastern	1.85	2.05	2.34	-0.20	(-0.28,-0.11)	-0.30	(-0.40,-0.19)	-0.49	(-0.60,-0.39)
	Border, Midland and Western	1.95	2.23	2.48	-0.28	(-0.43,-0.14)	-0.25	(-0.42,-0.08)	-0.53	(-0.70,-0.36)
	Total	1.88	2.10	2.38	-0.22	(-0.29,-0.14)	-0.28	(-0.37,-0.19)	-0.50	(-0.59,-0.41)
Lithuania	Vilnius	1.37	1.54	1.58	-0.16	(-0.22,-0.09)	-0.05	(-0.18,0.08)	-0.21	(-0.35,-0.07)
	Rest of Lithuania	1.63	1.95	2.11	-0.31	(-0.34,-0.29)	-0.16	(-0.22,-0.10)	-0.47	(-0.54,-0.41)
	Total	1.56	1.90	2.06	-0.29	(-0.31,-0.26)	-0.14	(-0.20,-0.08)	-0.43	(-0.49,-0.37)
Netherlands	Groningen	1.62	1.78	1.83	-0.16	(-0.22,-0.11)	-0.04	(-0.10,0.03)	-0.20	(-0.28,-0.13)
	Noord-Holland	1.56	1.67	1.69	-0.11	(-0.13,-0.08)	-0.03	(-0.06,0.01)	-0.13	(-0.17,-0.10)
	Utrecht	1.71	1.79	1.79	-0.08	(-0.11,-0.04)	0.00	(-0.05,0.05)	-0.07	(-0.13,-0.02)
	Noord-Brabant	1.79	1.81	1.69	-0.02	(-0.05,0.01)	0.12	(0.09,0.15)	0.10	(0.07,0.14)
	Zuid-Holland	1.48	1.87	2.47	-0.40	(-0.45,-0.35)	-0.59	(-0.64,-0.54)	-0.99	(-1.04,-0.93)
	Gelderland	1.79	1.89	1.88	-0.11	(-0.14,-0.08)	0.01	(-0.03,0.05)	-0.10	(-0.14,-0.06)
	Overijssel	1.88	1.99	2.03	-0.10	(-0.15,-0.06)	-0.04	(-0.09,0.01)	-0.14	(-0.20,-0.08)
	Limburg	1.66	1.66	1.56	0.01	(-0.03,0.05)	0.10	(0.06,0.14)	0.11	(0.06,0.16)
	Zeeland	1.75	1.88	2.17	-0.13	(-0.19,-0.06)	-0.28	(-0.37,-0.20)	-0.41	(-0.52,-0.31)
	Flevoland	1.83	1.91	2.18	-0.08	(-0.15,0.00)	-0.27	(-0.36,-0.19)	-0.35	(-0.45,-0.25)
	Friesland	1.92	2.01	1.92	-0.10	(-0.15,-0.05)	0.10	(0.03,0.16)	0.00	(-0.08,0.07)
	Drenthe	1.84	1.88	1.83	-0.03	(-0.08,0.03)	0.05	(-0.02,0.11)	0.02	(-0.06,0.10)
	Total	1.71	1.82	1.89	-0.10	(-0.11,-0.08)	-0.03	(-0.04,-0.01)	-0.12	(-0.14,-0.11)
Norway	Oslo and Akershus	1.72	1.69	1.67	0.03	(-0.03,0.09)	0.01	(-0.07,0.09)	0.05	(-0.03,0.12)
	Agder and Rogaland	2.21	2.25	2.28	-0.04	(-0.11,0.04)	-0.04	(-0.13,0.05)	-0.08	(-0.18,0.02)
	Western Norway	2.21	2.29	2.33	-0.08	(-0.16,-0.02)	-0.05	(-0.14,0.04)	-0.13	(-0.24,-0.04)
	Trøndelag	2.15	2.17	2.18	-0.02	(-0.11,0.06)	0.00	(-0.08,0.14)	-0.02	(-0.11,0.12)
	Northern Norway	2.13	2.20	2.24	-0.07	(-0.15,0.01)	-0.06	(-0.19,0.03)	-0.13	(-0.26,-0.03)
	South Eastern Norway	1.99	1.97	1.97	0.03	(-0.03,0.10)	-0.02	(-0.10,0.06)	0.01	(-0.07,0.10)
	Hedmark and Oppland	2.02	2.01	2.01	0.02	(-0.05,0.12)	0.01	(-0.08,0.12)	0.03	(-0.06,0.16)
	Total	1.99	2.04	2.05	-0.01	(-0.04,0.02)	-0.02	(-0.06,0.03)	-0.03	(-0.07,0.02)

Appendix 7 continues

Country	Region	High	Med	Low	Δ High - Med (95% CI)		Δ Med - Low (95% CI)		Δ High - Low (95% CI)	
Romania	Bucharest - Ilfov	1.01	1.27	1.78	-0.27	(-0.32,-0.20)	-0.51	(-0.60,-0.41)	-0.77	(-0.87,-0.67)
	West	1.08	1.46	2.10	-0.38	(-0.46,-0.31)	-0.64	(-0.73,-0.56)	-1.02	(-1.12,-0.93)
	Center	1.22	1.61	2.41	-0.38	(-0.46,-0.29)	-0.80	(-0.91,-0.71)	-1.18	(-1.29,-1.08)
	Northwest	1.20	1.64	2.38	-0.44	(-0.51,-0.36)	-0.74	(-0.82,-0.66)	-1.18	(-1.27,-1.08)
	South - Muntenia	1.15	1.55	2.15	-0.40	(-0.46,-0.33)	-0.60	(-0.68,-0.52)	-1.00	(-1.08,-0.90)
	South East	1.12	1.50	2.23	-0.38	(-0.45,-0.31)	-0.74	(-0.82,-0.66)	-1.12	(-1.21,-1.03)
	South-West Oltenia	1.13	1.60	2.21	-0.46	(-0.54,-0.38)	-0.61	(-0.70,-0.52)	-1.07	(-1.17,-0.96)
	Northeast	1.18	1.82	2.61	-0.65	(-0.72,-0.57)	-0.79	(-0.87,-0.70)	-1.43	(-1.53,-1.33)
	Total	1.12	1.57	2.28	-0.42	(-0.45,-0.40)	-0.68	(-0.71,-0.65)	-1.10	(-1.14,-1.07)
Spain	Madrid	1.10	1.19	1.36	-0.10	(-0.13,-0.06)	-0.17	(-0.24,-0.10)	-0.26	(-0.34,-0.19)
	Basque Community	1.35	1.42	1.50	-0.06	(-0.08,-0.05)	-0.08	(-0.11,-0.05)	-0.14	(-0.17,-0.11)
	Navarre	1.35	1.51	1.66	-0.16	(-0.18,-0.14)	-0.15	(-0.18,-0.12)	-0.31	(-0.35,-0.28)
	Catalonia	1.32	1.47	1.83	-0.15	(-0.21,-0.09)	-0.37	(-0.47,-0.28)	-0.51	(-0.62,-0.42)
	Aragon	1.43	1.72	1.86	-0.29	(-0.33,-0.25)	-0.14	(-0.19,-0.10)	-0.43	(-0.49,-0.38)
	La Rioja	1.44	1.65	1.89	-0.21	(-0.23,-0.20)	-0.24	(-0.26,-0.22)	-0.45	(-0.47,-0.43)
	Castile-Leon	1.22	1.31	1.35	-0.09	(-0.14,-0.05)	-0.04	(-0.11,0.04)	-0.13	(-0.21,-0.05)
	Cantabria	1.48	1.68	1.91	-0.20	(-0.24,-0.16)	-0.23	(-0.28,-0.17)	-0.43	(-0.48,-0.37)
	Principality of Asturias	1.35	1.64	1.76	-0.29	(-0.32,-0.26)	-0.12	(-0.16,-0.08)	-0.41	(-0.46,-0.37)
	Galicia	1.23	1.42	1.55	-0.19	(-0.22,-0.17)	-0.13	(-0.17,-0.09)	-0.32	(-0.36,-0.28)
	Valencian Community	1.31	1.42	1.47	-0.11	(-0.14,-0.08)	-0.05	(-0.11,0.01)	-0.16	(-0.23,-0.09)
	Murcia	1.21	1.38	1.43	-0.16	(-0.18,-0.14)	-0.06	(-0.10,-0.01)	-0.22	(-0.26,-0.17)
	Castille-La Mancha	1.28	1.27	1.37	0.02	(-0.01,0.04)	-0.10	(-0.15,-0.05)	-0.08	(-0.13,-0.03)
	Andalucia	1.33	1.39	1.50	-0.06	(-0.08,-0.05)	-0.11	(-0.15,-0.08)	-0.17	(-0.21,-0.14)
	Extremadura	1.37	1.43	1.62	-0.06	(-0.10,-0.01)	-0.19	(-0.27,-0.11)	-0.25	(-0.33,-0.16)
	Total	1.34	1.48	1.71	-0.14	(-0.14,-0.13)	-0.14	(-0.15,-0.13)	-0.28	(-0.29,-0.27)
Sweden	Stockholm	1.80	1.78	1.88	0.02	(-0.01,0.05)	-0.08	(-0.14,-0.02)	-0.06	(-0.12,0.00)
	Upper Norrland	2.00	2.03	2.11	-0.03	(-0.08,0.00)	-0.06	(-0.13,0.04)	-0.10	(-0.16,-0.01)
	West Sweden	1.93	1.94	2.04	-0.01	(-0.04,0.02)	-0.10	(-0.15,-0.05)	-0.11	(-0.16,-0.06)
	Middle Norrland	2.01	2.03	2.13	-0.02	(-0.06,0.02)	-0.10	(-0.18,-0.03)	-0.12	(-0.20,-0.05)
	East Middle Sweden	1.98	1.99	2.11	-0.01	(-0.04,0.03)	-0.12	(-0.18,-0.07)	-0.13	(-0.19,-0.08)
	Småland and the islands	2.05	2.08	2.16	-0.03	(-0.08,0.01)	-0.07	(-0.14,0.02)	-0.10	(-0.17,-0.02)
	South Sweden	1.90	1.89	2.03	0.01	(-0.02,0.05)	-0.14	(-0.21,-0.08)	-0.13	(-0.20,-0.08)
	North Sweden	2.00	2.01	2.12	-0.01	(-0.04,0.03)	-0.10	(-0.16,-0.03)	-0.11	(-0.17,-0.03)
	Total	1.93	1.94	2.04	0.00	(-0.02,0.01)	-0.10	(-0.13,-0.07)	-0.10	(-0.13,-0.08)

Note: Results for Austria, France, and Spain are based on a weighted sample. Sub-national regions within a country are ranked by the GDP (per capita) of the region, from highest to lowest. 95% CI = 95 percent credible interval. Meckl.-West. Pom. and Sax.-Anh. = Mecklenburg-Western Pomerania and Saxony-Anhalt.

Appendix 8

Coefficients and p-values from linear models regressing differences in cohort fertility rates between educational groups and educational group-specific cohort fertility rates on logged GDP per capita: without and with country fixed effects in the sample of 15 European countries. Estimation is based on Empirical Bayesian cohort fertility rates.

	Δ High - Med		Δ Med - Low[1]		Δ High - Low		High		Medium		Low	
	b	P>t	b	P>t	b	P>t	b	P>t	b	P>t	b	P>t
All countries												
without country fe[2]	0.174	0.000	0.244	0.000	0.418	0.000	0.153	0.008	-0.021	0.670	-0.265	0.000
with country fe	0.066	0.023	0.069	0.114	0.134	0.031	-0.251	0.000	-0.317	0.000	-0.385	0.000
Without Eastern and Central (Belarus, Hungary, Lithuania, Romania)												
without country fe	0.079	0.035	0.166	0.001	0.245	0.001	0.024	0.799	-0.055	0.527	-0.221	0.018
with country fe	-0.006	0.876	-0.027	0.615	-0.033	0.671	-0.331	0.000	-0.324	0.000	-0.297	0.001
Without Northern (Finland, Norway, Sweden)												
without country fe	0.165	0.000	0.220	0.000	0.385	0.000	0.057	0.289	-0.108	0.021	-0.328	0.000
with country fe	0.063	0.051	0.083	0.090	0.145	0.039	-0.236	0.000	-0.299	0.000	-0.381	0.000
Without German-speaking and Southern (Austria, Germany, Spain, Greece)												
without country fe	0.174	0.000	0.244	0.000	0.418	0.000	0.153	0.008	-0.021	0.670	-0.265	0.000
with country fe	0.066	0.023	0.069	0.114	0.134	0.031	-0.251	0.000	-0.317	0.000	-0.385	0.000
Without Western (Belgium, France, Ireland, Nerherlands)												
without country fe	0.175	0.000	0.249	0.000	0.424	0.000	0.144	0.037	-0.031	0.600	-0.280	0.000
with country fe	0.094	0.001	0.084	0.062	0.178	0.002	-0.198	0.000	-0.292	0.000	-0.376	0.000

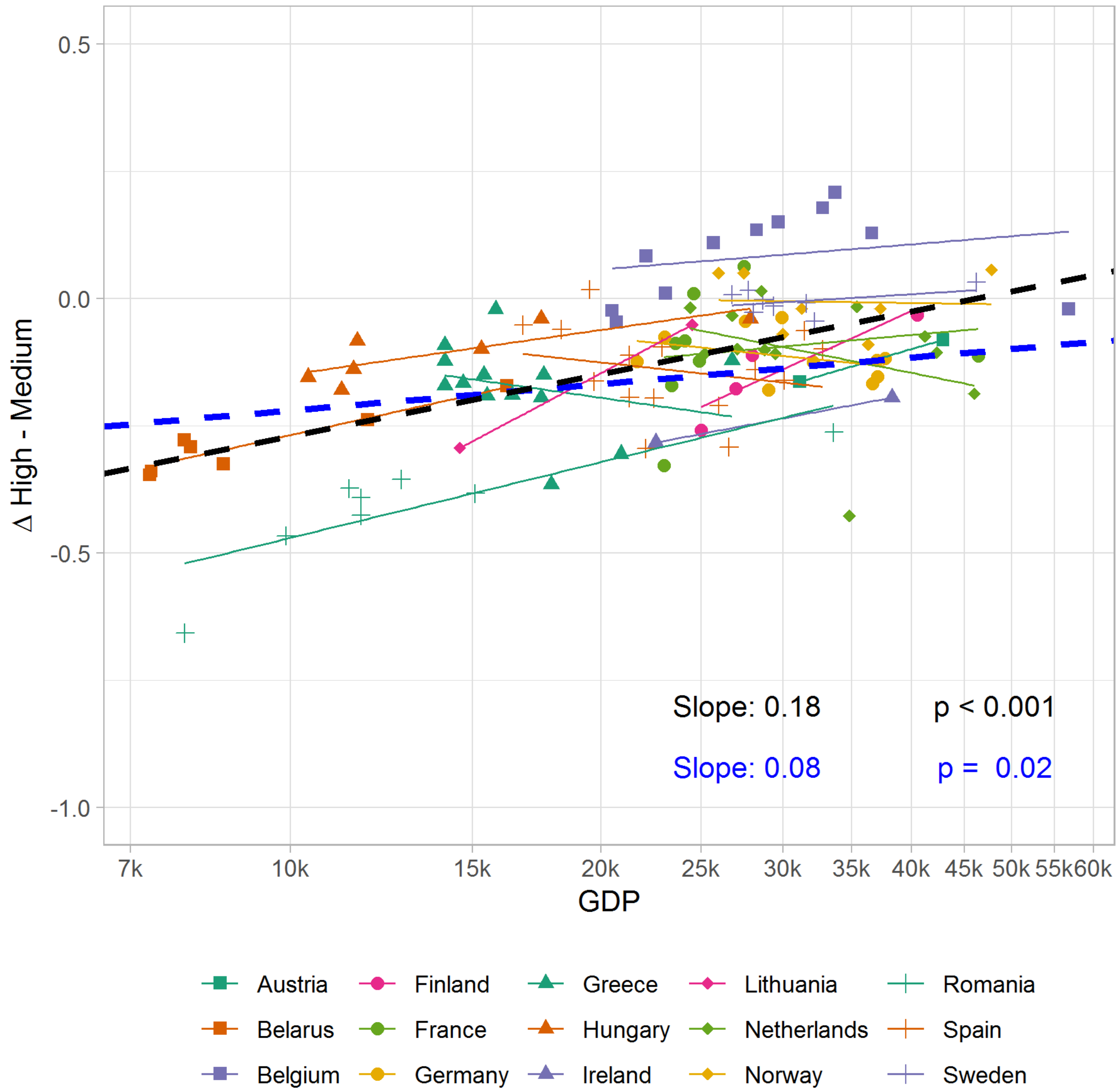
[1]Med = Medium [2]fe = fixed effects

Coefficients and p-values from linear models regressing differences in cohort fertility rates between educational groups and educational group-specific cohort fertility rates on logged GDP per capita: without and with country fixed effects in the sample of 15 European countries. Estimation is based on observed cohort fertility rates.

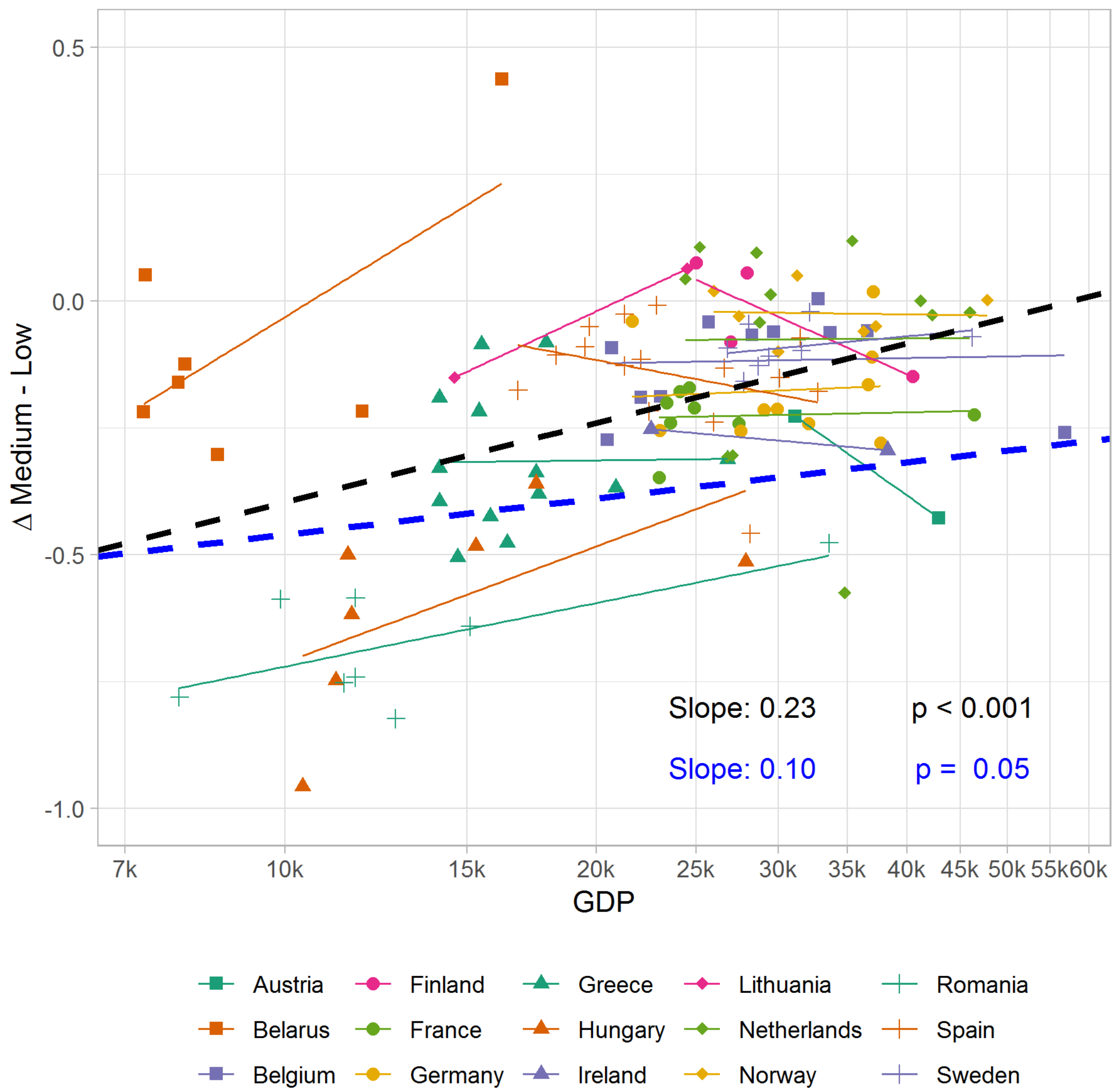
	Δ High - Med[1]		Δ Med - Low[1]		Δ High - Low		High		Medium		Low	
	b	P>t	b	P>t	b	P>t	b	P>t	b	P>t	b	P>t
All countries												
without country fe[2]	0.177	0.000	0.229	0.000	0.413	0.000	0.149	0.009	-0.029	0.563	-0.258	0.000
with country fe	0.077	0.023	0.109	0.035	0.184	0.008	-0.256	0.000	-0.333	0.000	-0.442	0.000
Without Eastern and Central (Belarus, Hungary, Lithuania, Romania)												
without country fe	0.095	0.018	0.134	0.006	0.228	0.002	0.010	0.917	-0.086	0.325	-0.220	0.020
with country fe	-0.006	0.888	-0.025	0.665	-0.031	0.698	-0.350	0.000	-0.344	0.000	-0.319	0.000
Without Northern (Finland, Norway, Sweden)												
without country fe	0.166	0.000	0.210	0.000	0.384	0.000	0.053	0.323	-0.113	0.016	-0.323	0.000
with country fe	0.074	0.048	0.127	0.029	0.198	0.011	-0.241	0.000	-0.316	0.000	-0.442	0.000
Without German-speaking and Southern (Austria, Germany, Spain, Greece)												
without country fe	0.177	0.000	0.229	0.000	0.413	0.000	0.149	0.009	-0.029	0.563	-0.258	0.000
with country fe	0.077	0.023	0.109	0.035	0.184	0.008	-0.256	0.000	-0.333	0.000	-0.442	0.000
Without Western (Belgium, France, Ireland, Nerherlands)												
without country fe	0.179	0.000	0.242	0.000	0.428	0.000	0.143	0.037	-0.037	0.539	-0.278	0.000
with country fe	0.103	0.004	0.151	0.010	0.251	0.000	-0.203	0.000	-0.306	0.000	-0.458	0.000

[1]Med = Medium [2]fe = fixed effects

Appendix 9 The difference in cohort fertility rate between high- and medium-educated women according to the GDP per capita level of the region of 15 European countries. Regression lines are fitted for the global trend without (black dashed line) and with (blue dashed line) country fixed effects, and for the within-country trends for each country separately (solid lines). Estimation is based on observed cohort fertility rates.



Appendix 10 The difference in cohort fertility rate between medium- and low-educated women according to the GDP per capita level of the region of 15 European countries. Regression lines are fitted for the global trend without (black dashed line) and with (blue dashed line) country fixed effects, and for the within-country trends for each country separately (solid lines). Estimation is based on observed cohort fertility rates.



Appendix 11 The difference in cohort fertility rate between high- and low-educated women according to the GDP per capita level of the region of 15 European countries. Regression lines are fitted for the global trend without (black dashed line) and with (blue dashed line) country fixed effects, and for the within-country trends for each country separately (solid lines). Estimation is based on observed cohort fertility rates.