Educational gradient and parity contribution to completed cohort fertility decline in low fertility settings

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Abstract

Extended literature documents the contribution of rising education to decrease in cohort fertility in virtually all Western industrialized nations, although important variations in their interaction have been noticed over time and in different contexts. A key question related to the education-fertility relationship is to what extent the decrease in fertility can be considered the result of changes in the educational composition and how much is caused by the change in fertility behaviours across educational categories. By using a new demographic-decomposition technique, we quantify the contributions of the educational composition and parity specific components to the changes in cohort fertility rates among women born between 1940 and 1970 in eight low fertility countries. Our results show that the pathways to low and lowest low fertility have distinctive patterns by countries, which reflect the complexity and heterogeneity in the relationship between education and fertility.

Introduction

In all developed countries, completed cohort fertility (CCF) has decreased considerably over the last few decades (Zeman et al. 2017), propelled by a preference for smaller families as well as by an increase in childbearing postponement and in the rate of childless women (Lesthaeghe 2010). The marked declines in cohort fertility experienced by Western industrialized countries coincided with the expansion in women education and labour force participation. The proportion of women who completed secondary and tertiary education has been rising considerably since the 1940, and today mass schooling is well established in almost all countries, with large proportions of women falling into the tertiary schooling category (The World Bank 2019).

A key question related to the education-fertility relationship is to what extent the decrease in fertility can be considered as the result of changes in the educational composition and how much is caused by the change in fertility behaviours across educational categories.

Although the negative relationship between fertility and educational attainment has been widely documented in virtually all developed countries (Bongaarts 2003), important variations in their interaction have been noticed over time and in different contexts (Thomson et al. 2012). Before the onset of the fertility decline, high social status has a strong negative effect on fertility (Skirbekk, 2008), while after the decline a less clear picture emerges. Some countries show permanent differences in fertility levels by education (Impacciatore and Dalla Zuanna, 2016), whereas others are characterized by gradually diminishing variations (Yoo 2014) and, in some cases, by a trend reversal among the most recent cohorts (Kravdal and Rindfuss 2008).

When considering the educational gradient in the progression to first births, there is a general consensus in the literature about the association between higher education and childbearing

postponement and childlessness, although studies on the educational gradient of second and higher order births have come up with mixed results (Wood, 2014).

These examples suggest that the relationship between fertility and level of education is far from linear and that significant differences exist due to compositional change in education and contextual factors, such as a country's welfare regime and economic stability, which can alter the link between the two variables.

This paper contributes to the literature on the association between educational attainment and fertility by using demographic-decomposition techniques to disentangle the contribution of education and parity to changes in CCF over time and across countries. We further dissect the effect of parity into two components: parity progression (the probability of transitioning to higher order births), and parity structure (the distribution of women across parities).

Using population censuses and large-scale surveys, we analyse changes in CCF in eight countries characterized by low and lowest-low fertility among women with primary, secondary and tertiary education, born between 1940 and 1970, who had almost completed their reproductive life at the time of data collection.

Theoretical Framework

Association between education and fertility

Considerable attention in fertility research has been devoted to the association between education and fertility. Theories about the role played by education on fertility have been strongly influenced by Becker's pioneering approach to explaining fertility choices of highly educated women as a trade-off between family and career (Becker, 1965; 1991). According to the *New Home Economics*, women with higher levels of education have a higher opportunity cost with regard to

becoming mothers than less educated ones, since they have more to loose from job interruption through wage loss. Therefore, highly educated women are more likely to pursue careers compared to their less educated counterparts and, as some more recent research has shown, for the same reason they also tend to start families later as the postponement of motherhood results in a substantial increase in career earnings (Miller 2010).

Education may also influence fertility decisions through its effects on individual values and orientations. Higher education may encourage to shift attention away from the family formation process and to attach increasing importance to individual self-realization (Lesthaeghe 1995; Van de Kaa 1987). Beside from having an impact on fertility quantum, higher educated women also have a higher chance to delay fertility (Rindfuss et al. 1996; Bhrolchain and Beaujouan 2012) because of the incompatibility of student and mother roles first, and because of their higher desire to pursue a career, after. With the onset of the trend towards fertility postponement (Kohler et al. 2002), women face a higher chance of remaining childless (Keizer et al. 2008), partly due to the increase in infertility rates with age (ESHRE Capri Workshop Group 2005) and partly to the existence of social deadlines for childbearing (Billari et al. 2011).

On the other hand, education can contribute to raise fertility in at least two ways. First, by considering high education as a proxy for higher social status, highly educated women would have more children because of their better chance to provide for them – the so-called "income effect" (Becker, 1991). Second, better educated women have a larger chance of being in a stable relationship, which in turn encourages childbearing (Jalovaara, 2012; Musick and Michelmore, 2018).

Fertility across educational categories

Although our study represents the first attempt to decompose CCF into education and parity specific components, many studies have investigated the relationship between education, parity and fertility. Theoretically, the transition to lower fertility by level of education can follow two different patterns. According to the leader-follower model (Bongaarts 2003), fertility starts declining from the better-educated women, and then the medium and low educated women follow the declining fertility trend. Therefore, fertility differentials by educational attainment tend to widen first and to decrease and eventually disappear as the lowest educated women gradually start to adapt to the new fertility behaviours. Rising female education becomes a relatively modest force behind fertility decline over time, particularly in the later phase of the transition when downward trends in fertility may be more pronounced in the lower than in the higher educational categories (Cleland 2002). By contrast, according to the permanent difference model (Bongaarts 2003), fertility differentials persist throughout the transition and women in different educational categories are characterized by a permanent divide. In this scenario, the educational composition may contribute significantly to changes in fertility. The empirical research suggests that both models are possible and likely to fit in different contexts (Sobotka 2018).

For instance, in the Czech Republic the decline in CCF has been mainly driven by changes in the population structure by education, especially by the decline in the proportion of women with primary education (Zeman 2018). Similarly, in Belgium the persistence of educational differentials in cohort fertility together with the expansion in female education suggests that fertility decline was mainly driven by the increase in the proportion of highly educated women, characterized by lower fertility levels (Neels and De Watcher 2010). On the other hand, fertility patterns of South Korean women have been converging downwards to very low fertility levels across all educational categories, with the increase in educational attainment accounting for only one-fifth of the total

decline in fertility (Yoo 2014). Educational differences have been found to decrease and even reverse in countries where welfare policies have played an important role in helping women to reconcile work and family life (Rønsen and Skrede 2010), suggesting that the reduction in fertility differentials across educational categories might be only temporary and that fertility behaviours can return to be education-specific after the convergence. For example, in the Nordic countries, educational differences in completed fertility became fairly small (Andersson et al. 2009), with women across different educational categories experiencing a convergence to a stable moderately low fertility level (Sobotka 2018).

Summing up these region-specific trends, we expect that the educational composition of the population dominates CCF decline in countries characterized by permanent divides in fertility differentials across educational categories, whereas it plays a less crucial role in countries where fertility behaviours converged to similar patterns.

Relationship between education and parity-specific fertility

Despite the extended literature documenting the importance of rising education in driving the fertility transition, studies investigating the educational gradient in the progression to first and higher order births in low fertility settings are relatively scarce. On the one hand, there is a general agreement among scholars about the positive effect of higher education on the postponement and reduction in the propensity of entry into motherhood (Mills et al., 2011). On the other hand, once the process of childbearing has begun, the educational gradient in progression to second and higher order births significantly varies between countries (Wood et al., 2014). As a consequence, we expect to find a strong negative effect of education on entry into motherhood and heterogeneous results in second and higher order births propensities across educational categories.

Assessing the "true impact" of education on higher order births is complicated by the presence of potential self-selection biases (Kreyenfeld, 2002). Women who are at risk of second and higher order births are a selected group of women that are already mothers to a first child. Therefore, they have manifested a propensity to bear children compared to those who stayed childless. Previous studies accounting for self-selection bias found contradictory results in Norway (Kravdal, 2007) and in Western Germany (Kreyenfeld, 2002), no significant effect in Austria (Hoem et al., 2001), and a significantly negative effect of education on the likelihood of transitioning to higher order births in Italy (Impacciatore and Dalla Zuanna, 2017). Keeping this in mind, we do not assume any causal relationship between education and fertility, but rather we are mainly interested in assessing the relationship between the two variables across time and in different contexts.

Data

To conduct this analysis, we selected 8 developed countries, currently characterized by high levels of education and relatively low fertility levels, namely: Australia, Croatia, Finland, Greece, Hungary, Ireland, South Korea, and Spain. The data were mainly drawn from the Cohort Fertility and Education (CFE) database (CFE 2017; Zeman et al. 2014), which collects information from censuses and large sample surveys and provides high-quality data on CCF by level of education and parity. Data for Australia were sourced from the Australian Bureau of Statistic (ABS) Census of Population and Housing (2016), which allows to retrospectively estimate fertility by order of birth and educational attainment. A summary of the data used is shown in Table 1.

Information about female educational attainment correspond to their educational level at the time of data collection, when they had almost completed their reproductive life. Ideally, one should consider using retrospective maternity and education histories, as women may have

different educational levels at each parity. The CFE database does not provide information on education histories. Therefore, no casual inference can be made between educational attainment and parity progression due to reverse causality. Effects of primary schooling may be largely correct, since this level of education is typically reached at a very young age in all developed countries. Generally, also education effects on second and higher-order births would probably not be substantially biased, as few women would probably return to study after having become mothers (Kravdal, 2004). Results should be interpreted with caution mainly when considering the effects of secondary and tertiary education on first births, as these might be generally more biased.

However, in this paper we do not aim to establish any causal relationship between education and parity progression, but rather we analyse the association between the educational attainment and the number of children a woman had given birth to at the end of her reproductive life. To address this limitation we plan in the future to assess survey data where full education and fertility histories are collected and to compare them with our current results.

Table 1. List of selected cohorts and data sources.

Country	Year of data collection	Age at data collection	Cohort	Source
Australia	2016	46-76	1940-70	Census 2016
Croatia	2011	41-71	1940-70	Census 2011
Finland	2015	45-75	1940-70	Population Register 2015
Greece	2011	41-71	1940-70	Census 2011
Hungary	2011	41-71	1940-70	Census 2011
Ireland	2011	41-71	1940-70	Census 2011
Russia	2010	40-70	1940-70	Census 2010
South Korea	2010	40-70	1940-70	Census 2010
Spain	2011	41-71	1940-70	Census 2011

Source: CFE database (www.cfe-database.org) and ABS Census of Population and Housing (2016), accessed on August 2019.

Methods[1]

The cohort fertility, or CCF(t), of a female cohort born in year *t* that has completed their reproductive years is computed as:

$$CCF(t) = \frac{B(t)}{W(t)} \tag{1}$$

where $B(t)$ is the number of all births from mothers born in year *t*, and $W(t)$ is the number of women born in year *t*. At the end of the reproductive lifespan, women are characterized by the number of children they have given birth to and by their level of educational attainment. We assume in this study that education is a time invariant variable, corresponding to the educational level achieved by a woman by the end of the reproductive life. This helps further disentangling the cohort's births by education and parity as,

$$B(t) = \sum_{i=1}^{8} \sum_{e=L}^{H} B_i^e(t) \tag{2}$$

where $B_i^e(t)$ corresponds to the number of births from mothers holding education *e* (ranging from L: low, M: medium, and H: high) and birth order *i* (for parities $1, 2, 3, \dots, 8$).

Therefore, equation (1) can be formulated as:

$$CCF(t) = \sum_{i=1}^{8} \sum_{e=L}^{H} \frac{B_i^e(t)}{W(t)} \tag{3}$$

From equation (3), it is possible to calculate parity or education specific CCF. For example, the CCF of parity 1, denoted as $CCF_1(t)$, is

$$CCF_1(t) = \frac{B_1^H(t) + B_1^M(t) + B_1^L(t)}{W(t)} \tag{3.1}$$

or the CCF of women having high education, $CCF^H(t)$, can be written as

[1] Details of this section on methodology as well as the estimation procedure to data obtained for the illustrations are found in the appendix A and B.

$$CCF^H(t) = \frac{B_0^H(t)+B_1^H(t)+\cdots+B_8^H(t)}{W(t)} \quad (3.2)$$

Furthermore, components corresponding to the parity and education composition can be readily integrated to equation (3) as,

$$CCF\ (t) = \sum_{i=1}^{8}\sum_{e=L}^{H} P_{i-1,i}^{e}(t)E^{e}(t)S_{i-1}(t) \quad (4)$$

where $\mathrm{P}_{\mathrm{i-1,i}}^{\mathrm{e}}(\mathrm{t}) = \frac{\mathrm{B}_{\mathrm{i}}^{\mathrm{e}}(\mathrm{t})}{\mathrm{B}_{\mathrm{i-1}}^{\mathrm{e}}(\mathrm{t})}$, $E^{e}(t) = \frac{W^{e}(t)}{W(t)}$ and $S_{i-1}(t) = \frac{B_{i-1}^{e}(t)}{W^{e}(t)}$ correspond to parity progression ratio (the proportion of births of order *i* over births of order *i-1*) for women of education *e*, educational composition (the proportion of women of education *e* over all women), and parity structure (the proportion of women at parity *i-1* over women of education *e* at all parities), respectively.

To quantify the effects of changes in the parity progression, educational composition, and parity structure to changes in completed cohort fertility over time, equation (4) is decomposed. The partial derivative respect to time, denoted with a dot on top of the variable of interest, allows such decomposition as

$$\dot{CCF}\ (t) = \frac{\partial}{\partial t}\sum_{i=1}^{8}\sum_{e=L}^{H} P_{i-1,i}^{e}(t)E^{e}(t)S_{i-1}(t)\,,$$

$$= \sum_{i=1}^{8}\sum_{e=L}^{H}[\dot{P}_{i-1,i}^{e}(t)E^{e}(t)S_{i-1}(t) + P_{i-1,i}^{e}(t)\dot{E}^{e}(t)S_{i-1}(t) + P_{i-1,i}^{e}(t)E^{e}(t)\dot{S}_{i-1}(t)], \quad (5)$$

where each term in equation (5) is the change in $CCF\ (t)$ resulting from changes in the parity progression ratio, educational composition, and parity structure respectively.

If the change in the educational composition term $\left(\frac{\partial E_i^e(t)}{\partial t}\right)$ is the largest out of the three terms, changes in the female population structure by education played the major role in explaining completed fertility change over time. This corresponds to the effect that educational expansion would have on cohort fertility change assuming stable fertility behaviours within each educational category. In the presence of significant educational differentials in cohort fertility, changes in the

educational composition will have the largest effect on fertility. On the other hand, if the changes in the progression parity ratio term $\left(\frac{\partial P_i^e(t)}{\partial t}\right)$ or in the parity structure term $\left(\frac{\partial S_i^e(t)}{\partial t}\right)$ where larger, changes in the fertility behaviours are the main contributors to changes in completed fertility. This corresponds to the effect that changing fertility rates would have on cohort fertility change assuming that the shares in women educational attainment did not change over time. Both parity progression and parity structure provide information on women's parity specific behaviour, albeit they have a different interpretation. Parity progression ratios determine the risk that a woman of parity i experiences another birth, whereas parity structure refers to the proportion of women who gave birth to at least *i* children out of all women in the population, irrespective of their parity. A reduction in the parity progression ratios between two cohorts lead to a decrease in CCF. However, this negative effect is mediated by the proportion of women that entered into motherhood, as they represent the base of those progressing into higher order births.

The interaction between parity structure and parity ratios corresponds to the interaction between incidence rates and childbearing intensities (Kohler and Ortega, 2004). The former uses as denominator the number of all women in the population, whereas in the latter the denominator corresponds to the number of women at risk of experiencing the event (a birth of order i+1).

Preliminary Results

Descriptive Analysis

Female educational attainment has been rising considerably over the past few decades in all developed countries (Figure 1). Despite a general trend towards educational expansion, the speed of expansion varies in different contexts. For example, South Korea showed a very rapid increase in the share of women with a university degree, from less than 3 percent to almost 40 percent in

only few decades. On the other hand, in Finland already almost 20 percent of women born in 1940 had more than an upper secondary education, a share that increased to 53 percent in the 1970 cohort.

When looking at the completed cohort fertility of women born between 1940 and 1970 (Figure 2), an overall downward trend can be recognised, with considerable variations across educational categories. In some countries (i.e. Spain and Australia), educational groups experienced analogous fertility declines, and they maintained similar relative fertility levels over time. In other countries (i.e. Finland and South Korea) completed fertility across educational strata has been gradually converging towards low or lowest-low fertility levels, with minimal educational differences among the most recent cohorts.

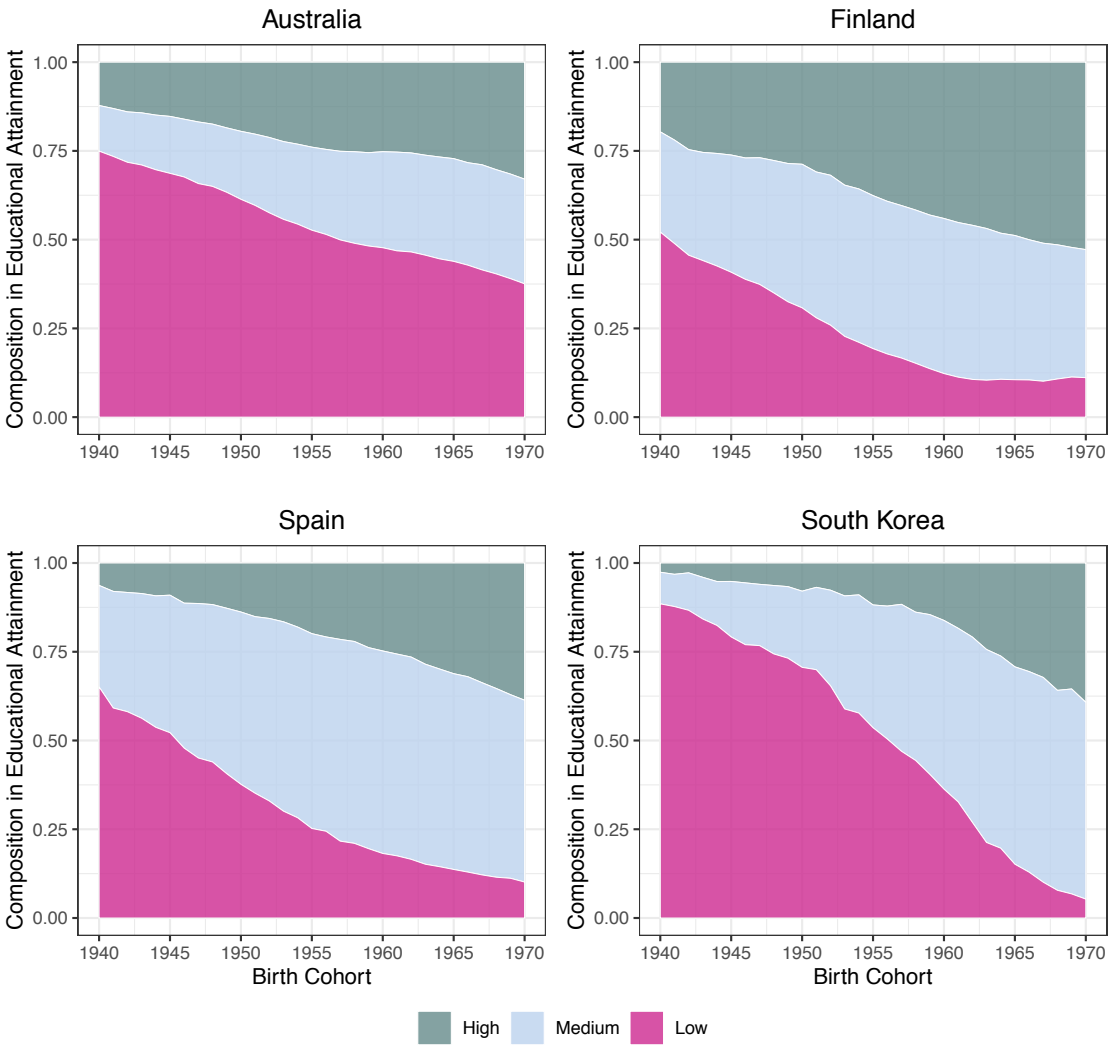

Fig. 1: Compositional change is the educational attainment among women born in 1940-1970.

Note: Educational attainment was measured using three categories, based on the standardized 1997 International Standard Classification of Education (ISCED): low education (ISCED 0-2A), corresponding to secondary education or second stage of basic education, medium education (ISCED 3C-4A), corresponding to upper secondary education and post-secondary non-tertiary education, and high education (ISCED 5B-6), corresponding to the first stage of tertiary education, bachelor and doctoral degree.
Source: Authors' calculations using data described in Table 1.

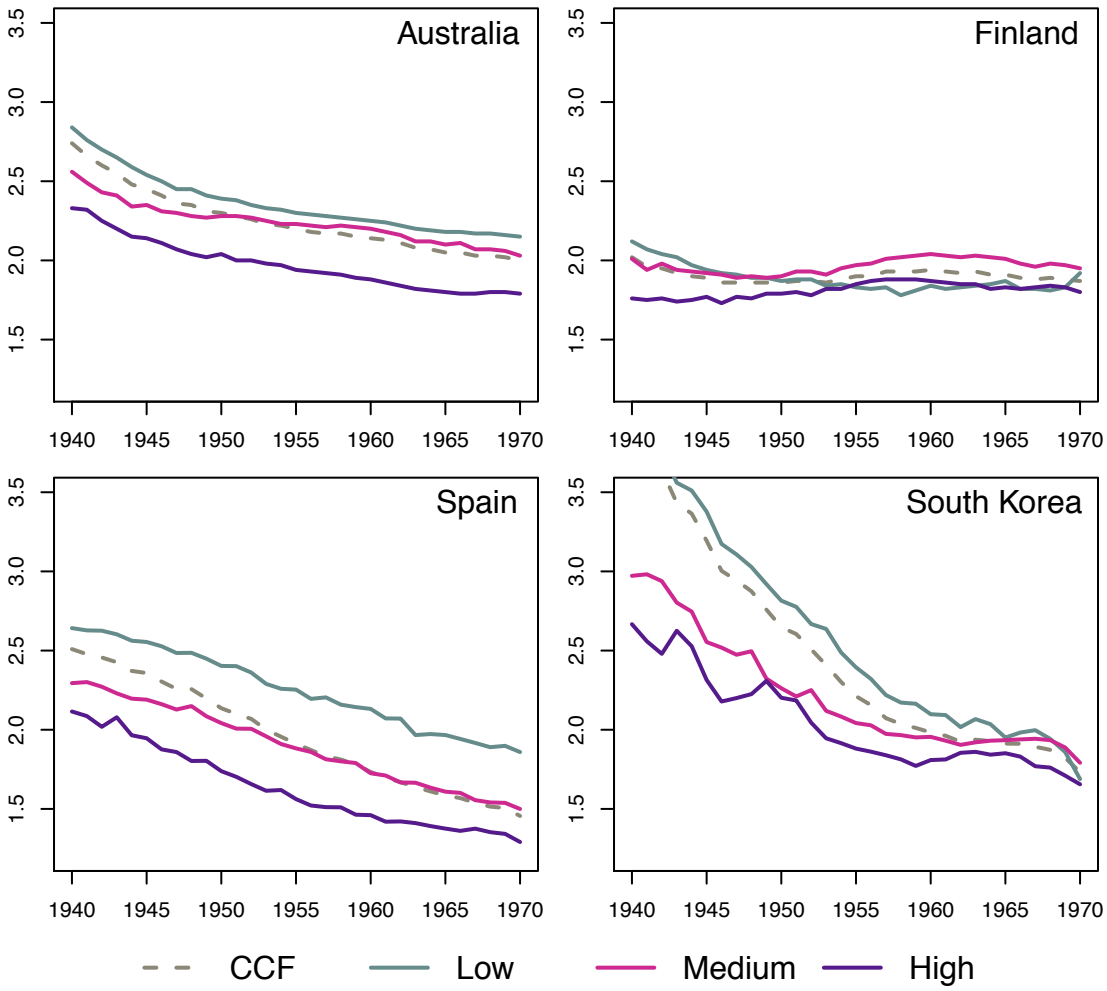

Fig. 2: Completed cohort fertility by educational attainment among women born in 1940-1970 in selected countries.

Source: Authors' calculations using data described in Table 1.

Analytical Results

Figure 3 illustrates the contribution of progression parity ratios (P), parity structure (S) and educational composition (E) to changes in completed cohort fertility among the 1940-1970 birth cohorts. Overall, the fertility decline was mostly driven by a general change in fertility behaviours that affected educational categories in almost all countries. Among women born between 1940 and 1965, educational composition played its most important role in fertility decline, due to fertility being strongly stratified by education and countries experiencing rapid educational expansion. Cross-country differences on the impact of educational composition mainly emerged among

younger cohorts born between 1955 and 1970, due to the persistence of educational differentials in some countries (i.e. Australia, Ireland, Spain and Greece) and the convergence towards similar fertility behaviours across educational categories in others (i.e. Finland and South Korea). Interestingly, parity components positively contributed to completed fertility among the 1940-1960 birth cohorts in Hungary and among the 1940-1945 birth cohorts in Croatia, whereas educational expansion was the only contributor to fertility decline.

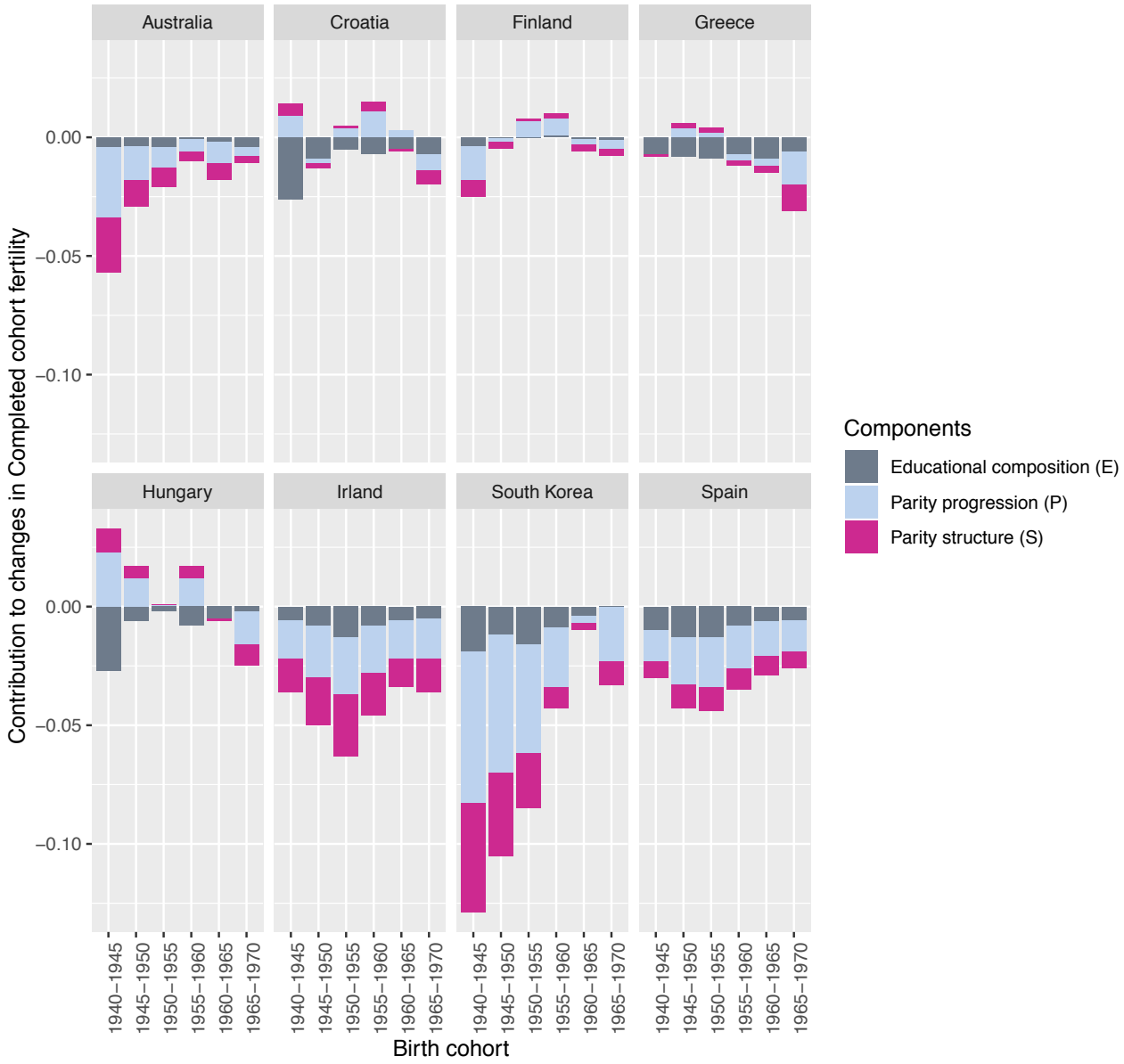

Fig. 3: Decomposition of the change over time in completed cohort fertility of women born in 1940-1970.
Source: Authors' calculations using data described in Table 1.

Table 2. Contribution of parity ratio, parity structure and education to changes in completed cohort fertility among women born in 1940-70, selected countries.

Cohort	Mid-year	P	S	E	$\dot{CCF}_{(t,t+5)}$*	$\dot{CCF}_{(t,t+5)}$**
Australia						
1940-45	1942	-0.030	-0.023	-0.004	-0.058	-0.058
1945-50	1947	-0.014	-0.011	-0.004	-0.029	-0.029
1950-55	1952	-0.009	-0.008	-0.004	-0.021	-0.021
1955-60	1957	-0.005	-0.004	-0.001	-0.011	-0.011
1960-65	1962	-0.009	-0.007	-0.002	-0.018	-0.018
1965-70	1967	-0.004	-0.003	-0.004	-0.011	-0.011
Finland						
1940-45	1942	-0.014	-0.007	-0.0039	-0.026	-0.026
1945-50	1947	-0.002	-0.003	-0.0004	-0.006	-0.006
1950-55	1952	0.007	0.001	0.0002	0.008	0.008
1955-60	1957	0.007	0.002	0.0008	0.009	0.009
1960-65	1962	-0.002	-0.003	-0.0011	-0.006	-0.006
1965-70	1967	-0.004	-0.003	-0.0014	-0.009	-0.009
South Korea						
1940-45	1942	-0.064	-0.046	-0.019	-0.129	-0.131
1945-50	1947	-0.058	-0.035	-0.012	-0.106	-0.109
1950-55	1952	-0.046	-0.023	-0.016	-0.086	-0.087
1955-60	1957	-0.025	-0.009	-0.009	-0.044	-0.045
1960-65	1962	-0.003	-0.003	-0.004	-0.011	-0.014
1965-70	1967	-0.023	-0.010	0.0002	-0.033	-0.035
Spain						
1940-45	1942	-0.013	-0.007	-0.010	-0.030	-0.030
1945-50	1947	-0.020	-0.010	-0.013	-0.044	-0.044
1950-55	1952	-0.021	-0.010	-0.013	-0.044	-0.045
1955-60	1957	-0.018	-0.009	-0.008	-0.035	-0.036
1960-65	1962	-0.015	-0.008	-0.006	-0.029	-0.030
1965-70	1967	-0.013	-0.007	-0.006	-0.026	-0.026

Note: * Observed difference in CCF over cohorts ** Estimated difference in CCF over cohorts using the decomposition method, explained in the *Methods* section. Further details on the methods can be found in Appendix B.
Source: Authors' calculations using data described in Table 1.

The effect of the parity progression factor on CCF change is further decomposed into its parity and education specific components. This allows to investigate which parity and which educational category contributed most to the fertility decline to low levels. Figure 4 presents the contribution of parity progression ratios by educational categories to changes in completed cohort fertility.

In Spain the decrease in completed cohort fertility between the 1940 and 1955 cohorts resulted mainly from declines in progression to third order births across all educational categories,

albeit the effect was more pronounced among women with low and medium education. Among women born between 1955 and 1960, the reduction in second order births and the increase in the proportion of childless women were the main contributors to the fertility decline. In South Korea, changes in the fertility behaviour of the lowest educated cohorts were the major contributor to changes in CCF. The fall in fertility among women born between 1940 and 1960 was mostly driven by the decreasing transition to fourth and third births, whereas the change among the younger cohorts born between 1960 and 1970 was mostly due to falling transitions to second births and to an increase in the proportion of those remaining childless.

Parity structure can also be decomposed into its parity and education specific components (Figure 5). Spain saw a rise in childlessness across all educational groups, represented by a decrease in the proportion of women with at least one child (S1). In South Korea, middle and highly educated women tended to remain childless more often than their less educated counterparts among the most recent cohorts. As a consequence, the negative contribution of decreasing progression parity ratios to CCF are reduced among the medium and high educational groups, as less women are transitioning to motherhood in the first place.

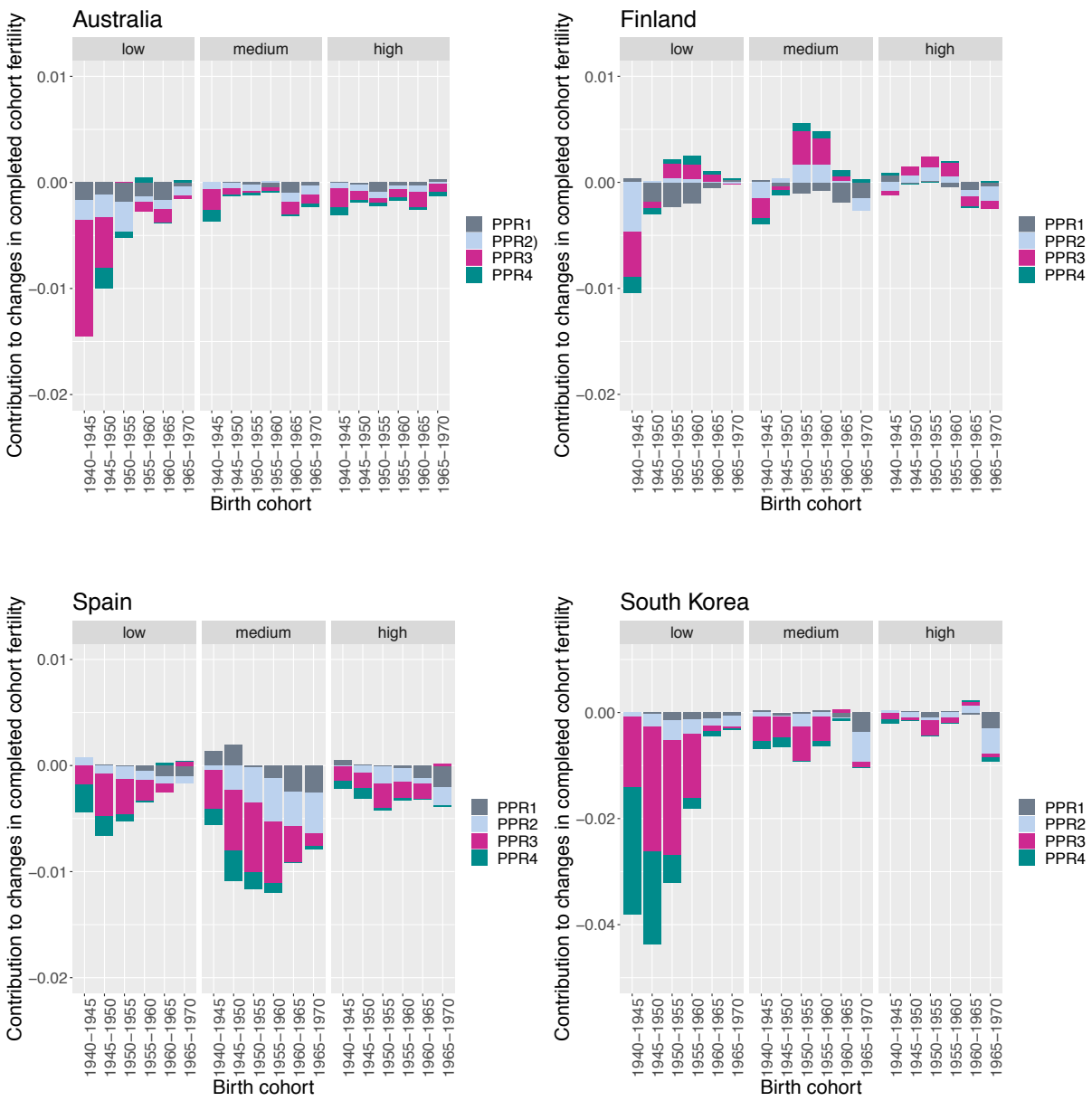

Fig. 4: Decomposition of the change over time in parity progression ratios to first, second, third and fourth birth among women born in 1940-1970 by educational level in selected countries.

Source: Authors' calculations using data described in Table 1.

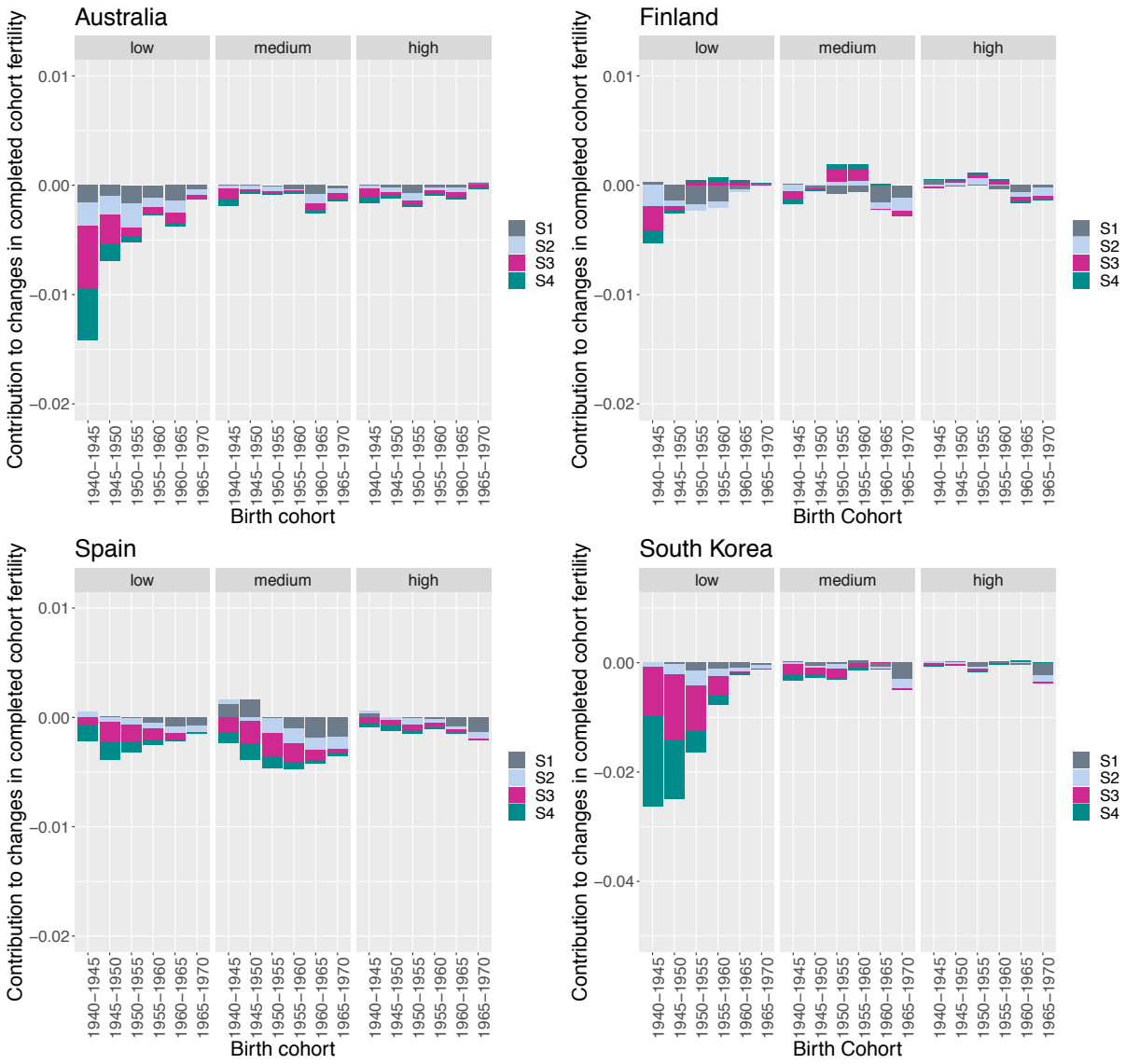

Fig. 5: Decomposition of the change over time in parity structure among women born in 1940-1970 by educational level in selected countries.
Source: Authors' calculations using data described in Table 1.

Discussion

Taking eight low fertility countries as our starting point, we analysed changes in completed fertility among women born between 1940 and 1970, who had almost completed their reproductive life at the time of the data collection. The striking cross-country differences in the contribution of education and parity components to changes in CCF suggest that context plays a crucial role in determining fertility decisions.

The new decomposition method described in this paper allows to conduct a systematic analysis of the educational and parity specific components contributing to cohort fertility change, and to compare fertility trends across countries and periods. In the near future, we plan to extend our analysis to a larger number of countries, in order to better detect regional and country-specific trends in fertility decline.

Appendix A: Decomposition of completed cohort fertility in parity and educational components

This appendix provides the detailed formulation of equation (4).

The CCF by birth of order i can be decomposed according to the mothers' educational attainment as follows:

$$\mathrm{CCF_i} = \frac{\mathrm{B_i^H(t)}}{\mathrm{W(t)}} + \frac{\mathrm{B_i^M(t)}}{\mathrm{W(t)}} + \frac{\mathrm{B_i^L(t)}}{\mathrm{W(t)}}, \tag{6}$$

Equation (6) can be further decomposed as follows:

$$\mathrm{CCF_i} = \frac{\mathrm{B_i^H(t)}}{\mathrm{W(t)}} * \frac{\mathrm{W^H(t)}}{\mathrm{W^H(t)}} * \frac{\mathrm{B_{i-1}^H(t)}}{\mathrm{B_{i-1}^H(t)}} + \frac{\mathrm{B_i^M(t)}}{\mathrm{W(t)}} * \frac{\mathrm{W^M(t)}}{\mathrm{W^M(t)}} * \frac{\mathrm{B_{i-1}^M(t)}}{\mathrm{B_{i-1}^M(t)}} + \frac{\mathrm{B_i^L(t)}}{\mathrm{W(t)}} * \frac{\mathrm{W^L(t)}}{\mathrm{W^L(t)}} * \frac{\mathrm{B_{i-1}^L(t)}}{\mathrm{B_{i-1}^L(t)}}, \tag{7}$$

By re-arranging the terms in (7) and by considering all orders of births, equation (4) is obtained:

$$CCF(t) = \sum_{i=1}^{8} \sum_{e=H}^{L} \frac{\mathrm{B_i^e(t)}}{\mathrm{B_{i-1}^e(t)}} * \frac{W^e(t)}{W(t)} * \frac{B_{i-1}^e(t)}{W^e(t)}, \tag{4}$$

Notice that the total parity specific birth numbers are defined as:

$$\mathrm{B_0\ (t)} = \sum_{i=0}^{8} \mathrm{W_i^e(t)}, \tag{8}$$

$$\mathrm{B_1\ (t)} = \sum_{i=1}^{8} \mathrm{W_i^e(t)}, \tag{9}$$

$$\mathrm{B_2\ (t)} = \sum_{i=2}^{8} \mathrm{W_i^e(t)}, \tag{10}$$

And so on, up to parity 8.

Therefore, $\frac{B_1^H(t)}{B_0^H(t)}$ is the progression parity ratio from birth of order i-1 to birth of order i can be defined as follows:

$$PPR\ (i-1,i) = \frac{B_i^H(t)}{B_{i-1}^H(t)}, \tag{11}$$

Appendix B: Decomposition to discrete data

This appendix provides the detail derivation of equation (5).

By following Vaupel and Canudas-Romo (2003) approach, we applied the continuous decomposition equation to discrete time data. The first step of this method require to estimate each variable at its midpoint over a time interval.

$$v_{x,t+\frac{h}{2}} = \sqrt{v_{x,t}(\frac{v_{x,t+h}}{v_{x,t}})}, \tag{12}$$

Assuming an exponential change over time, the derivative of (12) can be estimated as follows:

$$\dot{v}_{x,t+\frac{h}{2}} = v_{x,t+\frac{h}{2}} \left[\frac{\log\left(\frac{v_{x,t+\frac{h}{2}}}{v_{x,t}}\right)}{h}\right], \tag{13}$$

Appendix C: Decomposition results for eight low fertility countries.

Table C1. Contribution of progression parity ratio, parity structure and education to changes in completed cohort fertility among women born in 1940-70 in 8 low fertility countries.

Cohort	Mid-year	P	S	E	$CCF_{(t,t+5)}$*	$CCF_{(t,t+5)}$**
Australia						
1940-45	1942	-0.030	-0.023	-0.004	-0.058	-0.058
1945-50	1947	-0.014	-0.011	-0.004	-0.029	-0.029
1950-55	1952	-0.009	-0.008	-0.004	-0.021	-0.021
1955-60	1957	-0.005	-0.004	-0.001	-0.011	-0.011
1960-65	1962	-0.009	-0.007	-0.002	-0.018	-0.018
1965-70	1967	-0.004	-0.003	-0.004	-0.011	-0.011
Croatia						
1940-45	1942	-0.064	-0.046	-0.019	-0.129	-0.132

	1945-50	1947	-0.058	-0.035	-0.012	-0.106	-0.109
	1950-55	1952	-0.047	-0.023	-0.016	-0.086	-0.087
	1955-60	1957	-0.025	-0.009	-0.009	-0.044	-0.046
	1960-65	1962	-0.003	-0.004	-0.004	-0.011	-0.014
	1965-70	1967	-0.023	-0.010	-0.000	-0.033	-0.036
Finland							
	1940-45	1942	-0.014	-0.007	-0.0039	-0.026	-0.026
	1945-50	1947	-0.002	-0.003	-0.0004	-0.006	-0.006
	1950-55	1952	0.007	0.001	0.0002	0.008	0.008
	1955-60	1957	0.007	0.002	0.0008	0.009	0.009
	1960-65	1962	-0.002	-0.003	-0.0011	-0.006	-0.006
	1965-70	1967	-0.004	-0.003	-0.0014	-0.009	-0.009
Greece							
	1940-45	1942	-0.0004	-0.001	-0.007	-0.006	-0.006
	1945-50	1947	-0.004	0.002	-0.008	-0.002	-0.002
	1950-55	1952	-0.002	0.002	-0.009	-0.005	-0.004
	1955-60	1957	-0.003	-0.002	-0.007	-0.012	-0.012
	1960-65	1962	-0.003	-0.003	-0.009	-0.016	-0.016
	1965-70	1967	-0.014	-0.011	-0.006	-0.032	-0.032
Hungary							
	1940-45	1942	0.023	0.010	-0.027	0.006	0.007
	1945-50	1947	0.012	0.005	-0.006	0.012	0.012
	1950-55	1952	0.001	0.0001	-0.002	-0.002	-0.002
	1955-60	1957	0.012	0.005	-0.008	0.009	0.009
	1960-65	1962	-0.0002	-0.001	-0.005	-0.007	-0.007
	1965-70	1967	-0.014	-0.009	-0.002	-0.026	-0.026
Ireland							
	1940-45	1942	-0.016	-0.014	-0.006	-0.037	-0.037
	1945-50	1947	-0.022	-0.020	-0.008	-0.049	-0.049
	1950-55	1952	-0.024	-0.026	-0.013	-0.063	-0.063
	1955-60	1957	-0.020	-0.018	-0.008	-0.046	-0.046
	1960-65	1962	-0.016	-0.012	-0.006	-0.035	-0.035
	1965-70	1967	-0.017	-0.014	-0.005	-0.036	-0.036
South Korea							
	1940-45	1942	-0.064	-0.046	-0.019	-0.129	-0.131
	1945-50	1947	-0.058	-0.035	-0.012	-0.106	-0.109
	1950-55	1952	-0.046	-0.023	-0.016	-0.086	-0.087
	1955-60	1957	-0.025	-0.009	-0.009	-0.044	-0.045
	1960-65	1962	-0.003	-0.003	-0.004	-0.011	-0.014
	1965-70	1967	-0.023	-0.010	0.0002	-0.033	-0.035
Spain							
	1940-45	1942	-0.013	-0.007	-0.010	-0.030	-0.030
	1945-50	1947	-0.020	-0.010	-0.013	-0.044	-0.044
	1950-55	1952	-0.021	-0.010	-0.013	-0.044	-0.045
	1955-60	1957	-0.018	-0.009	-0.008	-0.035	-0.036
	1960-65	1962	-0.015	-0.008	-0.006	-0.029	-0.030

1965-70	1967	-0.013	-0.007	-0.006	-0.026	-0.026

Note: ** Obtained by using the decomposition method, as explained in the *Methods* section. For details on the methods used to compute derivatives, see Appendix B.
Source: Authors' calculations using data described in Table 1.

Table C2. Contribution of parity progression ratios structure components to changes in completed cohort fertility among women born in 1940-70, selected countries.

Cohort	Mid-year	P1			P2			P3		
		Low	Medium	High	Low	Medium	High	Low	Medium	High
Australia										
1940-45	1942	-0.0017	0.0001	0.0000	-0.0019	-0.0006	-0.0006	-0.0109	-0.0020	-0.0017
1945-50	1947	-0.0011	-0.0001	-0.0002	-0.0022	-0.0004	-0.0006	-0.0048	-0.0006	-0.0008
1950-55	1952	-0.0018	-0.0002	-0.0009	-0.0028	-0.0006	-0.0006	0.0001	-0.0002	-0.0004
1955-60	1957	-0.0014	-0.0004	-0.0003	-0.0004	0.0001	-0.0004	-0.0009	-0.0004	-0.0007
1960-65	1962	-0.0016	-0.0010	-0.0003	-0.0009	-0.0009	-0.0007	-0.0013	-0.0012	-0.0014
1965-70	1967	-0.0004	-0.0003	0.0003	-0.0008	-0.0009	-0.0001	-0.0003	-0.0009	-0.0008
Croatia										
1940-45	1942	0.0007	0.0011	0.0006	0.0033	0.0036	0.0015	-0.0004	0.0001	0.0003
1945-50	1947	0.0000	0.0000	-0.0004	0.0017	0.0019	-0.0002	-0.0034	0.0000	-0.0002
1950-55	1952	-0.0004	-0.0002	-0.0001	0.0012	0.0017	-0.0004	-0.0001	0.0020	0.0006
1955-60	1957	-0.0004	-0.0001	-0.0003	0.0005	0.0017	0.0003	0.0020	0.0044	0.0015
1960-65	1962	-0.0003	-0.0019	-0.0013	-0.0002	-0.0003	0.0001	0.0021	0.0044	-0.0002
1965-70	1967	-0.0004	-0.0034	-0.0018	-0.0001	-0.0007	-0.0009	0.0015	0.0001	-0.0006
Finland										
1940-45	1942	0.0004	0.0002	0.0007	-0.0047	-0.0015	-0.0008	-0.0043	-0.0018	-0.0004
1945-50	1947	-0.0019	-0.0004	-0.0001	0.0001	0.0004	0.0007	-0.0006	-0.0004	0.0008
1950-55	1952	-0.0023	-0.0010	0.0001	0.0004	0.0017	0.0013	0.0013	0.0032	0.0010
1955-60	1957	-0.0020	-0.0008	-0.0004	0.0003	0.0017	0.0006	0.0014	0.0025	0.0013
1960-65	1962	-0.0005	-0.0019	-0.0008	0.0001	0.0001	-0.0005	0.0007	0.0004	-0.0010
1965-70	1967	0.0003	-0.0015	-0.0004	-0.0002	-0.0012	-0.0014	-0.0001	0.0000	-0.0007
Greece										
1940-45	1942	0.0014	0.0011	0.0000	0.0006	0.0004	-0.0002	-0.0023	0.0000	-0.0001
1945-50	1947	-0.0003	0.0004	0.0008	0.0012	0.0003	0.0002	0.0016	0.0000	-0.0003
1950-55	1952	0.0014	0.0009	0.0003	0.0000	0.0001	-0.0002	-0.0004	-0.0001	0.0000
1955-60	1957	-0.0002	0.0000	-0.0008	-0.0008	-0.0006	-0.0010	0.0004	-0.0005	-0.0001
1960-65	1962	-0.0005	-0.0014	-0.0005	-0.0011	-0.0012	0.0004	-0.0003	0.0004	0.0003
1965-70	1967	-0.0021	-0.0040	-0.0035	-0.0016	-0.0024	-0.0015	0.0001	0.0000	0.0006
Hungary										
1940-45	1942	0.0005	0.0004	0.0009	0.0068	0.0024	0.0014	0.0024	0.0016	0.0002
1945-50	1947	-0.0005	-0.0004	0.0008	0.0024	0.0007	0.0003	0.0023	0.0010	0.0002

1950-55	1952	-0.0003	-0.0003	0.0003	-0.0001	-0.0002	0.0003	0.0002	0.0000	0.0002
1955-60	1957	-0.0010	-0.0009	0.0001	0.0005	-0.0002	0.0001	0.0046	0.0017	0.0008
1960-65	1962	-0.0005	-0.0005	-0.0006	-0.0005	-0.0005	-0.0004	0.0019	0.0006	0.0007
1965-70	1967	-0.0006	-0.0005	-0.0025	-0.0008	-0.0008	-0.0017	0.0007	0.0000	0.0008
Ireland										
1940-45	1942	0.0009	0.0003	0.0017	-0.0005	0.0002	-0.0002	-0.0033	-0.0009	-0.0002
1945-50	1947	0.0004	0.0005	0.0008	-0.0009	-0.0008	-0.0005	-0.0028	-0.0024	-0.0015
1950-55	1952	-0.0010	-0.0007	-0.0001	-0.0007	-0.0010	-0.0005	-0.0050	-0.0030	-0.0012
1955-60	1957	-0.0002	0.0001	-0.0009	-0.0018	-0.0010	-0.0009	-0.0023	-0.0033	-0.0024
1960-65	1962	-0.0006	0.0004	-0.0006	-0.0012	-0.0022	-0.0006	-0.0021	-0.0029	-0.0011
1965-70	1967	-0.0005	-0.0012	-0.0012	-0.0013	-0.0023	-0.0022	-0.0009	-0.0021	-0.0016
South Korea										
1940-45	1942	0.0000	0.0004	-0.0001	-0.0009	-0.0007	0.0005	-0.0132	-0.0047	-0.0013
1945-50	1947	-0.0002	-0.0007	0.0002	-0.0025	-0.0002	-0.0009	-0.0235	-0.0038	-0.0005
1950-55	1952	-0.0016	-0.0003	-0.0009	-0.0036	-0.0024	-0.0006	-0.0217	-0.0065	-0.0028
1955-60	1957	-0.0013	0.0004	0.0003	-0.0029	-0.0009	-0.0009	-0.0120	-0.0044	-0.0010
1960-65	1962	-0.0011	-0.0010	-0.0004	-0.0013	-0.0002	0.0014	-0.0011	0.0006	0.0006
1965-70	1967	-0.0006	-0.0037	-0.0030	-0.0022	-0.0056	-0.0048	-0.0003	-0.0010	-0.0008
Spain										
1940-45	1942	0.0014	0.0007	0.0005	0.0007	-0.0005	-0.0001	-0.0018	-0.0036	-0.0014
1945-50	1947	0.0019	-0.0008	0.0001	-0.0008	-0.0023	-0.0007	-0.0040	-0.0057	-0.0015
1950-55	1952	-0.0002	-0.0012	-0.0001	-0.0012	-0.0034	-0.0017	-0.0034	-0.0066	-0.0022
1955-60	1957	-0.0012	-0.0008	-0.0003	-0.0008	-0.0041	-0.0013	-0.0020	-0.0058	-0.0015
1960-65	1962	-0.0025	-0.0007	-0.0012	-0.0007	-0.0032	-0.0006	-0.0008	-0.0034	-0.0015
1965-70	1967	-0.0026	-0.0007	-0.0020	-0.0007	-0.0038	-0.0017	0.0004	-0.0012	0.0002

Source: Authors' calculations using data described in Table 1.

Table C3. Contribution of parity structure components to changes in completed cohort fertility among women born in 1940-70, selected countries.

Cohort	**Mid-year**	**S1**			**S2**			**S3**		
		Low	Medium	High	Low	Medium	High	Low	Medium	High
Australia										
1940-45	1942	-0.0016	0.0001	0.0000	-0.0021	-0.0003	-0.0003	-0.0059	-0.0009	-0.0008
1945-50	1947	-0.0010	-0.0001	-0.0002	-0.0017	-0.0003	-0.0004	-0.0026	-0.0003	-0.0004
1950-55	1952	-0.0016	-0.0002	-0.0008	-0.0023	-0.0004	-0.0006	-0.0008	-0.0002	-0.0003
1955-60	1957	-0.0012	-0.0004	-0.0002	-0.0008	-0.0001	-0.0003	-0.0007	-0.0002	-0.0003
1960-65	1962	-0.0014	-0.0008	-0.0002	-0.0012	-0.0008	-0.0004	-0.0009	-0.0007	-0.0005
1965-70	1967	-0.0004	-0.0003	0.0003	-0.0006	-0.0005	0.0001	-0.0003	-0.0005	-0.0002
Croatia										

1940-45	1942	0.0006	0.0008	0.0004	0.0017	0.0008	0.0003	0.0005	0.0002	0.0001
1945-50	1947	0.0000	0.0000	-0.0003	0.0007	0.0003	-0.0001	-0.0010	0.0001	0.0000
1950-55	1952	-0.0003	-0.0002	-0.0001	0.0003	0.0003	-0.0001	0.0001	0.0005	0.0001
1955-60	1957	-0.0004	-0.0001	-0.0002	0.0001	0.0004	0.0000	0.0007	0.0010	0.0003
1960-65	1962	-0.0003	-0.0015	-0.0010	-0.0002	-0.0005	-0.0002	0.0007	0.0010	-0.0001
1965-70	1967	-0.0003	-0.0027	-0.0012	-0.0002	-0.0011	-0.0005	0.0005	-0.0002	-0.0002
Finland										
1940-45	1942	0.0003	0.0001	0.0005	-0.0019	-0.0006	-0.0001	-0.0022	-0.0008	-0.0001
1945-50	1947	-0.0014	-0.0003	-0.0001	-0.0005	0.0000	0.0002	-0.0004	-0.0001	0.0003
1950-55	1952	-0.0017	-0.0008	0.0001	-0.0005	0.0004	0.0006	0.0003	0.0011	0.0004
1955-60	1957	-0.0015	-0.0007	-0.0003	-0.0006	0.0005	0.0001	0.0003	0.0010	0.0004
1960-65	1962	-0.0004	-0.0015	-0.0006	-0.0002	-0.0007	-0.0005	0.0002	-0.0001	-0.0004
1965-70	1967	0.0002	-0.0012	-0.0003	0.0000	-0.0012	-0.0007	0.0000	-0.0004	-0.0004
Greece										
1940-45	1942	0.0009	0.0009	0.0000	0.0003	0.0003	0.0000	0.0001	0.0001	0.0000
1945-50	1947	0.0003	0.0003	0.0006	0.0001	0.0001	0.0002	0.0000	0.0000	0.0000
1950-55	1952	0.0007	0.0007	0.0002	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000
1955-60	1957	0.0000	0.0000	-0.0006	-0.0001	-0.0001	-0.0003	-0.0001	-0.0001	-0.0001
1960-65	1962	-0.0011	-0.0011	-0.0004	-0.0005	-0.0005	0.0000	0.0000	0.0000	0.0001
1965-70	1967	-0.0030	-0.0030	-0.0025	-0.0012	-0.0012	-0.0008	-0.0003	-0.0003	-0.0001
Hungary										
1940-45	1942	0.0004	0.0017	0.0006	0.0024	0.0014	0.0003	0.0016	0.0005	0.0001
1945-50	1947	-0.0004	0.0010	0.0005	0.0007	0.0012	0.0002	0.0010	0.0002	0.0001
1950-55	1952	-0.0003	0.0001	0.0002	-0.0002	-0.0001	0.0001	0.0000	0.0001	0.0001
1955-60	1957	-0.0009	0.0002	0.0001	-0.0002	0.0003	0.0000	0.0017	0.0007	0.0001
1960-65	1962	-0.0005	-0.0010	-0.0004	-0.0005	-0.0009	-0.0002	0.0006	0.0002	0.0001
1965-70	1967	-0.0005	-0.0028	-0.0017	-0.0008	-0.0026	-0.0009	0.0000	-0.0004	0.0000
Ireland										
1940-45	1942	0.0009	0.0002	0.0015	0.0003	0.0004	0.0010	-0.0022	-0.0004	0.0005
1945-50	1947	0.0003	0.0004	0.0008	-0.0005	-0.0003	0.0002	-0.0022	-0.0016	-0.0007
1950-55	1952	-0.0009	-0.0006	-0.0001	-0.0012	-0.0011	-0.0004	-0.0038	-0.0021	-0.0008
1955-60	1957	-0.0002	0.0001	-0.0008	-0.0014	-0.0006	-0.0010	-0.0021	-0.0018	-0.0014
1960-65	1962	-0.0005	0.0003	-0.0005	-0.0011	-0.0010	-0.0006	-0.0017	-0.0016	-0.0006
1965-70	1967	-0.0004	-0.0010	-0.0010	-0.0011	-0.0017	-0.0017	-0.0009	-0.0014	-0.0011
South Korea										
1940-45	1942	0.0000	0.0003	-0.0001	-0.0007	-0.0002	0.0002	-0.0091	-0.0020	-0.0003
1945-50	1947	-0.0002	-0.0006	0.0002	-0.0020	-0.0004	-0.0003	-0.0120	-0.0012	-0.0001
1950-55	1952	-0.0014	-0.0003	-0.0008	-0.0027	-0.0008	-0.0004	-0.0084	-0.0017	-0.0005
1955-60	1957	-0.0011	0.0004	0.0002	-0.0014	-0.0001	-0.0001	-0.0035	-0.0008	-0.0001
1960-65	1962	-0.0010	-0.0008	-0.0003	-0.0006	-0.0002	0.0002	-0.0003	0.0001	0.0001

1965-70	1967	-0.0005	-0.0030	-0.0024	-0.0006	-0.0016	-0.0011	-0.0001	-0.0003	-0.0002
Spain										
1940-45	1942	0.0000	0.0012	0.0004	0.0005	0.0004	0.0002	-0.0007	-0.0014	-0.0005
1945-50	1947	0.0001	0.0016	0.0001	-0.0004	-0.0003	-0.0003	-0.0020	-0.0021	-0.0005
1950-55	1952	-0.0001	-0.0001	-0.0001	-0.0006	-0.0013	-0.0006	-0.0016	-0.0022	-0.0006
1955-60	1957	-0.0005	-0.0010	-0.0002	-0.0006	-0.0015	-0.0004	-0.0010	-0.0016	-0.0004
1960-65	1962	-0.0009	-0.0018	-0.0008	-0.0006	-0.0011	-0.0003	-0.0006	-0.0009	-0.0003
1965-70	1967	-0.0008	-0.0018	-0.0014	-0.0006	-0.0011	-0.0006	-0.0001	-0.0005	-0.0001

Source: Authors' calculations using data described in Table 1.

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