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All-time low period fertility in Finland: tempo or quantum effect?

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Tiivistelmä - Referat - Abstract

The decreasing number of births has caused concerns among researchers and decision-makers and is currently a hot topic in Finland. The most commonly used fertility index, the total fertility rate (TFR), has been rapidly decreasing during the last seven years and reached an all-time low rate of 1.49 children per woman in 2017. The total fertility rate is a synthetic measure that is sensitive to changes in the timing of births and it does not necessarily reflect underlying changes in the level of fertility. A reduction in the total fertility rate could reflect that women are postponing their childbearing while the final number of children they ultimately will have remains unchanged, or, it could reflect that women actually are having less children. The aim with this thesis is to conclude to what extent the decrease in the total fertility rate is due to fertility timing and whether the expressed concern is truly valid.

This thesis is a descriptive study produced in collaboration with Statistics Finland. Age-specific fertility rates were calculated by birth order, region and level of education based on data maintained by Statistics Finland. The produced contributions to the decrease in the total fertility rate were analysed by demographic decomposition, tempo-adjusted fertility rates were calculated to adjust for fertility timing and the completed cohort fertility rate for cohorts not yet reached age 44 was estimated mainly by a new Bayesian forecasting method. In addition, high quality fertility data from the Human Fertility Database was used to build a prior belief of already known demographic information about plausible age patterns of fertility.

The results confirmed that the main reason for the rapid decrease in the total fertility rate in 2010-2017 was decreasing first order births mainly at ages 25-29. The massive decrease in first order births was observed in both urban and rural areas and by all levels of education, but particularly for higher educated women. Overall, fertility rates at younger ages have experienced a long-term decline while fertility rates at older ages have been increasing. Nevertheless, the fertility rates at ages 30-37 have in recent years also started to decrease. The tempo-adjusted TFR did show a period tempo effect of on average 0.17 live births per woman, but since the adjusted TFR also did decrease since 2010, the possibility that women only postpone but not reduce their number of births is not enough as the only explanation to the all-time low period fertility observed. The cohort fertility forecasts did in fact confirm that women actually are reducing their lifetime number of children. Women currently in their childbearing age have delayed or even eschewed entry to motherhood to such an extent that their average lifetime number of children is very unlikely to remain close to 2 children, which has been the approximately constant level observed over the last thirty years. The completed cohort fertility rate is instead likely to decline dramatically and fall below 1.50 children for women currently in their late 20s. Thus, the decrease in the total fertility rate in 2010-2017 does reflect a massive cohort quantum effect and the expressed concern about the decreasing number of births is indeed very much valid.

Avainsanat – Nyckelord – Key words
Total fertility rate, postponement of births, tempo effect, cohort fertility forecasting

CONTENTS

1 INTRODUCTION

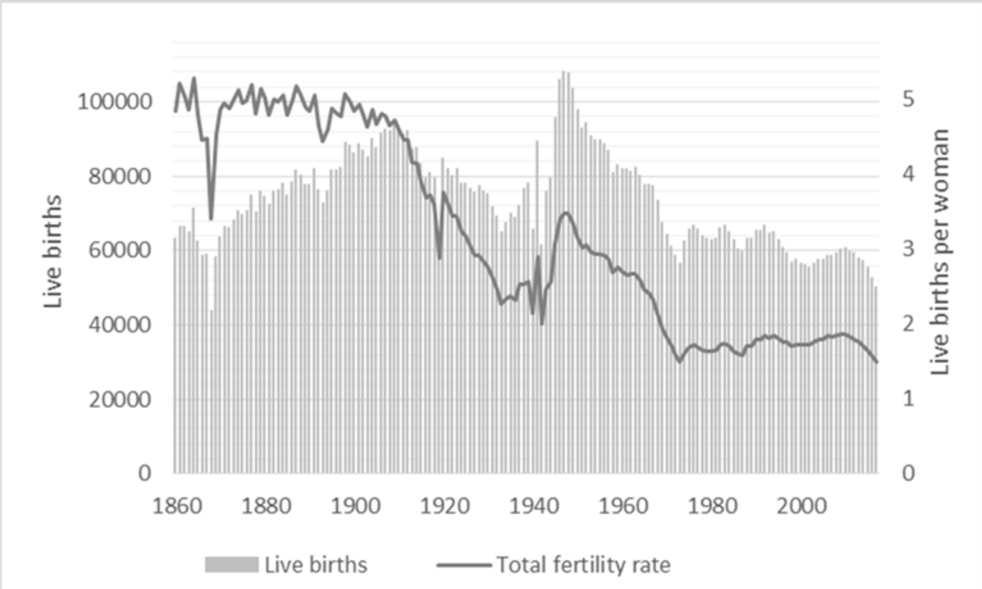
1.1 SUBJECT OF THESIS

This thesis examines current fertility trends in Finland. Fertility refers in this context to the actual production of offspring, not to fecundity, which is the potential for reproduction of a population. Together with mortality and migration, fertility largely affects future size and age structures for a population. The size and growth of a country's population reflects both the causes and effects of economic and social developments (OECD 2014). Changing age structures affects many socio-economic factors such as future labor market participation and thus social protection system, pensions and overall health (Skibiński 2017). Fertility trends in a country therefore highly interests researchers, planners and decision-makers.

Fertility trends are not only important from a macro-level perspective, but of great interest on an individual level as well. Childbearing is nowadays highly based on individual decision-making and family formation includes both the desired number of children a woman wishes to have as well as the timing of her childbearing. Current trends in fertility behavior such as shifts in the prime age of childbearing and reduced or increased family sizes among women are the essential part of understanding fertility changes. Since fecundity declines with age, the timing of childbirth may thus affect the final number of children women have (Andersson et al. 2009). Further, it is crucial to detect sudden fertility changes and to be aware of fertility variation among subgroups of a population so that decision-makers can be able to respond to those changes and to support all individuals in their reproductive plans.

Consequently, the recent years' decreasing number of births in Finland is the center of attention in this thesis. The number of live births has declined steadily every year from 60 980 live births in 2010 to 50 321 live births in 2017 (figure 1). Last time the number of births was lower than in 2017 was during the great famine in 1868, when slightly under 44 000 children were born. The most commonly used fertility index, the total fertility rate (TFR), did also decrease rapidly in the 2010s and experienced an all-time low rate of 1.49 children per woman in 2017. Without the impact of immigration, the total population in Finland would have decreased during the last two years. The recent years' decline in the number of births and in the total fertility rate is a subject of concern that has been frequently in the Finnish news lately. This thesis therefore aims to understand the rapid decrease in the total fertility rate in recent years: is the phenomena of decreasing births temporary and for example due to postponement of births or does it reflect an underlying reduction in the total number of children women eventually will have during their lifetime?

Figure 1: The number of live births and the total fertility rate in Finland in 1860-2017.



Source: Statistics Finland 2018

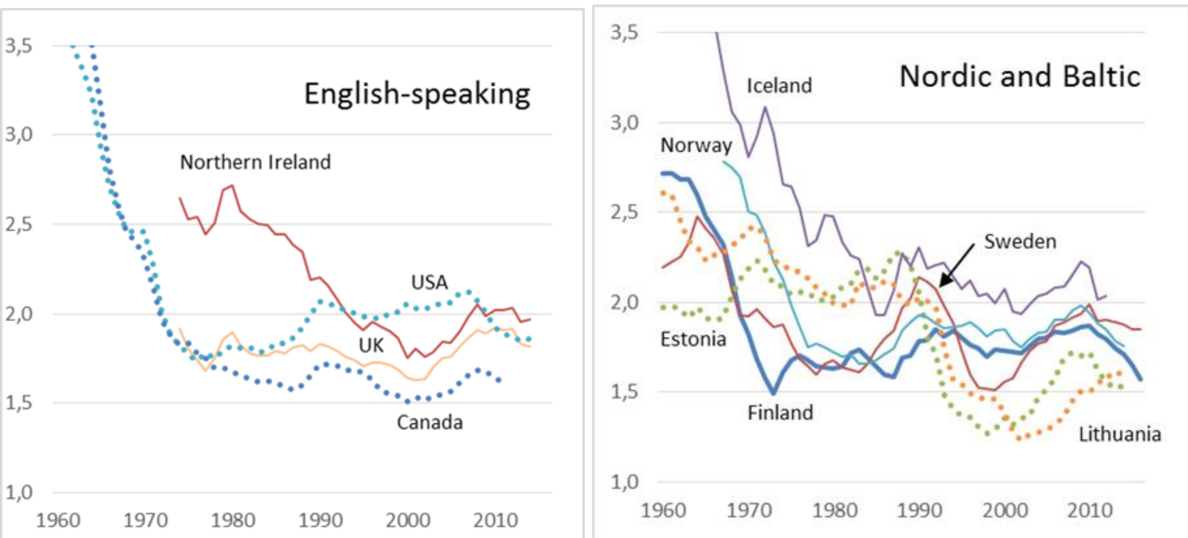
1.2 INTERNATIONAL FERTILITY TRENDS

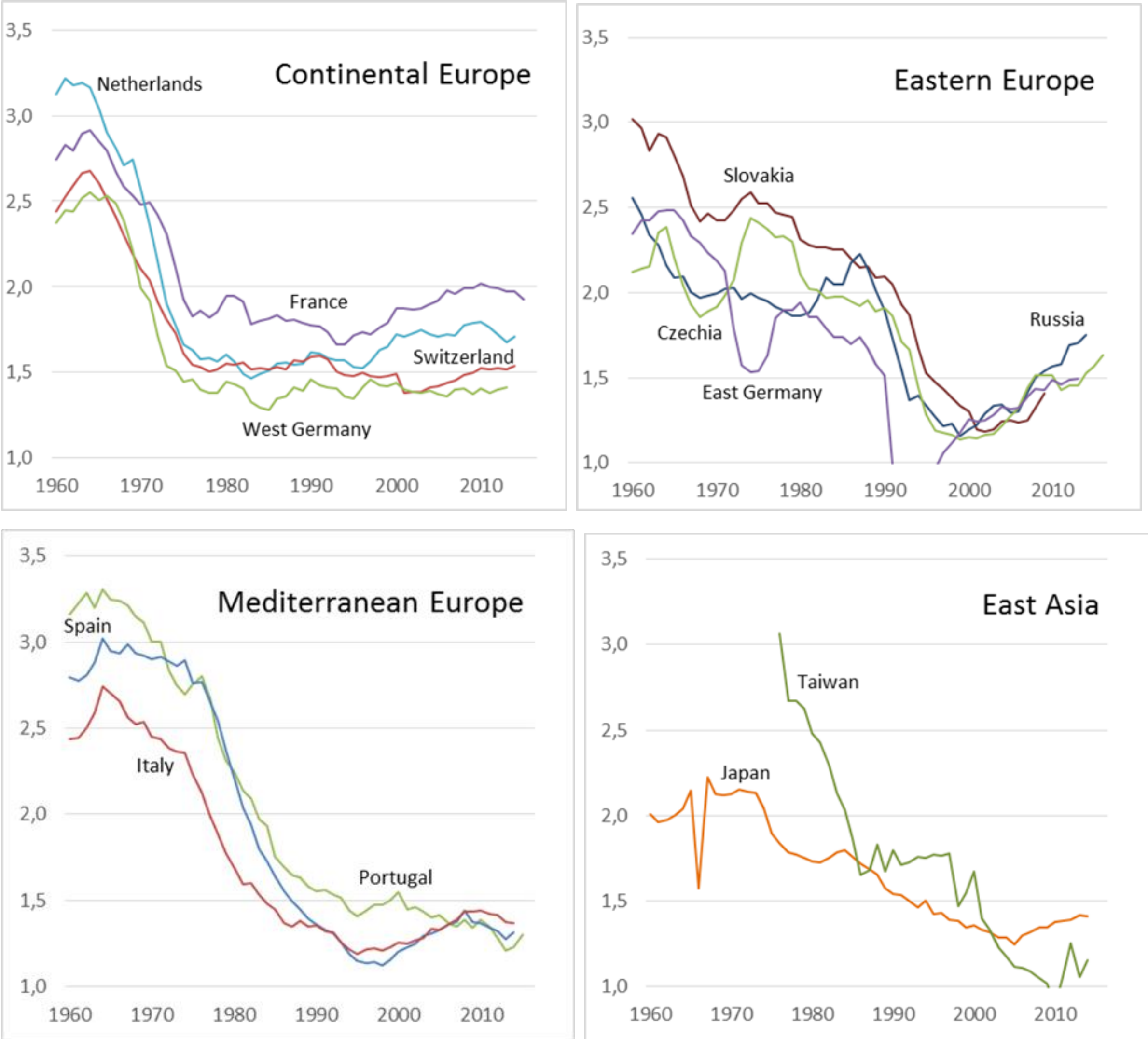
Figure 2 shows the total fertility rates mainly for European countries but also for the US, Canada and some countries in East Asia in 1960-2016. Most countries in figure 2 have experienced similar trends in the total fertility rate as Finland since 1960, especially the Nordic countries, the English-speaking countries and continental European countries. The total fertility rate fell rapidly from a level of over 2.5 live births per woman to far below replacement level in 1960-1970 for many countries. The great decline during that period has been explained by increased female labor force, the advent of modern contraceptive use, access to safe and legal induced abortion, increasing divorce rates and the economic situation (Frejka and Sardon 2004). Since 1974, the total fertility rate has fluctuated between 1.49 and 1.87 in Finland.

The fertility trends over the whole time period differ especially for Estonia and Japan; the total fertility was only about 2 live births per woman in 1960 in these countries. For Japan, the smooth decline started after 1974 and for Estonia, the decline was greatest in 1990-2000. Great declines in the fertility rates in the 1990s have been observed especially for eastern European countries. 1990s was the time period when communism and Soviet Union did collapse as well. In Russia, Slovakia and Czechia, the total fertility rate fell from about 2 live births per woman in 1990 to about 1.20 live births in 2000. In East Germany, the total fertility rate was as low as 0.78 live births per woman in 1994. Since 2000, the fertility rates for the eastern European countries have recovered and the total fertility rate reached a level of 1.75 live births per woman in Russia in 2014.

Since 2010, Iceland is the only European country where the total fertility has been above the replacement level (2.2 live births per woman observed in 2010). Iceland, together with Canada and the US, did also have the highest fertility rates in 1960. Northern Ireland, France and the US are countries that have experienced fairly high fertility rates compared to other European countries in recent years. Taiwan and some Mediterranean countries again have experienced lowest-low fertility rates (below 1.3 live births per woman) since 2010. In 2016, the total fertility rate in Finland was already below average in Europe and the lowest of all Nordic countries (Eurostat 2018). Finland’s rapid decrease in the total fertility rate since 2010 seems to be somewhat unique internationally. Some small decreases can still be observed in Nordic and Baltic countries, especially in Norway, but also in the US. Norway is also the country with the most similar trends and levels in the total fertility rate as Finland.

Figure 2: The total fertility rate in 1960-2016, mainly in European countries





Source: Human Fertility Database 2018

2 THEORETICAL BACKGROUND

2.1 FERTILITY MEASURES

Fertility can be measured in several ways. It is important to know the meaning of each of the different fertility indexes and to recognize their strengths and limitations to be able to draw correct conclusions about fertility as a phenomena. The period and the cohort approach to fertility is discussed in this section and the understating of these two completely different approaches lays the foundation of this thesis. A basic introduction to demography as well as the definitions of the fertility measures defined below can be found in for example Suomen Väestö (2007).

The *crude birth rate* is the number of live births in one year expressed as a proportion of the average population of that year. The average population of a year refers to the average of the population in the beginning of that specific year and the population in the end of that same year. The crude birth rate CBR_i at year i is hence

$$CBR_i = \frac{B_i}{\bar{P}_i} \times 1000,$$

where B_i is the number of live births at year i and $\bar{P}_i$ is the average population at year i. The ratio is multiplied by 1000 because population events are generally given as per 1000. The crude birth rate is called crude because the denominator includes the whole population, not just the specific population at risk for childbearing. If the majority of a population is the elderly population, the crude birth rate will be low even though fertility would be high. The crude birth rate does not measure fertility as a phenomena itself, but is an important index in terms of population growth.

The *general fertility rate* is the number of live births in a year expressed as a proportion of the average population[1] of women of childbearing age at that year. The general fertility rate GFR_i at year i is thus

$$GFR_i = \frac{B_i}{\bar{P}^f_{15-49,i}} \times 1000,$$

where B_i is the number of live births at year i and $\bar{P}^f_{15-49,i}$ is the average population of women aged 15 to 49 at year i. Since both males and women out of childbearing ages are excluded from the

[1] The proper way to compute fertility rates is to divide events by person-years. Person-years are still in practice replaced by the average population of a year.

denominator, the general fertility rate is a more appropriate measure of fertility as a phenomena itself compared to the crude birth rate. The general fertility rate does not however take the age structure among women in their childbearing age into account.

The *age-specific fertility rate* is the number of live births born to women at a specific age expressed as a proportion of the average population of women at that specific age. The age-specific fertility rate $ASFR_x$ at age x is though

$$ASFR_x = \frac{B_x}{\bar{P}_x^f} \times 1000,$$

where B_x is the number of live births born to women at age x and $\bar{P}_x^f$ is the average female population at age x. Age-specific fertility rates are standardized for age and can therefore be used to compare fertility trends in different populations or at different points in time.

Further, the *total fertility rate* (TFR) and the *completed cohort fertility rate* (CFR) are fertility indexes of great importance, but they are computed by two completely different approaches and tell very different stories. The TFR is the most used fertility index and is computed by a period-based or cross sectional approach that sums up the single year age-specific fertility rates at childbearing ages obtained from one calendar year. The CFR is then again more rarely used and is computed by a cohort-based or retrospective approach that sums up the single year age-specific fertility rates at childbearing ages obtained from one cohort. The total fertility rate is a synthetic measure that tells what the average number of children ever born to a woman would be is she experienced the exact current age-specific fertility rates through her lifetime and she were to live to the end of her child-bearing years. This rate is therefore not necessarily achieved by any real group of women whereas the completed cohort fertility rate by definition is the actual true average lifetime number of children ever born to a cohort. Thus, the completed cohort fertility rate truly is the goal of interest while the total fertility rate is a somewhat limited attempt to estimate it (Bhrolchain 1992).

The period- and the cohort-based approaches have also very different strengths and limitations and the weakness on one approach is the strength of the other approach and vice versa. The greatest limitation with the total fertility rate is its interpretative difficulty. Shifts in the total fertility rate depends both on temporary changes in fertility timing, tempo, and by changes in the total number of children women have, quantum (Myrskylä et al. 2013). The completed cohort fertility rate does not have this problem, because it depends only on the actual number of children women have, not the fertility timing. The limitation with the completed cohort fertility rate is instead incomplete observations because the rate is only obtained after women in a cohort have completed their childbearing. For cohort fertility analysis among women currently in their childbearing ages, one must either wait until they have completed their childbearing or make forecasts for the future. Since period fertility rates are obtained from one calendar year, they however give some up to date indication of current levels and trends of fertility among women who have not yet completed their childbearing age.

Replacement fertility level refers to levels of childbearing and is the level of fertility required to ensure that a population by time replaces itself in size. For the female population to replace itself, women need to have on average one female child who survives to her childbearing ages. If the same number of male and female children are born, an average of two children per woman will replace the parents. Due to mortality and the unbalanced sex ratio at birth, the replacement level fertility is normally presented as being 2.1 children per woman. Countries with a total fertility rate (TFR) below the replacement level of 2.1 children per woman are considered as low-fertility countries. (E.g. Smallwood and Chamberlain 2005)

The *mean age of childbearing* is calculated by the formula

$$\bar{a} = \frac{\sum_{x=15}^{45} x * ASFR_x}{\sum_{x=15}^{45} ASFR_x} + \frac{n}{2},$$

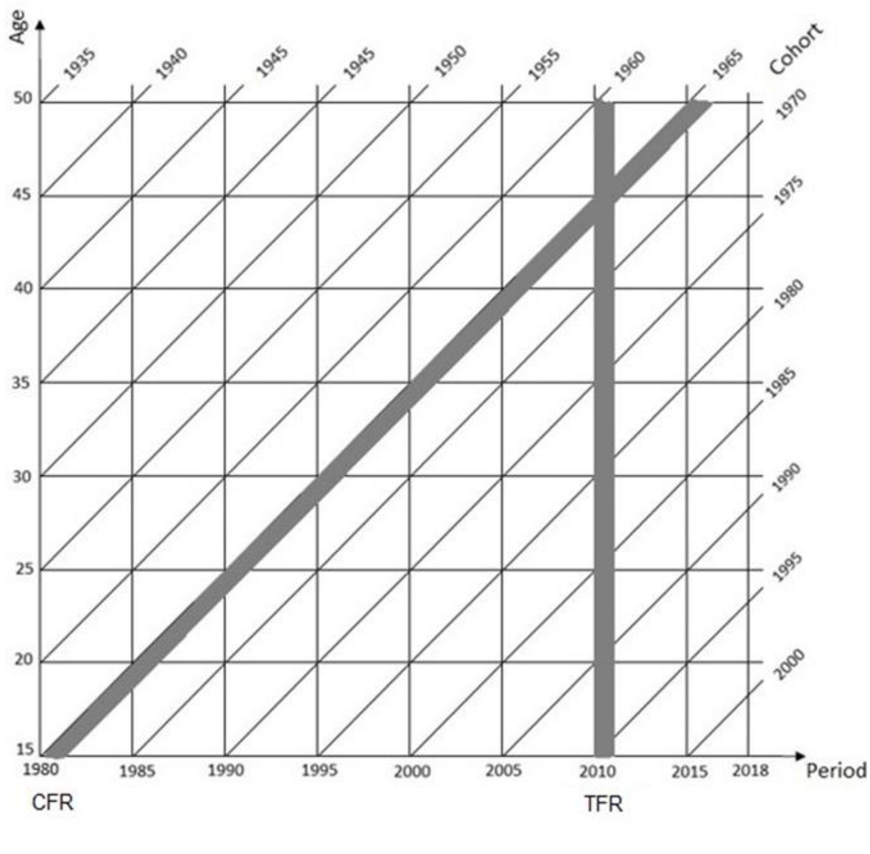
where x is the lower limit of the age group, $ASFR_x$ is the age-specific fertility rate at age group x and n is the length of the age group. The mean age of childbearing is calculated based on the age-specific fertility rates, not directly by the number of births by maternal age, to standardize differences in age distributions. The mean age of childbearing can thus be compared between two populations even though their age structure may differ significantly.

Lexis diagram

Lexis diagram is a visualization tool in demography named after the statistician, economist and social scientist Wilhelm Lexis in the late 1800's. The lexis diagram visualizes the relationship between demographic events in time and the population at risk for the events. Demographic events like births are characterized by when it occurs and the age of the mother to whom it occurs. Lexis diagram connects period, age and cohort via a Cartesian coordinate system where period is represented on the horizontal axis and age on the vertical axis. A cohort is in this thesis a group of women with a particular birth year and different cohorts are represented as diagonals in the Cartesian coordinate system. (E.g. Schöley and Willekens 2017)

Figure 3 illustrates a Lexis diagram for the period 1980-2018, for ages 15-50 and for cohorts born in 1935-2000. The thick vertical line in the figure represents the total fertility rate in 2010, which thus is the sum of the 15-year fertility rate for the cohort born in 1994, the 16-year fertility rate for the cohort born in 1993 and so on up to the 49-year fertility rate for the cohort born in 1960. The thick diagonal line in the figure represents the completed cohort fertility rate for the cohort born in 1965 which thus is the sum of all single year age-specific fertility rates from 15 to 49 for the cohort born in 1965. By 2018, the cohorts born before 1968 have reached the end of their childbearing age and for these cohorts the CFR is complete. Later cohorts are still in their childbearing age and their completed rates will be observed in the future.

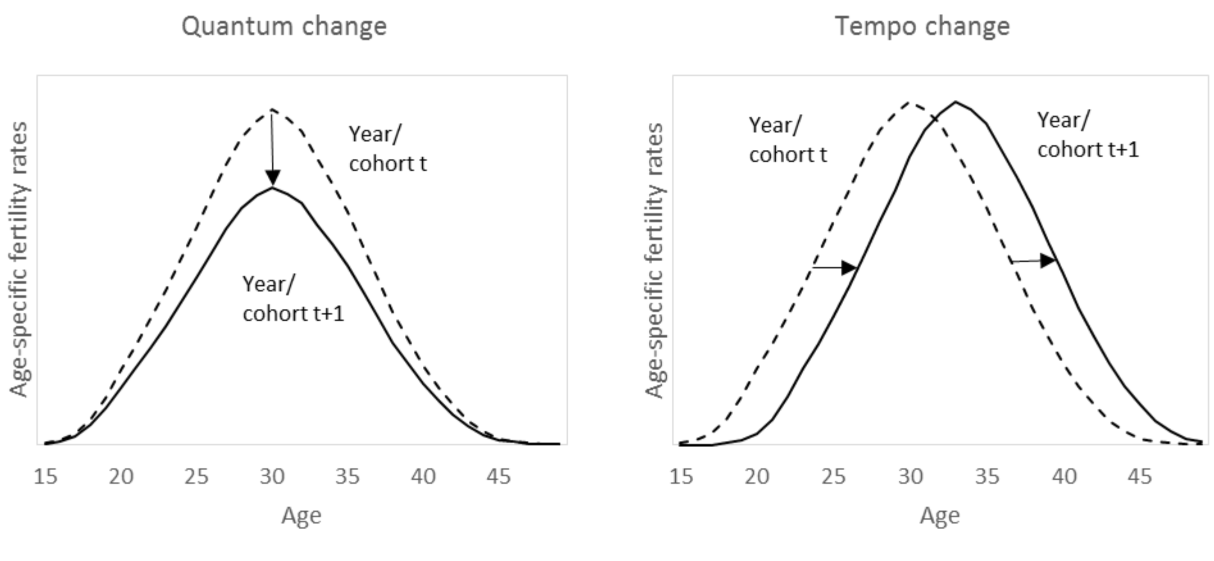
Figure 3: Lexis diagram



2.2 TEMPO VERSUS QUANTUM CHANGES

The fundamental goal of interest when it comes to declining birth rates is to distinguish between quantum and tempo changes and between period and cohort changes. Changes in age-specific fertility rates can be identified as four ideal types of changes; a period quantum change, a cohort quantum change, a period tempo change, and a cohort tempo change (see figure 4). A period quantum change in fertility is independent of age and cohort and means that the period fertility rates increases or decreases proportionally at all ages from one period to the next. A cohort quantum change in fertility is then again independent of age and period and means that the cohort fertility rates increase or decrease proportionally at all ages from one cohort to another. A change in the mean age at childbearing from one period to the next or from one cohort to another is defined as a period tempo change and a cohort tempo change respectively. The fertility rates thus may move up or down the age axis while its shape remains unchanged. Consequently, a tempo change means later but not less childbearing whereas a quantum change means purely less childbearing. Due to the complex real world, quantum and tempo changes do however often occur simultaneously and the challenge is to distinguish whether fertility changes are derived mainly by quantum or tempo effects. (Bongaarts and Sobotka 2012)

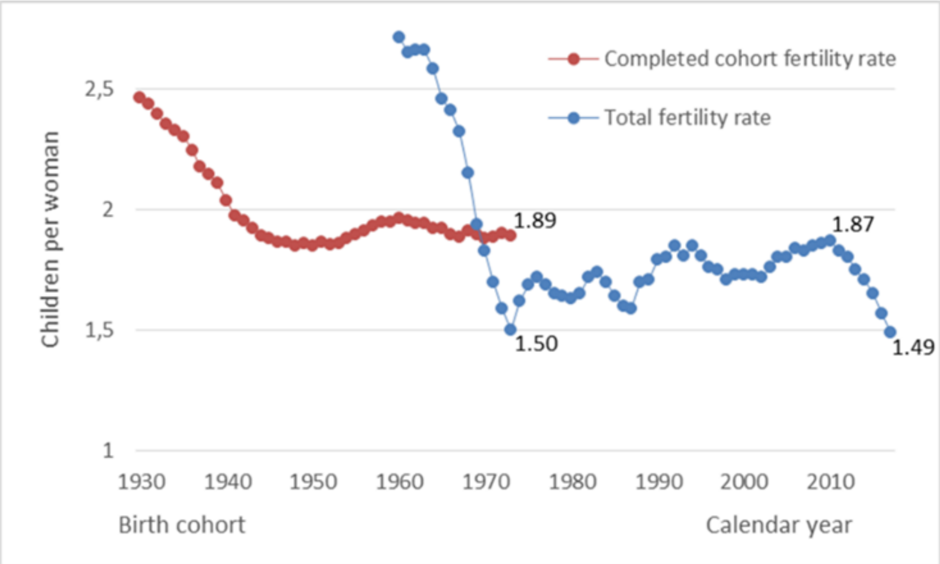
Figure 4: Simulated quantum and tempo changes in the age-specific fertility rates from one period to the next or from one cohort to another



Source: Own simulations based on figure 4a and 4b in Bongaarts and Sobotka 2012

The completed cohort fertility rate is the ideal measure of fertility quantum changes. A fall in cohort fertility is a pure quantum effect and reflects that women really are having less children during their lifetime (Myrskylä et al. 2013). Figure 5 shows the completed cohort fertility rate for Finnish cohorts born in 1930-1973 together with the total fertility rate observed in 1960-2017 in Finland. The completed lifetime number of children has decreased from 2.5 children per woman for the cohort born in 1930 to below replacement level for the cohort born in 1940. For cohorts born in 1941-1973, the completed fertility rate has stabilized on a level of almost 2 children per woman. Despite great fluctuations in the total fertility rate, there has not been any massive changes in the completed cohort fertility during the last 30 years. Women born in 1960 had still slightly more children than women born in 1950. However, women who already have reached the end of their reproductive age did most of their childbearing decades ago. The decreasing number of births depends exclusively on women currently in their childbearing age and since the total fertility rate has experienced a rapid decrease in the 2010s, the question is whether a decrease in the completed cohort fertility rate will be observed for women currently in their childbearing age after they have completed their childbearing.

Figure 5: The completed cohort fertility rate for cohorts born in 1930-1973 in Finland and the total fertility rate observed in 1960-2017 in Finland



Source: Human fertility database 2018 and Statistics Finland 2018. Note: For cohorts born in 1966-1973, the completed cohort fertility rate is due to lack of data from the HFD based on own estimates and the rate is considered complete at age 44

2.3 Previous research

In most developed countries, postponement of first birth is an ongoing and persistent process (Andersson et al. 2009). Andersson et al. (2009) did in their study about cohort fertility patterns in the Nordic countries use median age at first birth to illustrate this development. For Finnish women, more than 50 percent of the cohort 1940-1944 have become mothers by the age of 24. For cohort 1965-1969, the median age of first birth was 28.8. Even though women in the Nordic countries postpone their childbearing, they have still managed to have as many children as previous cohorts due to strong fertility recuperation, meaning that they at older ages catch up on births that were postponed at younger ages. The childlessness rate among women has been increasing but recently plateaued in all Nordic countries except in Finland. Finnish women have now a significantly higher childlessness rate compared to other Nordic countries. The cohort fertility level for Finnish women has however still remained stable due to increasing higher order childbearing. (Jalovaara et al. 2018)

Since the work of Hajnal (1947) and Ryder (1964), it has been known to demographers that delays in childbirth can have substantial effects on cross-sectional measures such as the total fertility rate (Goldstein et al. 2009). When women delay childbearing in a given period, fertility rates are depressed and when childbearing is accelerated, fertility is raised (Bongaarts and Feeney 1998). This leads to depressed or inflated numbers of births, which influences birth rates and thus the total fertility rate. Even though the completed cohort fertility rate remains unchanged, declines in the total fertility rate can be seen due to postponement of births to older ages. Bongaarts and Feeney (1998) were concerned about "basing policies on statistics that give potentially misleading information" and developed a tempo adjusted total fertility rate that adjust for distortions in the period-based total fertility rate due to changes in the timing of births. They illustrated how fertility rates calculated from one particular year are depressed when childbearing is postponed, even though the level of cohort fertility does not change. For example, if the mean age at birth increases by 0.2 years during the year, the number of births in that particular year declines by 20 percent.

In a study about forecasted cohort fertility in the developed world, Myrskylä et al. (2013) found that "cohort fertility in low-fertility countries is indeed much higher than period fertility". In their study, on average across 37 countries, the forecasted cohort fertility was on average 1.8 children for women born in the mid-1970s. The comparable period rates were on average only 1.5 across these countries. Myrskylä et al. claim that "reporting the total fertility rate as 'the average number of children women have' underestimates the actual experience of populations by some 20 percent".

Nevertheless, the most important reason for postponing childbearing has turned out to be educational expansion and higher education among women has in general been negatively associated with low fertility (e.g. Sobotka et al. 2017). Higher educated women also start their childbearing later than lower educated women (e.g. Andersson et al. 2009). Kravdal (2007) studied the effects on current education on second- and third-birth rates among Norwegian women and claimed that researchers "should not take for granted that women's education generally reduces fertility, and that it does so because of higher opportunity costs for the better educated". He also discussed the possibility of reverse causality of childbearing affecting further education instead of vice versa and the problem with confounding factors, meaning that something else such as individual interests or family background may by different reasons affect both a women's educational career and her fertility. However, the completed cohort fertility rate for women in the Nordic countries have recently converged among different levels of education and the difference between educational groups have practically disappeared. In Finland on the other hand, the differences in level of education still remain fairly stable and lower educated women have slightly more children than higher educated women. (Jalovaara et al. 2018)

Besides postponement of childbearing, economic development has also been an important influencer on fertility. More developed societies tend to have lower fertility levels than less developed societies. This has been explained by the fact that the costs of living for families increased faster in high developed areas compared to lower developed ones. However, there have recently been signs that the negative association between economic development and fertility might turn positive in more developed areas, potentially due to improvements in gender equality. Shifts in family policies, such as not only providing child benefits but also extending parental leave schemes and childcare as well as developing policies that support parents in reconciling both family and career goals, have also been discussed to contribute to a reversal of the relationship between economic development and fertility. Nevertheless, any signs of the reversal trend have not been found in Finland. Unlike in most of the European countries, the correlation between employee compensation per capita[2] and fertility in Finland has in fact remained consistently negative since 1990 and has even become slightly more negative in recent years. (Fox et al. 2018)

It is known that both the fertility levels and the timing of childbearing differ between urban and rural areas. The larger a settlement is, the lower the fertility and the later the childbearing. The differences in fertility levels between the smallest and the largest settlements have remained stable from the mid-1990s in Scandinavian countries but increased in Finland. In the early 2000s, postponement of childbearing was a common trend in both rural and urban areas but much more pronounced in the cities. The larger amount of higher educated women in urban areas and the fact that people are more likely to live as couples in smaller areas are possible explanations for the fertility variation between settlements, but the causality between the factors is far from clear. Besides socio-economic factors,

[2] Employee compensation was in the article of Fox et al. (2018) defined as "the total remuneration, in cash or in kind, payable by an employer to an employee in return for work done by the latter".

the fertility variation has also been explained by social and cultural norms, internal migration and differences in housing type and size in urban and rural areas. (Kulu et al. 2007)

The Nordic countries have relatively high fertility in Europe and are of high interest to many fertility and family researchers, they are even seen as forerunners of demographic development to some demographers (Kulu et al. 2007). Both period and cohort fertility analyses have shown remarkable similarities in fertility levels and childbearing behavior among the Nordic countries and a common Nordic fertility regime is considered to exist. Since the cohort fertility levels in Nordic countries have remained close to the reproduction level despite high levels of female participation in the labor market and because of their common characteristics in welfare policies, the Nordic countries have often been in focus in discussion. (Andersson et al. 2009) However, an outstanding decrease in the total fertility rate has been observed in Finland in recent years and signs of Finnish women lagging behind in the fertility development in terms of further increasing childlessness rates and consisting fertility differences among socioeconomic groups in Finland have been noticed. This thesis therefore aims to increase the understanding on current childbearing behavior in Finland.

Cohort fertility in Finland has recently been forecasted by Myrskylä et al. (2013) and Schmertmann et al. (2014). Those forecasts did not show any significant changes in the completed cohort fertility rate for cohorts born in 1970-1980 compared to earlier cohorts. However, the rapidly decreasing total fertility rate in recent years may indicate that cohort fertility also is starting to decrease and new updated forecasts are required. The focus is now also shifting to the cohorts born in 1980-1990 and even younger cohorts. The hypothesis of cohort fertility starting to decrease is supported by Rotkirch et al. (2017) who predicts the childlessness rate to increase and the frequency of large families to decrease in Finland. They also state that there are currently no signs that older women close to the end of their childbearing age will have time to replace the postponement in younger ages.

3 RESEARCH METHODOLOGY

3.1 RESEARCH QUESTIONS

The total fertility rate has been rapidly decreasing from a level of 1.87 children per woman in 2010 to an al-time low rate of 1.49 children per woman in 2017. The decreasing number of births has been discussed frequently in Finland lately but the decrease is not completely understood. Since the total fertility rate is a period-based measure, the decrease could be due to a tempo effect, meaning that women are postponing their births but not having less children. It could also be due to a quantum effect, meaning that women actually are having less children, which by time would be seen as a decrease in the completed cohort fertility rate. Thus, a reduction in the total fertility rate does not necessarily reflect underlying changes in the level of fertility. By studying cohort-based fertility indicators, which are not affected by changes in timing, it can be concluded to what extend the decrease in the total fertility rate is due to fertility timing.

This thesis had three main goals; (1) to describe period fertility trends in Finland among age, parity, regions and levels of education, (2) to calculate an alternative tempo adjusted fertility rate that adjust for fertility timing and (3) to forecast cohort fertility. For decision-makers to be able to respond to the decreasing births, it is important to detect whether this is a widespread phenomenon in Finland or whether the decrease is more pronounced within some sub groups of the population.

The leading research questions were:

1. Which age groups and what parity have produced the greatest contributions to the decrease in the total fertility rate in 2010-2017? Do the results differ for women in urban and rural areas or with different levels of education?
2. What would the total fertility rate have been in the absence of fertility postponement?
3. Will women currently in their childbearing age finally have less children compared to women who already have completed their childbearing?

This thesis is a descriptive study realized in collaboration with Statistics Finland that aims to broaden the understanding about the decreasing births in Finland as well as the childbearing behavior for women currently in their childbearing age. Period fertility trends were described by age-specific fertility rates, the contributions to the decrease in the total fertility rate were examined by demographic decomposition and the tempo-adjusted fertility rate was calculated by the method of

Bongaarts and Feeney (1998). Cohort fertility was forecasted using new methods, mainly a Bayesian method developed by Schmertmann et al. (2014) but also by simpler method like the Freeze rate method and the 5-year extrapolation method (Myrskylä et al. 2013). The data used in the analyses were provided by Statistics Finland and high quality fertility data from the Human Fertility Database were used specifically to form the prior distribution in the Bayesian forecasting model. The fertility rates and the decompositions were calculated and implemented in Excel and the forecasts were realized in R software.

3.2 DATA

Two separate sources of data were used in this thesis, data obtained by Statistics Finland and by the Human Fertility Database (HFD). Statistics Finland provided two different data sets, Births and Population structure, for calculating fertility rates among age, parity, region and level of education and thus also for the decompositions and the adjusted fertility rates. The data set Births includes information about live births in Finland, such as place and year of birth, birth order and nationality, and information about the parents' age, number of children, place of residence and level of education from 1990 to 2017. The data set Population structure includes information such as age, marital status, number of children, place of residence, level of education and nationality about the population resident in Finland on the last day of the year from 1987-2017. The Population Information System, maintained by the Population Register Centre and local register offices, is the main source that is used when Finnish population statistics are produced. The Population Information System is continuously updated with changes in the data on the vital events of the resident population by local population register authorities. For example, information about births are sent to the Population Information System by hospitals. Statistics Finland has obtained population data from the Population Register Centre since 1975.

The fertility trends were not only examined by regions in Finland but also by statistical grouping of municipality. Municipalities in Finland are divided into three groups; urban municipalities, semi-urban municipalities and rural municipalities (table 1). This statistical grouping of municipalities is developed by Statistics Finland and has been in use since 1989. The classification is made according to the municipality's proportion of people living in urban settlements and the population of the largest urban settlement.

Table 1: Statistical grouping of municipality.

Classification	Definition	Example
Urban municipalities	At least 90 per cent of the population lives in urban settlements or the population of the largest urban settlement is at least 15 000.	Helsinki Espoo
Semi-urban municipalities	At least 60 per cent but less than 90 per cent of the population lives in urban settlements and the population of the largest urban settlement is at least 4 000 but less than 15 000.	Raasepori Vihti
Rural municipalities	Less than 60 per cent of the population lives in urban settlements and the population of the largest urban settlement is less than 15 000, or At least 60 per cent but less than 90 per cent of the population lives in urban settlements and in which the population of the largest settlement is less than 4 000.	Liperi Pedersören kunta

Source: Statistics Finland

The level of education was measured as the mother's highest level of education at the time of childbirth. The levels of education examined were low, medium, high and unknown level of education and the classification is illustrated in table 2. Low level consists of upper secondary and post-secondary non-tertiary education, medium level consists of short-cycle tertiary and Bachelor's or equivalent level of education and high level consists of Masters and Doctoral level of education. Upper secondary education begins at age 16 or 17 and lasts about three years. It includes both matriculation examinations and vocational competence such as practical nurses and electricians. Post-secondary non-tertiary education is not necessarily more advanced than upper secondary education, but aims to broaden the knowledge for those who have completed upper secondary education. Short-cycle tertiary education usually lasts 2-3 years after upper secondary education and includes examinations that are not university degrees. Bachelor's or equivalent level of education lasts 3-4 years and is the lower level of tertiary education. It gives the competence to continue to the second stage of tertiary education but not to doctoral level of education. Master's or equivalent level of education is the second stage of tertiary education and gives the competence to continue to doctoral level of education. Doctoral or equivalent level of education is the highest level of tertiary education and leads to an advanced research qualification. Unknown level of education includes those women whose education information is missing but also those women who have completed some education of lower level than upper secondary education as well.

Table 2: Classification of educational level into low, medium, high and unknown level of education

Low level	Upper secondary education Post-secondary non-tertiary education
Medium level	Short-cycle tertiary education Bachelor's or equivalent level
High level	Master's or equivalent level Doctoral or equivalent level
Unknown level	Not elsewhere classified (including lower level than upper secondary education)

Source: Own classification

Data obtained by the Human Fertility Database were used for the cohort fertility forecasts. The HFD is a source of high-quality fertility data and the work on the database began as a collaborative project between the Max Planck Institute for Demographic Research and the Vienna Institute of Demography in 2007. The data used for the forecasts consists of estimated fertility rates by single-year of age, single calendar year and cohort year of birth from 23 countries or regions in Europe and North America. The vector of rates for a cohort at ages 15-44 is denoted as the cohort fertility schedule and is defined as complete if the rate estimates are available at all 30 ages. Two separate subsets are formed from the HFD; contemporary data and historical data. The contemporary dataset (such as figure 26) consists of 10 complete cohort schedules for Finnish cohorts born in 1964-1973 and 30 incomplete schedules for Finnish cohorts born in 1974-2003 and its surface is to be forecasted. The historical dataset consists of S = 648 complete cohort schedules for cohorts born in any of the 23 above mentioned countries or regions between 1900 and 1960 (Appendix 1) and is used as a priori information in the Bayesian forecasting model. The historical dataset is organized as a 30×648 matrix $\mathbf{\Phi}$ with each column containing one complete cohort fertility schedule.

3.3 RESEARCH METHODS

3.3.1 Demographic decomposition

Demographic decomposition is used to compare differences in the values of aggregate demographic measures between two populations. The difference is decomposed according to the effects of age and other factors. In this thesis, the differences in the TFR computed from conditional age- and parity-specific fertility rates (from now on denoted as TFR_p) in Finland in 2010 and in 2017 is decomposed according to age and birth order. The TFR_p does not only adjust for population age structure like the conventional period TFR, but it also adjust for differences between sequences of births. The aim with the decomposition is to estimate the additive contributions of the differences between age- and parity-specific fertility rates to the overall difference between the two values of the TFR_p. The decomposition is in practice done by a general algorithm realized as an Excel spreadsheet developed by Andreev and Shkolnikov in 2012. The algorithm uses stepwise replacements and was originally proposed by Andreev, Shkolnikov and Begun in 2002.

First of all, the conditional age- and parity-specific fertility rates $f_{x,par}$ are computed and collected as a matrix $F = \| f_{x,par} \|$ for each population of interest. The conditional age- and parity-specific fertility rate $f_{x,par}$ is a ratio of the number of par-order births to the mid-year population of women aged x with *par*-1 children, expressed as per 1 000 women. The age and birth order considered are the reproductive ages 12,..,55 and birth orders 1,2,3,4,5+. In matrix F, ages are presented as rows and birth orders as columns. Second, three additional tables are calculated based on matrix F; table of probability, table of population and table of number of births. The table of probability consists of the probabilities of giving *i*th birth by a woman with *i-1* children in age interval $[x, x+1)$, denoted as $\varphi_{x,par}$. The table of population consists of the sizes of the female population of parity *i* at age *x*, denoted as $l_{x,par}$. The table of number of births consists of the number of births of order *i* in age interval $[x, x+1)$, denoted as $b_{x,par}$. The following scheme is used for computing the three additional tables:

- $\varphi_{x,par} = \frac{f_{x,par}}{1000} / (1 + \frac{f_{x,par}}{2*1000})$
- $l_{\alpha,0} \equiv 1\,000$ and $l_{\alpha,par} \equiv 0$ for *par>0,* where α is the youngest age group

- $b_{x,1} = l_{x,0} * \varphi_{x,1}$ and $b_{x,par} = \left(l_{x,par-1} + \frac{b_{x,par-1}}{2}\right) * \varphi_{x,par}$ when $par > 1$
- $l_{x+1,0} = l_{x,0} - b_{x,1}$ and $l_{x+1,par} = \ l_{x,par} + b_{x,par} - b_{x,par+1}$ when $par > 0$.

The total parity-specific birth numbers are defined as $B_0 = 1000$ for $par = 0$ and $B_{par} = \sum_x b_{x,par}$ for $par > 0$. The total fertility rate adjusted for age and parity is $TFR_p = \sum_{par=1}^{3+} B_{par}/B_0$, or in other words, the sum of all age- and parity-specific birth numbers $b_{x,par}$.

The general replacement algorithm for decomposition of differences between TFR_p values replaces the conditional age- and parity-specific fertility rates for the two populations of interest and estimates the effects of each of the replacements. Five elementary replacements at each age are executed for *i*=1,2,3,4,5+ and each of them is performed 16 (2^{par-1}) times. For example, the element $f_{15,1}^1$ is replaced by $f_{15,1}^2$ with all possible combinations of rates $f_{15,k}^1$ and $f_{15,l}^2$ in the remaining 4 cells of the same row with $k \neq l$ and $k, l \in [2,3,4,5+]$. The average of all 16 effects then form the component produced by age 15 and parity 1. The external cycle of replacement runs across ages in ascending order, while the internal cycle runs across parities. The replacement of $f_{x,par}^1$ by elements $f_{x,par}^2$ begins only after all elements $f_{y,par}^1$ already are replaced by the elements $f_{y,par}^2$ for rows *y*<*x*. Each elementary fertility rate should be replaced in both directions ($f_{x,par}^1$ replaced by $f_{x,par}^2$ and $f_{x,par}^2$ replaced by $f_{x,par}^1$) to obtain symmetrical components.

3.3.2 Tempo adjustment-method

The method of Bongaarts and Feeney is a simple and widely used method since the adjustment procedure is intuitive and does not require more demanding data than period fertility rates by age and birth order. The method still have its limitations because it assumes that every age group postpone births by exactly the same amount in a given period (Bongaarts and Feeney 1998), which does not necessarily hold in real life. It further only control for age but not for the changing parity distribution of the female population (e.g. Kohler and Ortega 2002). Later on, tempo-adjusted period parity progression measured have been developed by Kohler and Ortega (2002) and tempo- and parity-adjusted TFR by Bongaarts and Sobotka (2012), but these measures are out of the scope of this thesis.

The tempo adjusted fertility rate $adjTFR(t)$ developed by Bongaarts and Feeney (1998) is the sum of order-specific adjusted fertility rates

$$adjTFR(t) = \sum_i adjTFR_i\,(t)$$

at year t. The order-specific adjusted fertility rates are computed by the formula

$$adjTFR_i(t) = \frac{TFR_i(t)}{1 - r_i(t)}$$

where $TFR_i(t)$ is the period total fertility rate by birth order i at year t and $r_i(t)$ is the adjustment factor for birth order i at year t. The adjustment factor is estimated by the formula

$$r_i(t) = \frac{MAC_i(t+1) - MAC_i(t-1)}{2}$$

where $MAC_i(t)$ is the mean age of childbearing by birth order i at year t. The birth orders considerer in this thesis are 1, 2, 3, 4 and 5+.

The last year's observation is lost in the Bongaarts-Feeney adjustment and in order to obtain that value, we would need to know the fertility rates from this ongoing year. To get some indication of the tempo effect from last year, a crude estimate is calculated to replace the lost observation. The crude estimate is calculated using the adjustment factor $r_i(t)' = MAC_i(t) - MAC_i(t-1)$ instead of the average change in the mean age from year $t-1$ to $t+1$ as in the Bongaarts-Feeney adjustment factor. This crude estimate is however fairly unreliable and there can be huge instability in this indicator. (Goldstein et al. 2009) Due to the great jumps in the adjustment factor $r_i(t)$, a smoothed version of the tempo adjusted fertility rate is also calculated using a three-year moving average of the adjustment factors by each birth order.

3.3.3 Cohort fertility forecasting

Cohort fertility for Finnish women will be forecasted using new methods, mainly a Bayesian forecasting method developed by Schmertmann et al. (2014). The aim with cohort forecasting is to answer the question; will cohorts who have postponed childbearing eventually have fewer children? Forecasting try to explain what is likely to happen in the future based on what has been seen so far. Girosi and King (2008) formulate that forecasting is "the (1) systematic distillation and summary of relevant information about the past and present that (2) by some specific assumption may have something to do with the future". Unobserved fertility rates for cohorts who still are in their childbearing ages, namely women already 15 but not yet 45, will be forecasted to estimate the completed cohort fertility rate for those cohorts.

Cohort fertility will be forecasted by three different methods; the Freeze Rate method, the 5-year extrapolation method and the Bayesian forecasting method. When observed fertility rates are to be extrapolated into the future, current demographic forecasting models use two main methods; the Freeze Rate approach and the Freeze Slope approach. The Freeze Rate method freezes the latest observed age-specific fertility rates into the future (e.g. Frejka and Sardon 2004) and the freeze slope method freezes the latest trends in age-specific fertility rates (measured as fitted slopes over some recent period) into the future. The most likely future fertility rate $\theta_{a,c+1}$ at age a is estimated as the last observed fertility rate $\theta_{a,c}$ at that age using the Freeze Rate method and as the last observed fertility rate $\theta_{a,c}$ plus a slope estimator $\hat{\Delta}_c$ based on rates at age a over the previous n cohorts using the Freeze Slope method. Both approaches are useful because age-specific rates do trend steadily upward or downward over periods of five or ten years (Schmertmann et al. 2014) but fertility trends cannot continue indefinitely due to biological constrains and the impossibility of negative rates.

Myrskylä et al. stated in their article in 2013 that the Freeze Rate method "can substantially underestimate completed cohort fertility when childbearing is shifting to older ages" and developed the 5-year extrapolation method that combines the Freeze Rate approach and the Freeze Slope approach. The 5-year extrapolation method estimates the past five years' fertility trends, extrapolates the estimated fertility trends five years into the future and then freezes the rates. The most likely future fertility rates $\theta_{a,c+i}$ at age a is estimated as $\theta_{a,c+i-1} + (\theta_{a,c} - \theta_{a,c-4})/4$ when $i=1,\dots,5$ and as $\theta_{a,c+i-1}$ when $i > 5$. The specifically 5-year trend was used in the article because alternative lengths failed to improve forecast accuracy. Myrskylä et al. argued that the 5-year extrapolation method is an improvement of existing methods due to its simplicity, its ability to estimate forecast uncertainty and due to greater forecast accuracy.

The Bayesian forecasting method (Schmertmann et al. 2014) is a more sophisticated method that automatically includes uncertainty estimates. The method combines already known demographic information about plausible age patterns of fertility together with recent age-specific fertility rates and it extrapolates fertility rates over both time and age into the future. An explicit choice between the Freeze Rate approach and the Freeze Slope approach do not need to be made in a Bayesian framework. The Bayesian forecasting method uses historical data to design the forecasting model and to calibrate uncertainty. The method is described in detail in the next section.

Bayesian forecasting of cohort fertility

This following forecasting method is developed by Schmertmann et al. (2014) and is largely based on the approach of Girosi and King (2008) for forecasting mortality. Fertility forecasting is more challenging because childbearing is unlike death both optional and repeatable and its timing depends strongly on conscious decisions. Mortality rates also change in one direction while fertility rates fluctuate. The notations in this section follow those of Schmertmann et al. (2014).

For contemporary data, let C represent the birth cohorts of interest ($c = 1 \dots C$) over A reproductive ages ($a = 1 \dots A$), $\mathbb{R}$ the set of real numbers, $\otimes$ the Kronecker product and let all vectors be defined as columns. Then,

$\theta_{ca} \in \mathbb{R}$ is the *true fertility rate* for cohort c between exact ages a and $a + 1$,
$\theta_c = (\theta_{c1} \dots \theta_{cA})' \in \mathbb{R}^A$ is the *fertility schedule* for cohort c,
$\theta_a = (\theta_{1a} \dots \theta_{Ca})' \in \mathbb{R}^C$ is the *time series* of rates at age a and
$\theta = (\theta_1' \dots \theta_C')' \in \mathbb{R}^{CA}$ is the vector of *all rates*, sorted by age within cohort.

Further,
$y \in \mathbb{R}^n$ is a vector of published data for some subset of θ and
$CFR_c = (1 \dots 1)\, \theta_c \in \mathbb{R}$ is the *completed fertility* of cohort c.

Finally, three matrices are defined;
$\mathbf{G}_c = [\mathbf{0} \dots \mathbf{I} \dots \mathbf{0}] \in \mathbb{R}^{A \times CA}$ such that $\theta_c = \mathbf{G}_c\theta$,
$\mathbf{H}_a = \mathbf{I}_C \otimes (0 \dots 1 \dots 0) \in \mathbb{R}^{C \times CA}$ such that $\theta_a = \mathbf{H}_a\theta$, and
$\mathbf{V} \in \mathbb{R}^{n \times CA}$, a matrix of ones and zeroes such that $\mathbf{V}\theta \in \mathbb{R}^n$ is the subset of parameters corresponding to y.

Vector *y* plays the role of observed data and vector θ the parameters in the $C \times A$ Lexis surface, including those extended into the future. Then, the Bayesian model for parameters θ is

$$\ln P(\theta|y) = \text{const} + \ln L(y|\theta) + \ln f(\theta),$$

where $P(\theta|y)$ is the posterior density, $L(y|\theta)$ is the likelihood function, $f(\theta)$ is the prior density and *const* is a term that does not vary with θ. The posterior density tells how likely alternative parameters θ are given the observations *y*, the likelihood function tells how likely the observations *y* are for alternative parameters θ and the prior density tells how likely alternative parameters θ before we see any observations y.

Since fertility rates usually come from very large risk populations, a normal approximation can be justified for the likelihood function. Thus, the normal approximation is

$$\ln L(y|\theta) = \text{const} - \frac{1}{2}(y - \mathbf{V}\theta)'\boldsymbol{\psi}^{-1}(y - \mathbf{V}\theta),$$

where $\boldsymbol{\psi} = \text{diag}_{i=1\dots n}[y_i(1 - y_i)/W_i]$ and W_i is the number of a-year-old woman in the (c, a) cell corresponding to the i-th rate. The sampling variances $y_i(1 - y_i)/W_i$ are near zero due to the typically large W_i values, which means that in the preforecasted period, estimates y are almost always close to the true fertility rates. The log prior density used in the model is

$$\ln f(\theta) = \text{const} - \frac{1}{2}\theta'\mathbf{K}\theta,$$

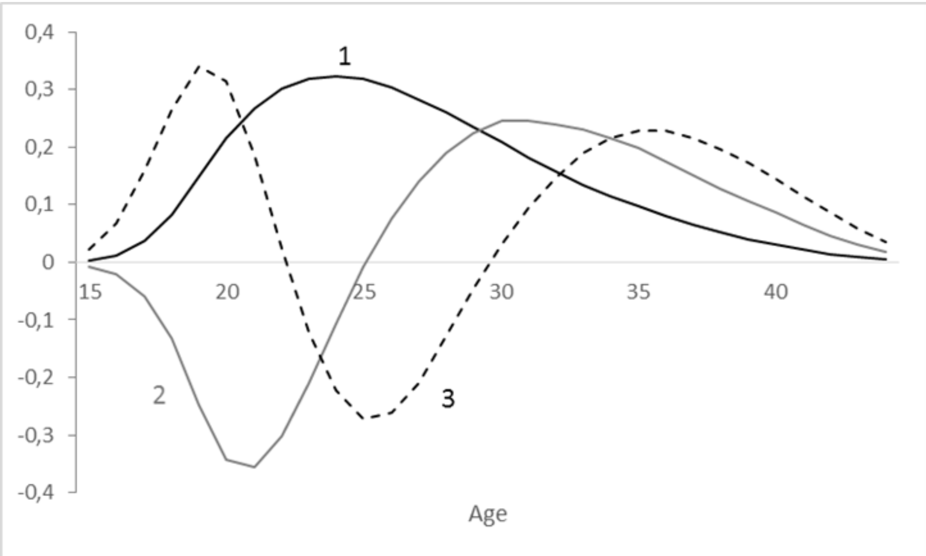
where $\mathbf{K}$ is a $CA \times CA$ matrix with its constants estimated from patterns in the historical dataset.

Penalties

The prior distribution for θ is constructed based of three basic categories of a prior information; cohort schedule shapes, time-series freeze rates and time-series freeze slopes. The cohort category of prior information tells what typical shapes of cohort schedules are based on historical data and the time-series categories of prior information tell how smooth a time series is likely to be at a given age based on historical data. These categories of a prior information is then combined to determine likely or unlikely Lexis surfaces. The general features of past rate surfaces is assumed to persist into the future. For each category of prior information, 30 squared-error penalties are calculated and standardized using empirical variance information from the cohorts born 1960 and earlier. Each penalty term $\boldsymbol{\theta}'\mathbf{R}_j'\mathbf{R}_j\theta$ is based on a residual vector $\mathbf{R}_j\theta$ that is usually near zero in historical surfaces. The prior then express that a surface θ is more likely a priori when all penalties are small and $\theta'\left(\mathbf{R}_1'\mathbf{R}_1 + \cdots + \mathbf{R}_j'\mathbf{R}_j\right)\theta = \theta'\mathbf{K}\theta$ is near zero. Historically unlikely θ surfaces that have age patterns in cohort fertility schedules $\theta_1 \dots \theta_C$ that differs from patterns in historical data and have patterns in time series of age-specific rates $\theta_{15} \dots \theta_{44}$ that differs from the corresponding series in historical data have high penalties and thus are assigned lower prior probabilities.

The cohort category of prior information is based on the assumption that each cohort schedule θ_c is well approximated by components of the singular value decomposition (SVD) of historical cohort schedules. The SVD decompose the 30×648 matrix $\boldsymbol{\phi}$ into three matrixes, $\boldsymbol{\phi} = \mathbf{UDV}'$, where $\mathbf{U}$ is a 30×30 matrix, $\mathbf{D}$ is a 30×648 diagonal matrix and $\mathbf{V}'$ is the transpose of a 648×648 matrix. The mutually orthogonal $\mathbf{U}$ columns corresponding to the three largest singular values in $\mathbf{D}$ form a 30×3 matrix denoted as $\mathbf{X}$. Figure 6 shows the first three components $\mathbf{X}$, where weights on component 1 affects the overall cohort fertility level, weights on component 2 affects the mean age of childbearing and weights on component 3 affects the variance of childbearing ages.

Figure 6: First three components X, from the SVD decomposition of the historical data set ϕ.



Source: Human fertility database, own decomposition

The cohort schedules θ_c can be decomposed into their projection onto the column space of $\mathbf{X}$ and an orthogonal remainder:

$$\theta_c = \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\theta_c + \varepsilon_c,$$

where the remainder vector is

$$\varepsilon_c = [\mathbf{I}_A - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}']\theta_c = \mathbf{M}\theta_c.$$

For all the complete cohort schedules in the historical dataset $\boldsymbol{\phi}$, residual vectors are constructed and their average outer products, or the empirical variance, are calculated:

$$\bar{\mathbf{\Omega}} = \frac{1}{S}\sum_s \varepsilon_s\, \varepsilon_s'.$$

Based on the so-called empirical variance calculated from the historical dataset $\boldsymbol{\phi}$, scalar cohort penalties are established for the badness of each cohort schedule's shape

$$\begin{aligned}\pi_c &= \varepsilon_c' \bar{\mathbf{\Omega}}^+ \varepsilon_c \\ &= \theta_c' [\mathbf{M}\bar{\mathbf{\Omega}}^+\mathbf{M}]\theta_c \\ &= \theta' [\mathbf{G}_c'\mathbf{M}\bar{\mathbf{\Omega}}^+\mathbf{M}\mathbf{G}_c]\theta \\ &= \theta' \mathbf{K}_c \theta.\end{aligned}$$

Since rank(**X**)=3 and thus rank(**M**)=*A*-3=27, the last several eigenvalues of omega may be extremely small negative numbers. The Moore-Penrose pseudoinverse 30×30 matrix $\bar{\mathbf{\Omega}}^+$ ensures zero eigenvalues instead of negative values and is calculated as

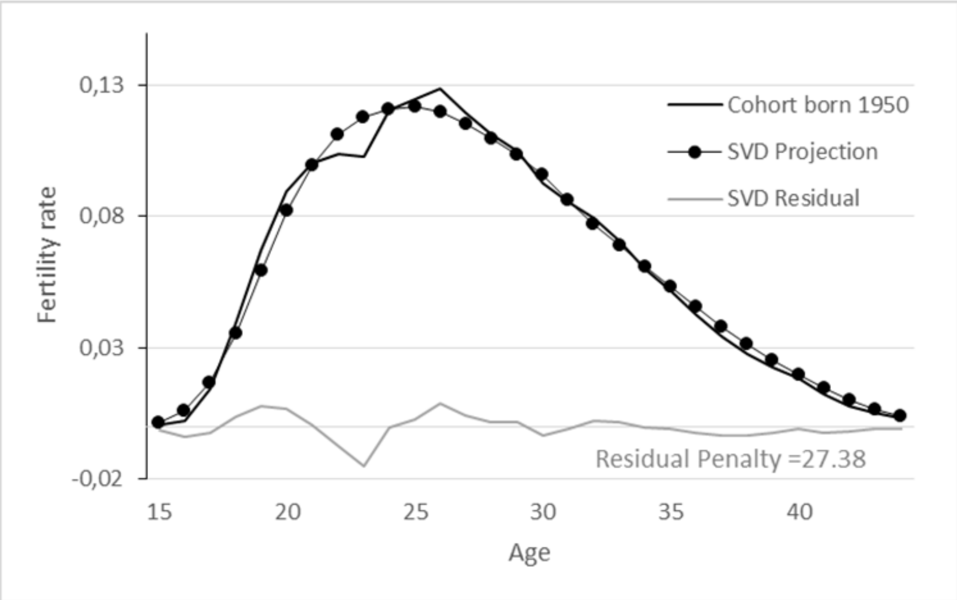
$$\bar{\mathbf{\Omega}}^+ = \mathbf{U}_r \mathbf{D}_r^{-1} \mathbf{U}_r',$$

where columns of the 30×27 matrix $\mathbf{U}_r$ are eigenvectors of $\bar{\mathbf{\Omega}}$ that corresponds to positive eigenvalues of $\bar{\mathbf{\Omega}}$ and $\mathbf{D}_r$ is a 27×27 diagonal matrix of positive eigenvalues of $\bar{\mathbf{\Omega}}$.

The cohort shape penalties π_c are used for cohorts with at least some unknown rates, namely for the 30 cohorts born in 1974 … 2003. The cohort shape penalties have an important feature of being improper, meaning that an infinite number of fertility schedules correspond to and given level of the penalty. For example, schedules that are an exact linear combination of **X** columns correspond to the minimum penalty $\pi_c = 0$, despite the specific weights on the columns. By applying this penalty, a surface θ is only assumed to be well approximated by the same components that best approximate historical schedules, no prior knowledge is assumed about the specific shapes or levels of cohort fertility schedules. This approach has an important benefit because a rate surface could have cohort schedules with levels and shapes not seen in the historical data without having heavy penalties. Since no prior knowledge on the component weights are assumed, a three-component approach of the SVD decomposition of $\boldsymbol{\phi}$ is still flexible enough to allow shapes and levels that are not well represented in the historical dataset.

Figure 7 illustrates the fertility schedule of the Finnish cohort born in 1950, the projection of that schedule onto the column space of SVD components **X**, the residuals ε that cannot be explained via the **X** components and the residual penalty. The projection approximates the fertility schedule fairly well, especially at ages older than 27. The residual penalty $\pi_c = 27.38$ is slightly higher than the empirical average of 27 and the projection differ most from the fertility schedule at ages 18-26.

Figure 7: Observed and SVD approximated cohort fertility schedule for Finnish women born in 1950 together with the approximation residuals and the residual penalty.



Source: Human fertility database 2018, own approximation

The time series category of prior information is based on the assumption that each time series of rates at age a θ_a is locally linear. Time series residuals are calculated for both freeze rates and freeze slopes and the larger the residuals are, the less plausible is the rate surface θ a priori. Time series penalties are constructed based on standardized residuals similarly as with the cohort penalties. The freeze rate forecast assumes that the next cohort's rate at age a is well predicted by the current rate and the freeze slope forecast assumes that the next cohort's rate at age a is well predicted by the recent trend. A vector of 30 freeze rate residuals is defined at each age on the Lexis surface for cohorts born in 1974-2003:

$$u_a = \begin{bmatrix} \theta_{a,1974} - \theta_{a,1973} \\ \vdots \\ \theta_{a,2003} - \theta_{a,2002} \end{bmatrix} = \begin{bmatrix} 0 & \cdots & -1 & 1 & 0 & \cdots & 0 \\ 0 & \cdots & 0 & -1 & 1 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \ddots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & -1 & 1 \end{bmatrix} \theta_a = \mathbf{W}_R \theta_a = \mathbf{W}_R \mathbf{H}_a \theta$$

and similarly a vector of 30 freeze slope residuals:

$$v_a = \begin{bmatrix} \theta_{a,1974} - (\theta_{a,1973} + \widehat{\Delta}_{1973}) \\ \vdots \\ \theta_{a,2003} - (\theta_{a,2002} + \widehat{\Delta}_{2002}) \end{bmatrix} = \mathbf{W}_S \theta_a = \mathbf{W}_S \mathbf{H}_a \theta.$$

The freeze-slope regression model is $\theta_c - \theta_{c-h} = h\Delta$ for $h = 0, \dots, 4$ and the OLS slope estimator for any regression model without an intercept is $\sum xy / \sum x^2$. In this case the slope estimator is $\sum_h [h(\theta_c - \theta_{c-h})] / \sum_h [h^2]$, or

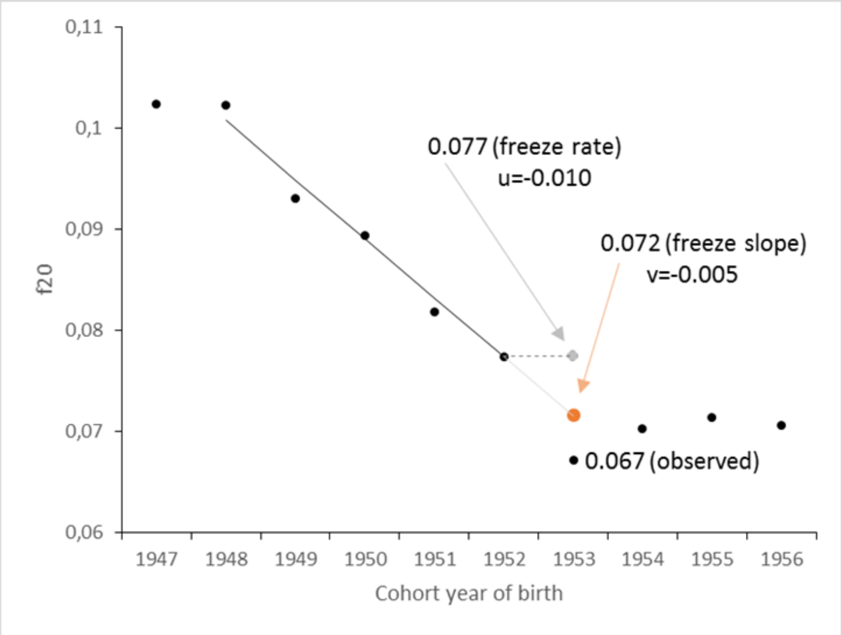
$$\widehat{\Delta}_c = \frac{1}{30}(10\theta_{a,c} - \theta_{a,c-1} - 2\theta_{a,c-2} - 3\theta_{a,c-3} - 4\theta_{a,c-4}).$$

The freeze slope residual for cohort $c + 1$ is then

$$v_{c+1} = \theta_{c+1} - \left(\theta_c + \widehat{\Delta}_c\right)$$
$$= \theta_{c+1} - \frac{1}{30}(40\theta_c - \theta_{c-1} - 2\theta_{c-2} - 3\theta_{c-3} - 4\theta_{c-4}).$$

Figure 8 shows the time series of fertility rates at age 20 for Finnish women born in 1947-1956, together with freeze rate residuals and freeze slope residuals. For women born in 1953, the freeze rate forecast equals the observed fertility rate for women born 1952 and the freeze slope forecast is based on the trend over cohorts born in 1948-1952. The freeze slope residual is smaller than the freeze rate residual in this case, with indicate that the freeze slope forecast for the cohort born in 1953 preforms better than the corresponding freeze rate forecast. The freeze rate forecast then again would perform better for the cohort born in 1954.

Figure 8: Time series of fertility rates at age 20 for Finnish women born in 1947-1956, together with freeze rate residuals (u) and freeze slope residuals (v).



Source: Human fertility database

Freeze rate and freeze slope residuals are estimated at each age in the historical dataset and the average squared residuals for each age and for both methods are used as estimates of residual variance, denoted as empirical variances s_{Ra}^2 and s_{Sa}^2. At age a for cohorts born in 1974-2003, the freeze rate penalty is then

$$
\begin{aligned}
\pi_{Ra} &= s_{Ra}^{-2} u_a' u_a \\
&= \theta' [s_{Ra}^{-2} \mathbf{H}_a' \mathbf{W}_R' \mathbf{W}_R \mathbf{H}_a] \theta \\
&= \theta' \mathbf{K}_{Ra} \theta
\end{aligned}
$$

and the freeze slope penalty is

$$
\begin{aligned}
\pi_{Sa} &= s_{Sa}^{-2} v_a' v_a \\
&= \theta' [s_{Sa}^{-2} \mathbf{H}_a' \mathbf{W}_S' \mathbf{W}_S \mathbf{H}_a] \theta \\
&= \theta'^{\mathbf{K}_{Sa}} \theta.
\end{aligned}
$$

Finally, the prior distribution combines in its log-likelihood additively all of the 90 penalty terms:

$$
\ln f(\theta, w) = \text{const} - \frac{1}{2} \sum_j w_j \pi_j
$$

$$= \text{const} - \frac{1}{2}\theta'\left(\sum_j w_j \boldsymbol{K}_j\right)\theta$$

$$= \text{const} - \frac{1}{2}\theta'\mathbf{K}\theta$$

where w_j is a set of weights that adjust the contribution of each penalty term $j = 1 \dots 90$. Nonunit weights are needed because the penalty terms are based on residuals that are not mutually independent. The weights are then iteratively adjusted (see Appendix 2) so that the expected value of the *j*th penalty given $\{w_i\}$ matches the empirical average for the penalty in historical data, such that $E^*(\pi_j|w) = \text{target}_j$ for $j = 1 \dots 90$. The empirical average for the penalties in historical data, target_j, equals by construction 27 for shape penalties and 30 for time series penalties. Appendix of Schmertmann et al. 2014 shows in detail that $E^*(\pi_j|w) = \text{trace}(\mathbf{K}_j\mathbf{K}^+)$ where E^* is a special expectation operator and $\mathbf{K}^+$ is the generalized Moore-Penrose inverse of the weighted sum **K**.

The log posterior distribution over the Lexis surface is then

$$\ln P(\theta|y) = \text{const} + \ln L(y|\theta) + \ln f(\theta)$$

$$= \text{const} - \frac{1}{2}(y - \mathbf{V}\theta)'\boldsymbol{\psi}^{-1}(y - \mathbf{V}\theta) - \frac{1}{2}\theta'\mathbf{K}\theta$$

$$= \text{const} - \frac{1}{2}(y'\boldsymbol{\psi}^{-1}y - 2(\mathbf{V}\theta)'\boldsymbol{\psi}^{-1}y + (\mathbf{V}\theta)'\boldsymbol{\psi}^{-1}(\mathbf{V}\theta) + \theta'\mathbf{K}\theta)$$

$$= \text{const} - \frac{1}{2}y'\boldsymbol{\psi}^{-1}y - \frac{1}{2}(-2\theta'\mathbf{V}'\boldsymbol{\psi}^{-1}y + \theta'\mathbf{V}'\boldsymbol{\psi}^{-1}\,\mathbf{V}\theta + \theta'\mathbf{K}\theta)$$

$$= \text{const} - \frac{1}{2}(\theta'(\mathbf{V}'\boldsymbol{\psi}^{-1}\,\mathbf{V} + \mathbf{K})\theta - 2\theta'\mathbf{V}'\boldsymbol{\psi}^{-1}y)$$

Thus, the model used for forecasting is

$$\theta|y \sim N(\mu_{post}, \Sigma_{post})$$

with $CA \times 1$ mean vector

$$\mu_{post} = [\mathbf{V}'\boldsymbol{\psi}^{-1}\,\mathbf{V} + \mathbf{K}]^{-1}[\mathbf{V}'\boldsymbol{\psi}^{-1}y]$$

which also is the maximum a posteriori (MAP) estimator of true rates θ and with $CA \times CA$ covariance matrix

$$\Sigma_{post} = [\mathbf{V}'\boldsymbol{\psi}^{-1}\,\mathbf{V} + \mathbf{K}]^{-1}$$

that quantifies posterior uncertainty. Since $CFR_c = (1 \ldots 1)\theta_c = \mathbf{1}'\mathbf{G}_c\theta$, the posterior distribution also provides a probabilistic forecast for the completed cohort fertility.

4 RESEARCH RESULTS

4.1 PERIOD FERTILITY TRENDS

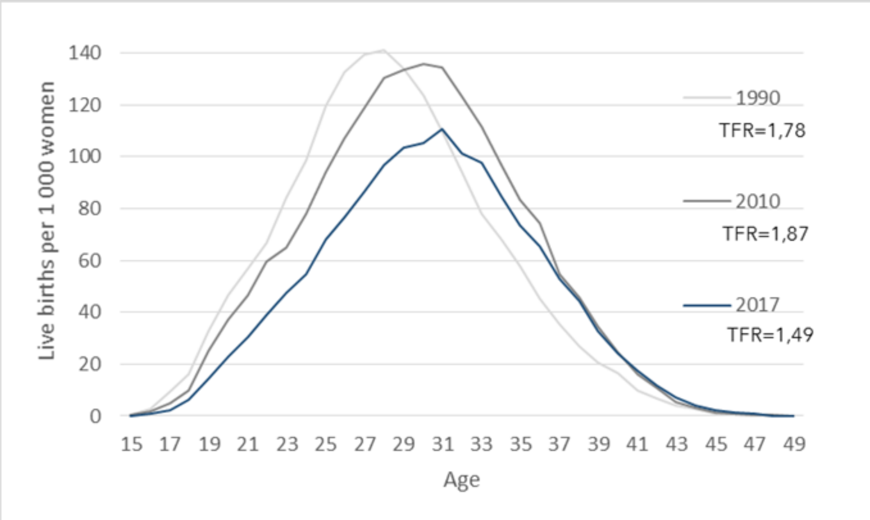
Recent period fertility trends and the drop in the total fertility rate in Finland are described in this section. The aim was to describe fertility trends by age, parity, regions and levels of education and the changes therein and to detect the greatest contributions to the recent years' decrease in the period total fertility rate. Fertility trends are examined by age-specific fertility rates by parity, regions and levels of education and the decrease in the total fertility rate is examined by demographic decomposition. The time period of interest is 2010-2017 when the period total fertility rate has been rapidly decreasing, but parts of the analyses start in 1990 for a longer perspective on fertility as a phenomena.

4.1.1 Age and parity

The majority of all live births in Finland are born by women aged 25-34. In 2017, almost two-thirds of all live births were born by women aged 25-34, nearly one third by women aged 20-24 or 35-39 and only a small fraction (below 6 percent) were born by women younger than 20 or older than 40 (Appendix 3). Figure 9 shows the age-specific fertility rates for ages 15-49 together with the period total fertility rate observed in 1990, in 2010 and in 2017. The fertility rates in 2017 were highest at ages 29-32 on a level of above 100 live births per 1 000 women and more than half of all live births were born by women older than 30. In 2010, the fertility rates peaked at ages 28-31 on a level of above 130 live births per 1000 women. The all-time low total fertility rate of 1.49 children per woman in 2017 is a 20 percent decrease since 2010, and the age-specific fertility rates have decreased at almost every ages but mainly around age 30 and younger.

From 1990 to 2010, there has been a clear shift in the age-specific fertility rates into older ages even though the period total fertility rates observed in these years are similar. Figure 10 shows the changes in the 5-years age group-specific fertility rates in 1990-2017. During the whole time period the fertility rates have been highest for age group 25-34, considerably lower for age group 20-24 and 35-39 and at the lowest for age groups 15-19 and 40-49. In 1990-2005 the fertility rates were higher for age group 25-29 compared to age group 30-34, but since 2006 the fertility rates for age group 30-34 have been higher than age group 25-29. The fertility rates for age group 20-24 were higher in 1990-2009 compared to the fertility rates for age group 35-39, but since 2010 the fertility rates for age group 35-39 have been higher. The same phenomena can be noticed for age groups 15-19 and 40-44, but the difference there is much smaller.

Figure 9: Age-specific fertility rates and the period total fertility rate in Finland in 1990, 2010 and 2017

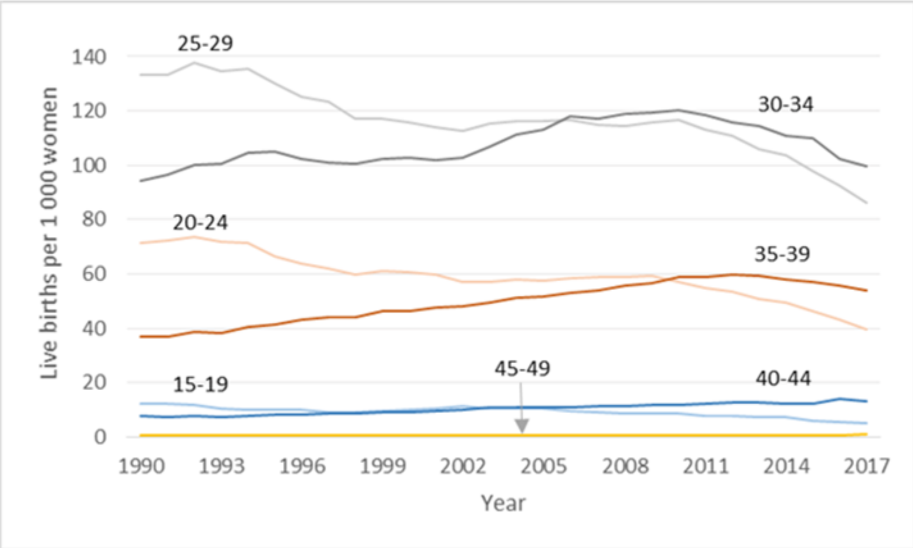


Source: Statistics Finland 2018, own estimates

The fertility rates for the three youngest age groups have overall been decreasing since the beginning of the 1990s, but since 2010, the decrease has been much more rapid. From 2010 to 2017 the fertility rate decreased from 8 to 5 live births per 1000 women for age group 15-19, from 57 to 39 live births per 1000 women for age group 20-24 and from 117 to 86 live births per 1000 women for age group 25-29. The fertility rates for age groups 30-34 and 35-39 have instead been increasing since 1990, but around 2010 these fertility rates also started to decrease. From 2010 to 2017 the fertility rate decreased from 120 to 100 live births per 1000 women for age group 30-34, and from 2012 to 2017 the fertility rate decreased from 60 to 54 live births per 1000 women for age group 35-39.

Age groups 40-44 and 45-49 are the only age groups where the fertility rates have remained on the same level or even increased in the whole time period since 1990. For age group 45-49, the fertility rates have been very low and fluctuated between 0.4 and 0.8 live births per 1000 women. Since 1990, there have been a small but smooth increase in the fertility rates for age group 40-44, from 8 to 13 live births per 1000 women in 2017. Since 2010, the period fertility rates have thus been decreasing for all age groups except the oldest age groups, 40-44 and 45-49. The fertility rates for women under 30 have experienced a much faster decrease than the fertility rates for women over 30.

Figure 10: Age group-specific fertility rates in Finland in 1990-2017.

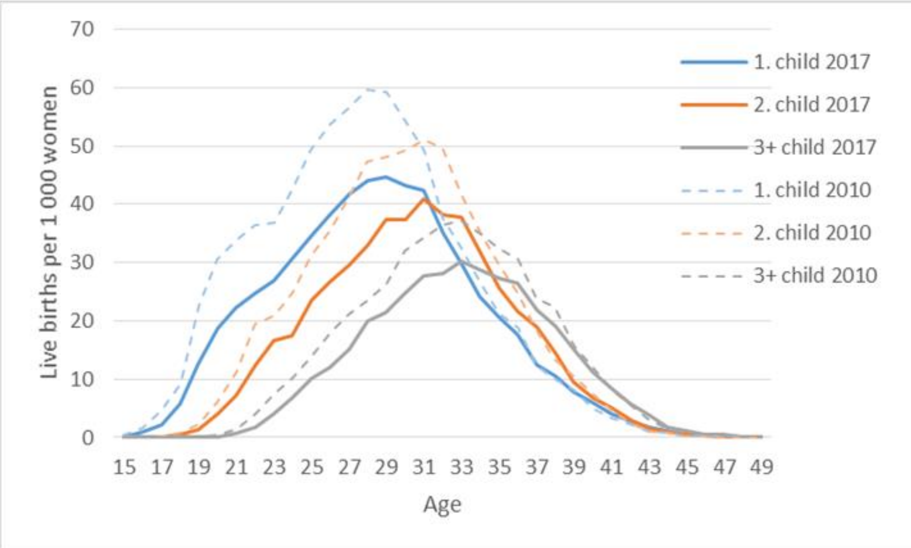


Source: Statistics Finland 2018, own estimates

The majority of all live births in Finland are not only born by women aged around 30, they are also births of first or second birth orders. Out of all live births born in 2017, 41% were first order live births, 34% were second order live births and only every fourth birth were of third or higher birth order (Appendix 3). For women aged 45-49 in 2017, the childlessness rate was 19.9 percent and less than three out of ten women had a total number of three or more children (Appendix 4a).

Figure 11 shows the age-specific fertility rates by birth order in 2010 and 2017. The fertility rates by first order live births were highest at ages 24-33, with the peak at age 29 on a level of 45 live births per 1 000 women in 2017. The fertility rates by second order live births were highest at age 27-34, with the peak at age 31 on a level of 41 live births per 1 000 women. By third or higher birth order, the fertility rates were highest at age 28-38 and peaked at age 33 on a level of 30 live births per 1 000 women. Since 2010, the fertility rates have decreased by every birth order mainly at younger ages, but the decreases in first order births seems to have been most important. Only for ages 25-29 did the fertility rates by first order births decrease with 75 live births per 1000 women, which is nearly as much as the fertility rates by third or higher birth order have decreased all in all. From 2010 to 2017, the total fertility rate did decrease from 0.78 to 0.61 live births per woman by first order live births, from 0.63 to 0.50 live births per woman by second order live births and from 0.46 to 0.38 live births per woman by third or higher order live births. The childlessness rate for women aged 45-49 increased with 1.6 percentage points and the rate of women with three or more children decreased with 1.7 percentage points (Appendix 4b).

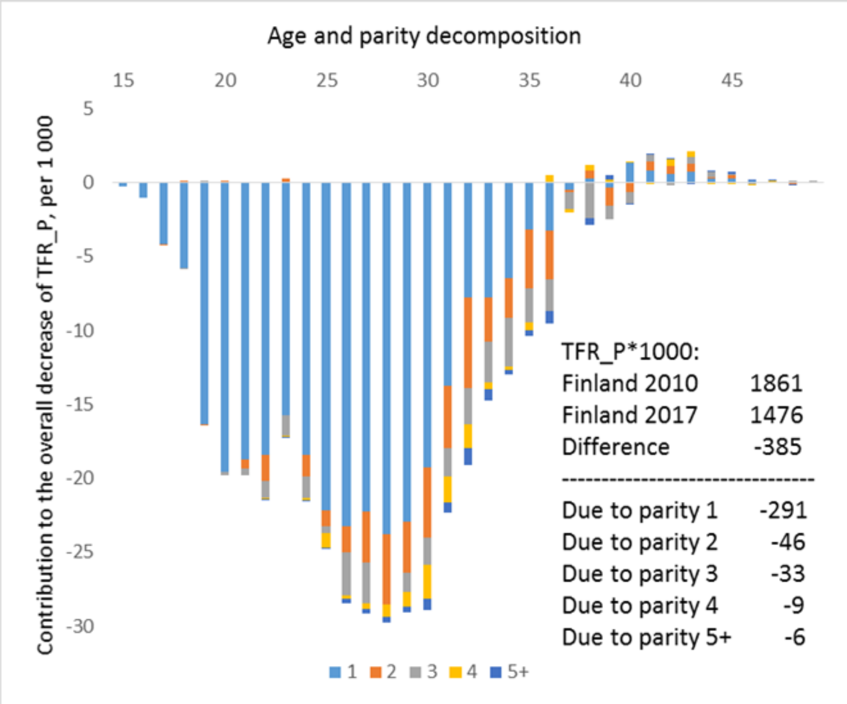
Figure 11: Age-specific fertility rates by birth order in Finland in 2010 and 2017



Source: Statistics Finland 2018

Figure 12 shows the decomposition of the decrease in the total fertility rate in 2010-2017 by age and parity. The period total fertility rate computed from age- and parity-specific fertility rates TFR_p fell from 1.86 live births per woman in 2010 to 1.48 live births per woman in 2017. The decrease in the TFR_p was essentially due to the decrease in first births by mothers at ages from 25 to 29. The decrease in first births has still been important at almost every ages; on average 18 live births per 1 000 women for age group 19-24, 23 live births per 1 000 women for age group 25-30 and 11 live births per 1 000 women for age group 30-34. The relatively small decreases in higher birth orders are observed mainly by mothers at ages from 26 to 36; on average 3.8 live births per 1 000 women for parity 2 and 2.2 live births per 1 000 women for parity 3. The smallest contributions are produced by decreases in fourth and higher births. Mothers at ages over 40 on then again contributed to a small increase in the total fertility rate.

Figure 12: Decomposition of the decrease in the total fertility rate in Finland in 2010-2017 by age and parity



Source: Statistics Finland, own decomposition

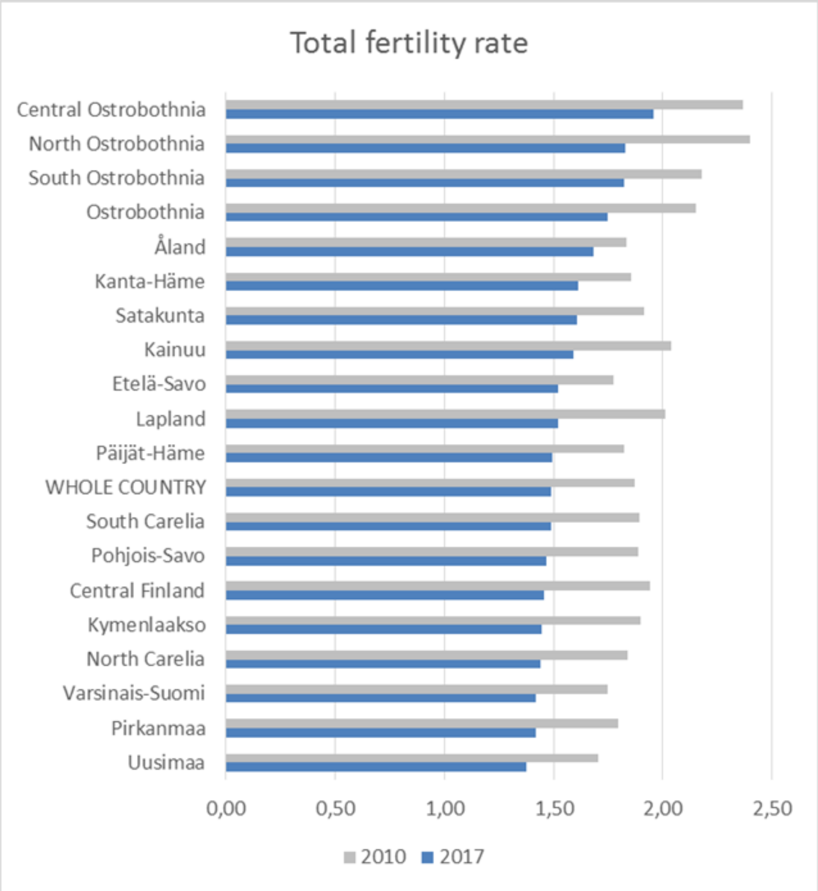
4.1.2 Region

In this section, period fertility trends are examined among regions and different kind of municipalities such as urban, semi-urban and rural municipalities. Figure 13 shows the total fertility rate by region in 2010 and 2017. In both 2010 and 2017, the total fertility rates were highest in the regions of Ostrobothnia and lowest in Uusimaa. In 2017, on average 1.96 children per woman were born in Central Ostrobothnia and 1.38 children per woman in Uusimaa. The total fertility rate was under the rate for the whole country in 8 regions and over the rate in 11 regions. None of the regions had a fertility rate above the replacement level in 2017. Central Ostrobothnia was the only region with a fertility rate above 2.1 in 2016.

In 2010, the total fertility rate was above 1.7 children per woman in every region and each of the regions of Ostrobothnia had a fertility rate above the replacement level. From 2010 to 2017, the total fertility rate has declined the most in absolute terms in North Ostrobothnia, in Lapland and in Central Finland with a change of 0.57, 0.49 and 0.49 live births per woman respectively. The decline was smallest in Åland, Kanta-Häme and Etelä-Savo, with a change of 0.15, 0.24 and 0.25 live births respectively.

Uusimaa, Varsinais-Suomi and South Carelia are the only regions where the total fertility rate has declined every year since 2010. The rest of the regions have some rises between certain years. Uusimaa is also the one with the most stable decline every year, on average 2.4% in 2010-2014 and 4.4% in 2015-2017. Varsinais-Suomi did have its greatest decline (7.1%) in 2015-2016 and South Carelia (9.5%) in 2015-2016. Overall, the decline in the total fertility rates have been faster in the period 2014-2017 compared to the period 2010-2013 for most regions.

Figure 13: Total fertility rate by regions in Finland 2010 and 2017

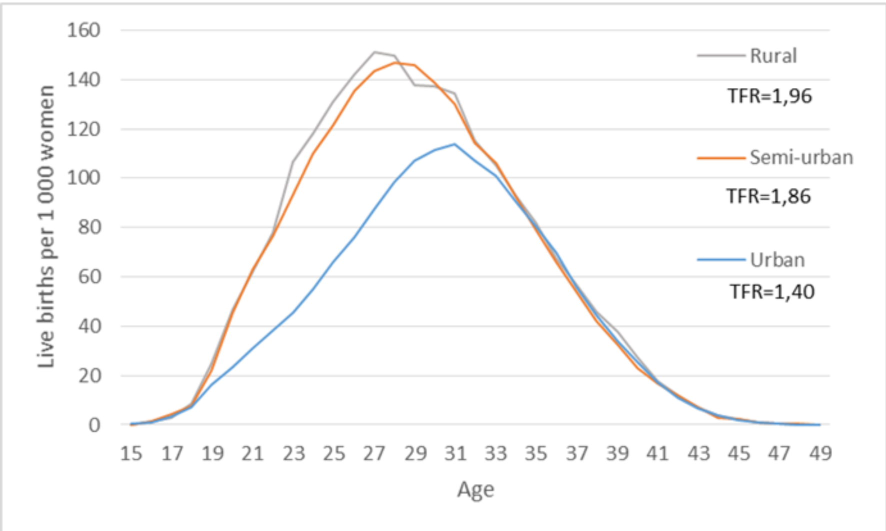


Source: Statistics Finland 2018

For further analyses, fertility trends were also examined in more detail among different types of municipalities. The majority of all live births in Finland are born in urban municipalities. In 2017, three out of four live births were born in urban municipalities and only one out of four in semi-urban or rural municipalities (Appendix 3). Women in urban municipalities have in general lower fertility rates than women in semi-urban and rural municipalities, especially at younger ages. Figure 14 shows the average age-specific fertility rates from 2013-2017 and the latest observed total fertility rate in urban, semi-urban and rural municipalities. In 2017, the total fertility rate was 1.96 in rural municipalities, 1.86 in semi-urban municipalities and 1.40 in urban municipalities. The age-specific fertility rates at ages 20-30 have clearly been lower for women in urban municipalities compared to the other who groupings of municipalities. In rural and in semi-urban municipalities, the highest age-specific fertility rates occurred at ages 26-29 on a level of above 140 live births per 1000 women and the fertility rates in urban municipalities then again peaked at ages 29-32 on a level of about 110 live births per 1000 women. Since semi-urban and rural municipalities turned out to have similar levels and trends of fertility, the results for these two groupings of municipalities are from now on merged together.

Women in rural or semi-urban municipalities do to a greater extent also have larger families compared to women in urban municipalities. In rural or semi-urban municipalities 35.0 percent of all women aged 45-49 in 2017 had a large family (as in three or more children) and only 25.6 percent in urban municipalities. The childlessness rate for these women was 16.6 percent in rural or semi-urban municipalities and 21.2 percent in urban municipalities. In 2017, every third birth was of third or higher birth order in semi-urban or rural municipalities and about every fifth birth was of third or higher order in urban municipalities. (Appendix 4a)

Figure 14: Age-specific fertility rates (averages from years 2013-2017) and the total fertility rate in 2017 by statistical grouping of municipalities



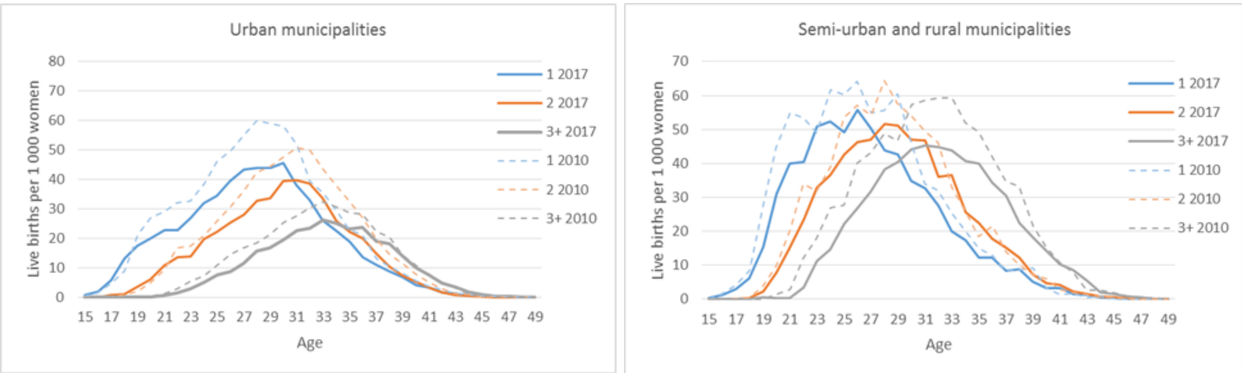
Source: Statistics Finland 2018, own estimates

Figure 15 shows the age-specific fertility rates by birth order and statistical grouping of municipalities in 2010 and 2017. The fertility rates by first order births did peak at age 23-27 on a level of about 50 live births per 1 000 women in rural or semi-urban municipalities and at age 27-30 on a level of above

40 live birth per 1 000 women in urban municipalities and in 2017. The total fertility rate by first order live births were still similar for both groupings of municipalities; 0.60 in urban municipalities and 0.67 in semi-urban or rural municipalities. The fertility rates by second order live births were highest at age 28 on a level of 52 live births per 1 000 women in semi-urban or rural municipalities and at age 31 on a level of 40 live births per 1 000 women in urban municipalities and the total fertility rate by second birth order was lower in urban municipalities. The greatest differences among the two groupings of municipalities are found in third or higher birth orders. In semi-urban or rural municipalities the total fertility rate by third or higher birth order was 0.60 and the highest level was observed at age 31 on a level of 45 third or higher order births per 1000 women. The total fertility rate by third or higher birth order was only 0.32 in urban municipalities and the highest level was observed at age 33 on a level of 26 third or higher order live births per 1000 women in 2017.

Since 2010, the total fertility rate did drop with about 0.37 live births per woman in both groupings of municipalities, which is a 16 percent decrease in semi-urban or rural municipalities and 21 percent decrease in urban municipalities. There has been a decrease in the fertility rates of every birth order, but the decrease in the fertility rates of first order live births seem to be most important for both groupings of municipalities. The decrease in third or higher birth orders seems to have been somewhat greater in semi-urban or rural municipalities compared to urban municipalities. The childlessness rate increased more and the rate of women with three or more children decreased more in semi-urban or rural municipalities compared to urban municipalities.

Figure 15: Age-specific fertility rates by birth order and statistical grouping of municipalities in Finland in 2010 and 2017



Source: Statistics Finland 2018, own estimates

Figure 16 shows the changes in the 5-year age group-specific fertility rates by statistical grouping of municipalities in 1990-2017. For age group 15-19, the decline in the fertility rates since 1990 have been nearly identical in both urban and rural areas, especially after 2008. The trends in the fertility rates for age groups 35-39 and 40-44 are also similar for urban municipalities and semi-urban or rural municipalities. The fertility rates for age group 30-34 differ slightly for the groupings of municipalities; these fertility rates have been on average 10 live births per 1 000 women lower since 1998 in urban municipalities compared to semi-urban or rural municipalities.

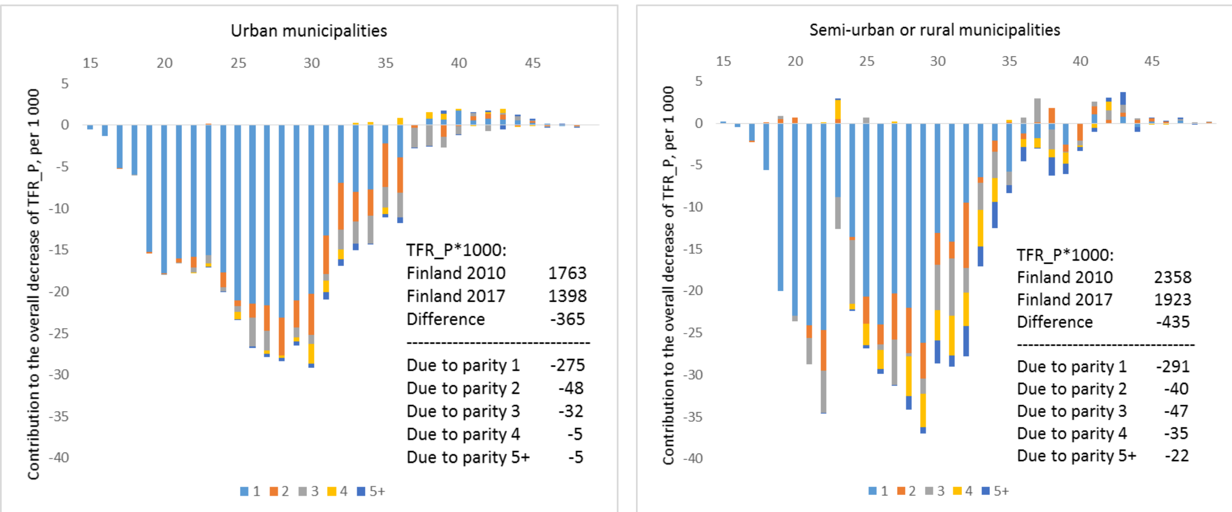
Figure 16: 5-year age specific fertility rates by statistical grouping of municipalities in 1990-2017

Source: Statistics Finland 2018, own estimates

The differences in the fertility rates among the groupings of municipalities have been greatest for age groups 20-24 and 25-29. These fertility rates have been significantly lower for urban municipalities compared to rural or semi-urban municipalities in 1990-2017. The fertility rates for urban municipalities have also experienced a much faster decline since 1990. The fertility rate for age group 20-24 was 66 live births per 1000 women in 1990, 49 live births per 1000 women in 2010 and 33 live births per 1000 women in 2017. In semi-urban or rural municipalities, the fertility rates for age group 20-24 have then again been more stable on level of 80-90 live births per 1000 woman until 2010, and then only then decreased to almost 70 live births per 1000 women. The fertility rate for age group 25-29 was 126 live births per 1000 women in 1990, 106 live births per 1000 women in 1990 and 77 live births per 1000 women in 1990 in urban municipalities. In semi-urban or rural municipalities, the fertility rate for age group 25-29 has been more stable on a level of 140-160 live births per 1000 women and decreased to 130 live births per 1000 women in 2017.

Figure 17 shows the decomposition of the decrease in the total fertility rate in urban and semi-urban or rural municipalities in 2010-2017 by age and parity. The period total fertility rate computed from age- and parity-specific fertility rates TFR_p fell from 1.76 to 1.40 in urban municipalities and from 2.36 to 1.92 in semi-urban or rural municipalities. In both urban and semi-urban or rural municipalities, the greatest contributions are produced by decreases in first births mainly by mothers aged 30 and younger. In semi-urban or rural municipalities the contributions produced by the decrease in third or higher births is much more important than in urban municipalities. The decrease in third or higher order births by mothers at ages from 30 to 34 produced a decrease in the TFR_p of 54 live births per 1 000 women in semi-urban or rural municipalities and 18 live births per 1 000 women in urban municipalities.

Figure 17: Decomposition of the decrease in the total fertility rate in urban and semi-urban or municipalities in 2010-2017 by age and parity



Source: Statistics Finland 2018, own decompositions

4.1.3 Education

In this section, period fertility trends are examined among mother's highest level of education at the time of childbirth. In Finland, about half of the female population aged 30-44 have at least a medium level of education (Statistics Finland 2018). Out of all live births born in 2016, 40.2 percent were born by women with low level of education, 26.7 percent by women with medium level of education, 17.8 percent by women with high level of education and 15.3 percent by women with unknown level of education (Appendix 3). Figure 18 shows the age-specific fertility rates by levels of education in 2016. The fertility rates were highest at ages 28-29 for low level of education, at ages 30-31 for medium level of education, at ages 31-32 for high level of education and at ages 27-28 for unknown level of education. Women with low or unknown level of education have in general higher fertility rates at younger ages and lower fertility rates at older ages compared to women with medium or high level of education. In 2016, the fertility rates at age 25 were 76, 53, 32 and 97 live births per 1000 women respectively for low, medium, high and unknown level of education. The highest educated women then again gave birth almost twice as much at age 35 compared to women with low level of education.

Figure 18: Age-specific fertility rates by level of education in Finland in 2016

Source: Statistics Finland, own estimates. Note: Due to the small numbers of females younger than 19 with low level of education, younger than 22 with medium level of education or younger than 25 with high level of education, fertility rates at those ages are ignored

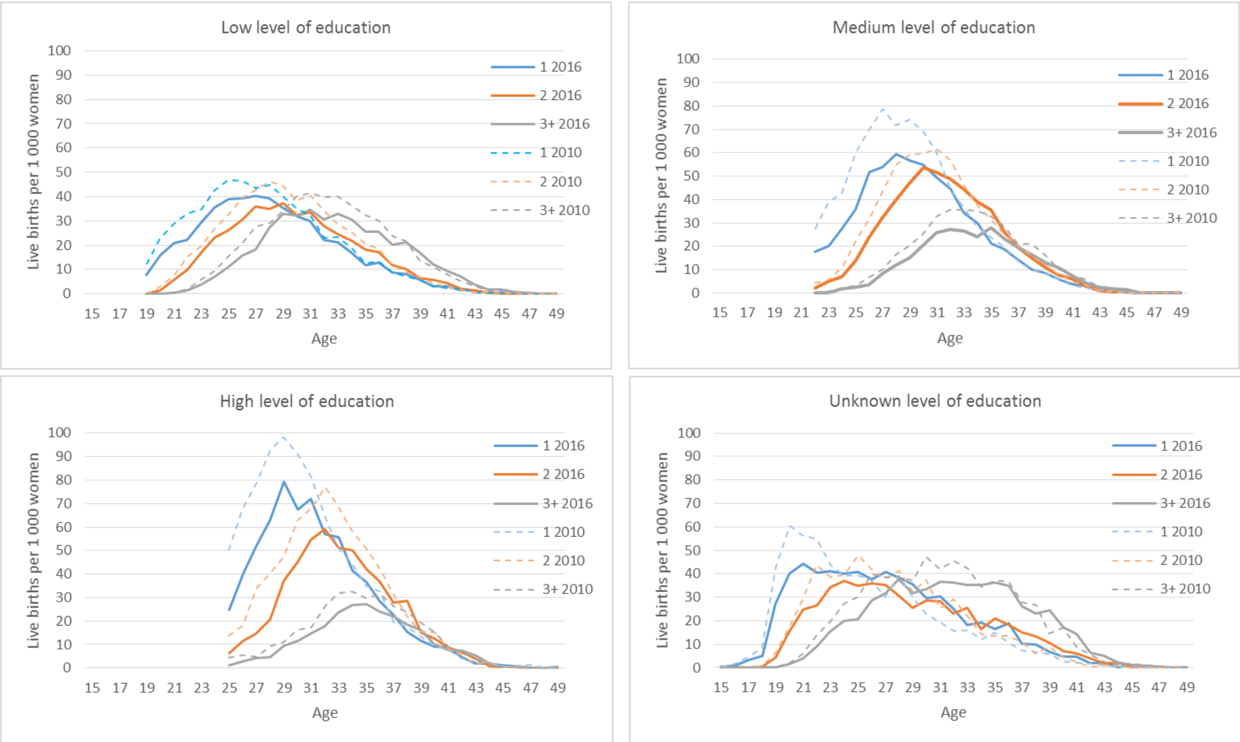
Women with low or unknown level of education do also have larger families to a higher extent than women with medium or high level of education. Three out of ten births in 2016 was of third or higher birth order for women with low or unknown level of education and only one out of five births for women with medium or high level of education. The childlessness rate for women aged 45-49 in 2016 was similar for women with low, medium and high level of education; 18.7 percent, 18.5 percent and 19.7 percent respectively but clearly higher for women with unknown level of education; 28.1 percent. (Appendix 4a)

Figure 19 shows the age-specific fertility rates by birth order and level of education in 2010 and in 2016. By first order live births, the fertility rates were higher for medium and high level of education compared to unknown and low level of education. The fertility rates by first order live births did peak at a level of 40 live births per 1 000 women at age 20-27 for unknown level of education and at age 25-28 for low level of education. The peak was at age 28 on a level of 60 live births per 1 000 women for medium level of education and at age 29 on a level of 80 live births per 1 000 women for high level of education. The peak was narrower for medium and high level of education and the fertility curves for low and unknown level of education were overall wider and smoother than for higher levels of education.

For fertility rates by second order births, the peak was also higher and narrower and observed later for medium and high level of education compared to low and unknown level of education. The total fertility rate by second order live births was still similar for each level of education, only slightly lower for low level of education. The fertility rates of third or higher birth orders were clearly lower for medium and high level of education compared to low and unknown level of education at almost every age. The total fertility rate by third or higher birth orders were 0.30 and 0.26 for medium and high level of education and 0.43 and 0.57 for low and unknown level of education.

Since 2010, the fertility rates have decreased for every level of education, but mainly for women with medium or high level of education. There seems to have been a decrease in the fertility rates of every births order mainly at younger ages for every levels of education, but for unknown level of education, there seem to have been some increases as well. The decrease in the fertility rates by first order live births seems to have been most important, especially for medium and high level of education.

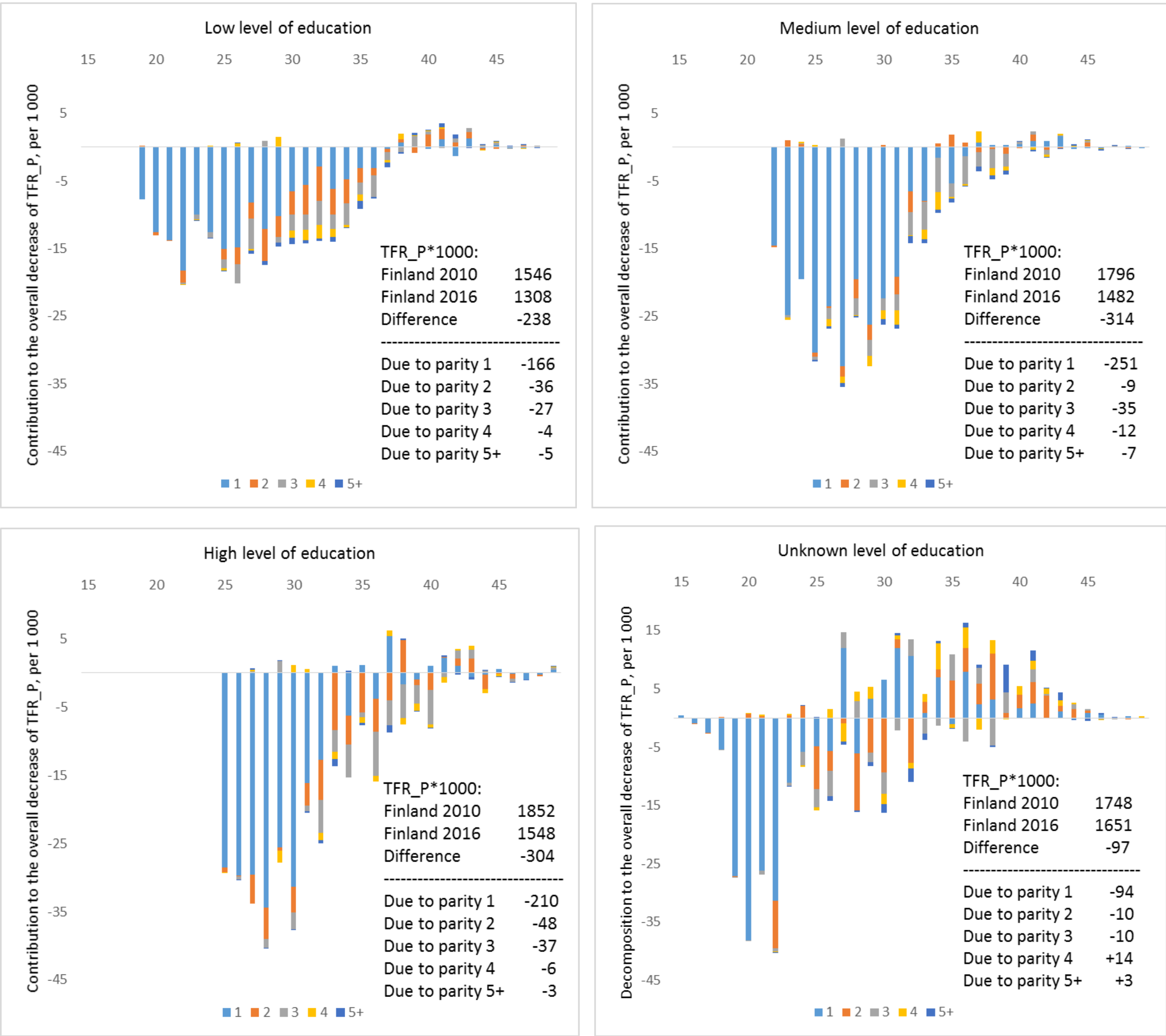
Figure 19: Age-specific fertility rates by birth order and level of education in Finland in 2010 and 2016



Source: Statistics Finland, own estimates.

Figure 20 shows the decomposition of the decrease in the total fertility rate by level of education in 2010-2016 by age and parity. The period total fertility rate computed from age- and parity-specific fertility rates TFR_p fell from 1.55 to 1.31 live births per woman for low level of education, from 1.80 to 1.48 live births per woman for medium level of education, from 1.85 to 1.55 live births for high level of education and from 1.75 to 1.65 live births for unknown level of education. The contributions produced by decreases in first births by mothers aged about 30 and younger have been most important for medium and high level of education. The contributions produced by decreases in second or higher births have been slightly more important for high level of education compared to medium level of education. For low level of education, the contributions have been similar for all ages from 20 to 33. The contributions are mainly produced by decreases in first births at ages 19 to 26 and by decreases in second or higher births at ages 30 to 36. The results of the decomposition differs most for unknown level of education. The contributions produced by decreases in first births have been important mainly for mothers at ages 19 to 22 and mothers aged 27 and older have even produced an increase in the TFR_p, at most 16 births per 1 000 women at age 36.

Figure 20: Decomposition of the decrease in the total fertility rate by levels of education in 2010-2016 by age and parity



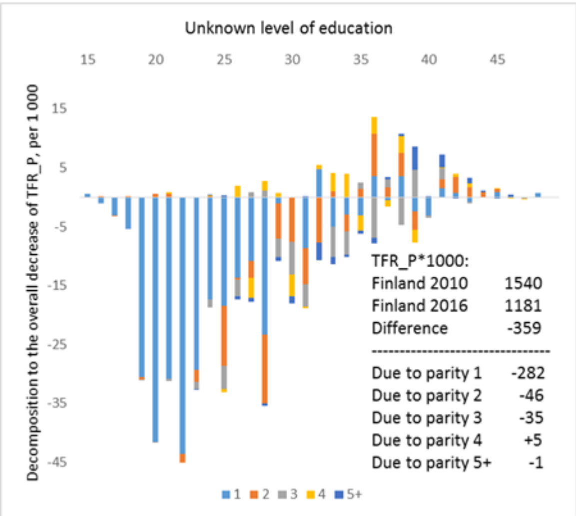
Remarks

It is important to notice that the number of live births born by women of Finnish origin is decreasing while the number of live births born by women with foreign background[3] is increasing. Finnish women gave birth to 56 220 children in 2010 and 46 114 children in 2016. The number of live births born by women with foreign background was 4 760 in 2010 and 6 700 in 2016. The increase in the number of live births born by women with foreign background can highly be explained by increasing immigration. The size of the female population aged 15-49 with foreign background was 71 903 in 2010 and 106 844 in 2016. A serious challenge is that the level of education is unknown for a great

[3] Women with foreign background refers to both immigrated women born abroad and women born in Finland but whose parents are born abroad.

amount of women with foreign background. The level of education was unknown for 58.8% of all women with foreign background who gave birth in 2016. For Finnish women, only 9.0% had an unknown level of education. Out of all women with unknown level of education who gave birth in 2016, almost one half were women with foreign background. This, in combination with the fact that fertility is higher for women with foreign background ($TFR = 1.95$ live births per woman in 2016, Statistics Finland 2018, own estimate) compared to Finnish women, should be kept in mind when interpreting the results of fertility rates among unknown level of education. Figure 21 shows the decomposition of the decrease in the total fertility rate in 2010-2016 for women by unknown level of education when women with foreign origin are excluded from the analyses. Now, a much greater decrease in the total fertility rate is observed and like the other levels of education, the decrease has mainly been due to decreasing number of births by first order births for young women. The fairly large positive contribution to the total fertility rate produced by increases in births by older women (figure 20) was also mainly due to the large amount of women with foreign background and their overall higher fertility rates.

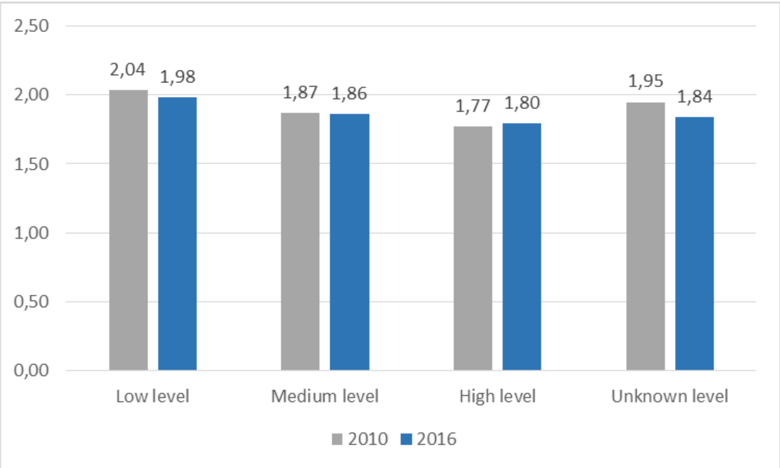
Figure 21: Decomposition of the decrease in the total fertility rate for women with unknown level of education (women with foreign background excluded) in 2010-2016 in Finland by age and parity



Source: Statistics Finland 2018, own decomposition

It is also crucial to notice the limitations with the period fertility rates for different levels of education. Time and temporal order of events are important for understanding a phenomena. The highest level of education reached in one particular calendar year or at the time of childbirth does not necessarily say anything about the completed level of education by a lifetime. This is an issue especially for women younger than 30 for whom the level of education is still changing. For example, the average female population by low level of education at ages 20-25 will to a large extent also consist of women that are currently studying for but not yet reached a university degree and that will make the average female population too large when the fertility rates are calculated. This means that the period fertility rates for young women with low level of education as well as for women with unknown level of education are too low. The period total fertility rate is hence lower for women with low level of education compared to women with medium or high level of education even though the case is completely the opposite for the average child rate for 45-49 year old women (figure 22). In 2016, the average child rate was 1.98 children per woman for low level of education and 1.86 and 1.80 children respectively for medium and high level of education. Period fertility measures at young ages can be misleading when it comes to different levels of education, but the focus should be firstly on how much the fertility rates have decreased by level of education in recent years and not on the period fertility levels. These somewhat misleading period fertility rates are also the reason why the mean age at childbearing and hence the tempo adjusted total fertility rates are not calculated by level of education.

Figure 22: The average child rate for 45-49 year old women by level of education in Finland in 2010 and 2016



Source: Statistics Finland 2018, own estimates

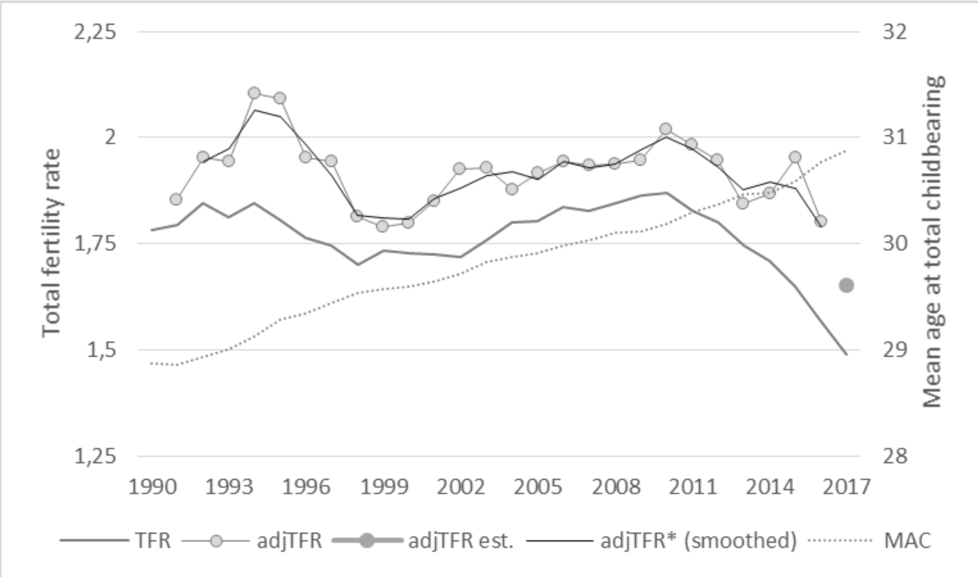
4.2 TEMPO ADJUSTED TOTAL FERTILITY RATE

The tempo adjusted fertility rate in this thesis was calculated by the method developed by Bongaarts and Feeney (1998). The aim with their tempo adjustment was to estimate the period total fertility rate without the influence of the changes in timing of childbirth. Since postponement of childbearing can depress the period total fertility rate (Bongaarts and Feeney 1998), tempo adjustments in this section try to estimate what the period total fertility rate would have been in the absence of fertility postponement in Finland in recent years. The tempo adjusted TFR aims to be a pure measure of fertility quantum in a given period. A decrease in the observed TFR can be attributed to increasing tempo effects if there is no decrease in the tempo adjusted TFR. Quantum changes can then again be held responsible if both the observed and tempo adjusted TFR decreases similarly. (Goldstein et al. 2009) It is however important to notice that the tempo adjusted TFR refer to synthetic cohorts and do not aim to estimate the completed cohort fertility rate (Bongaarts and Feeney 2000), since completed cohort fertility depends on the future paths of both fertility quantum and tempo (Kohler and Ortega 2002).

The adjusted TFR for Finland was calculated for the period 1990 to 2017. Figure 23 shows the observed and tempo-adjusted TFR and the mean age at total childbearing in 1990-2017. Until 2014, the total fertility rate has been quite stable on a level close to 1.75 children per woman. The highest observed total fertility was 1.87 children per woman in 2010, but the rate has been above 1.8 children per woman as well in 1992-1995 and in 2004-2012. The rapid decrease in the total fertility rate from 2010 to 2017 has been fastest from 2014-2017 with a decrease from 1.71 to 1.49 children per woman in three years.

The mean age of total childbearing was 30.9 years in 2017, which is an increase of two years since 1990. The increase has been quite smooth during the whole time period, but slightly faster in 1994-1995 and in 2015-2016. The calculated tempo-adjusted TFR was higher than the observed TFR in every year since 1990, which means that in the absence of fertility postponement, the total fertility rate would have been higher than the now observed rates in this period. If the mean age of childbearing would not have increased, the total fertility rate would have been above 2 children per woman in 1994, in 1995 and in 2010 and not less than 1.75 children per woman in any year in the time period 1990-2016. The value in 2017 is a crude estimate for the tempo-adjusted TFR and any big conclusions cannot be made based on that value. Since the tempo-adjusted TFR has been higher than the observed TFR, the tempo effect in this period is clear. The tempo effect is also evident after 2010. The total fertility rate would have in the absence of fertility postponement been close to 1.80 instead of 1.57 in 2016. However, the smoothed tempo-adjusted fertility rate has still been decreasing similarly as the observed TFR in 2010-2017, which indicates a quantum effect as well. There is neither no guarantee that completed cohort fertility rate eventually will reach the levels of the adjusted TFR (Stankuniene and Jasilioniene 2008).

Figure 23: Observed and tempo-adjusted TFR and mean age at total childbearing in Finland 1990-2017.

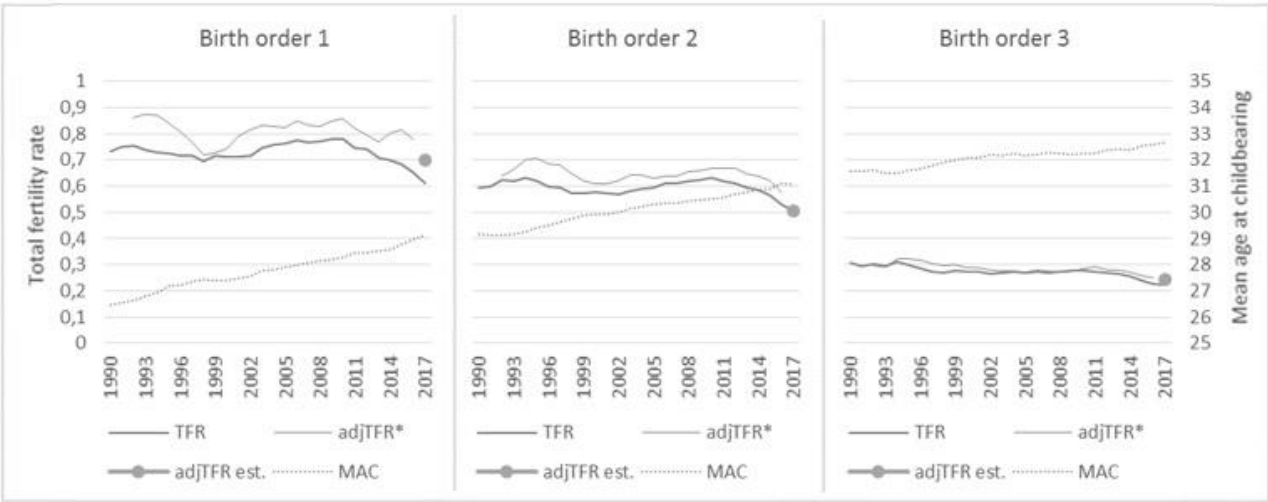


Source: Statistics Finland, own estimates

Figure 24 shows the observed and the smoothed tempo-adjusted TFR and the mean age of childbearing by birth order in Finland in 1990-2017. The total fertility rate by first order live births was slightly above 0.70 children per woman in 1990-2002, then it increased to 0.78 children per woman in 2010 and then again decreased to 0.61 children per woman in 2017. The total fertility rate by second and third order live births follows similar trends; a stable level of around 0.60 children per woman in 1990-2012 and a decrease to 0.50 children per woman in 2017 for second order live births and a stable level of around 0.30 children per woman in 1990-2013 and a decrease to 0.22 children per woman in 2017.

The mean age at childbearing was 29.1 years at first birth, 31.1 year at second birth and 32.9 at third birth in 2017. Since 1990, the mean age at childbearing has increased smoothly for each birth order; a total increase of 2.6 years at first birth, 1.9 year at second birth and 1.1 years at third birth. Since 2010, the increasing mean age at childbearing has also been fastest at first births. The tempo-adjusted fertility rate has been clearly higher than the observed total fertility rate at most years for first and second births but for third births, the observed and the tempo-adjusted fertility rates are similar. This means that in the absence of postponement of first and second births, the total fertility rates by first and second birth orders would have been higher than the now observed rates. The postponement of births and the tempo effect is clear for first and second order births. The tempo effect was still two times higher for first order births compared to second order births in 2016.

Figure 24: Observed and smoothed tempo-adjusted TFR and mean age of childbearing by birth order in Finland in 1990-2017



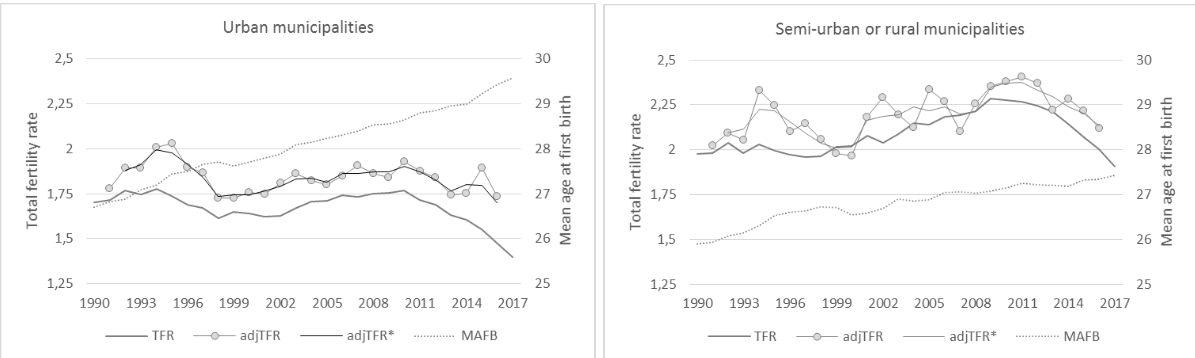
Source: Statistics Finland 2018, own estimates

The adjusted TFR in Finland was also calculated by statistical groupings of municipalities. Figure 25 shows the observed and the tempo-adjusted TFR as well as the mean age at first birth by statistical groupings of municipalities in 1990-2017. Until 2010, the total fertility rate in urban municipalities has been between 1.61 and 1.78 children per woman, but experienced a rapid decrease from 1.77 children per woman in 2010 to 1.40 children per woman in 2017. In semi-urban or rural municipalities, the total fertility rate has been stable on a level of 2 children per woman in 1990-2000, then increased to 2.29 children per woman in 2009 and then again experienced a rapid decrease from 2.24 children per woman in 2012 to 1.91 children per woman in 2017.

Women in semi-urban or rural municipalities do not only have larger families than women in urban municipalities, they also start their childbearing earlier. In 2017, the mean age at first birth was 27.4 in semi-urban or rural municipalities and 29.6 in urban municipalities. Since 1990, the mean age at first birth has increased in both groupings of municipalities, but the increase has been much faster in urban municipalities. The mean age at first birth has increased with 2.9 years since 1990 and with 0.9 years since 2010 in urban municipalities. In semi-urban or rural municipalities, the mean age at first birth has increase with 1.5 years since 1990 and with only 0.3 years since 2010.

The tempo adjusted TFR differs more from the observed TFR in urban municipalities compared to semi-urban or rural municipalities. In urban municipalities, the observed TFR would in the absence of postponement have been clearly higher than the now observed values. The TFR would then have been at most 2 children per woman in 1994 and not less than 1.75 children per woman in any year, except for the two recent years. In semi-urban or rural municipalities, the tempo adjusted TFR has been close to the observed TFR in most years. This means that in the absence of fertility postponement, the TFR would not have deviated very much from the now observed values. The tempo effect have thus been more important for urban municipalities during this period. In 2010-2017, the smoothed tempo adjusted TFR have decreased faster and have been closer to the observed TFR in semi-urban or rural municipalities compared to urban municipalities. Thus, the decline in the TFR in 2010-2017 seems to a higher extent consist of quantum changes in semi-urban or rural municipalities compared to urban municipalities.

Figure 25: Observed and tempo-adjusted TFR and mean age at first birth by statistical groupings of municipalities in Finland in 1990-2017

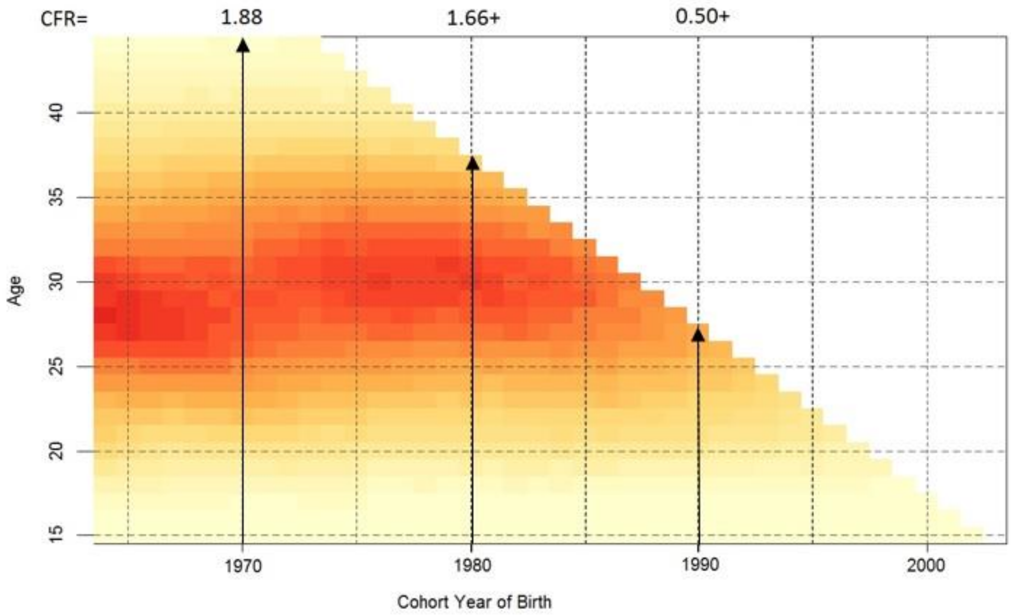


Source: Statistics Finland 2018, own estimates

4.3 COHORT FERTILITY

Until now, the fertility rates examined have been calculated by the period or the cross-sectional approach. Since period measures are sensitive to changes in timing, the total fertility rate calculated from one calendar year does not necessarily say anything about the final quantity of children any woman will have. Figure 26 the shows age-specific fertility rates by cohort year of birth and single year of age for women born between 1964 and 2003. Darker cells indicate higher rates, such as rates at ages 25-35 and lighter cells indicate lower rates, such as rates at ages under 20 or above 40. Cells in the upper right indicate fertility rates that will occur in the future, such as the fertility rate for the cohort born in 1995 aged 30 in 2025. Cohort fertility rates (CFR) above the plot are complete for cohorts born before 1974 and incomplete for cohorts born after 1974. To forecast the completed cohort fertility rate for cohort born for instance in 1980, the unobserved fertility rates at ages 38-44 are then extrapolated into the future.

Figure 26: Age-specific fertility rates in Finland by cohorts born in 1964-2003 as a Lexis surface. (Contemporary dataset)



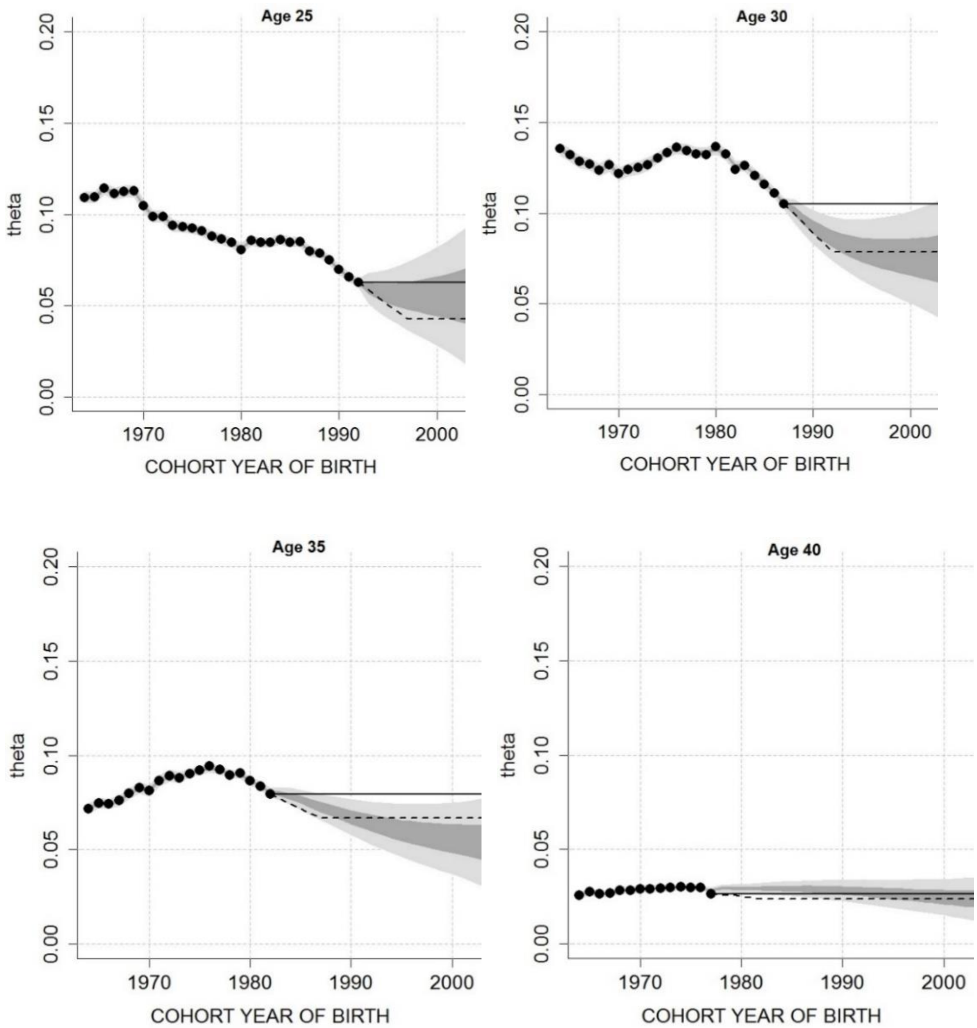
Source: Downloaded from Human Fertility Database (http://humanfertility.org) on 26 June 2018 together with own estimates based on data from Statistics Finland.

The forecast results based on the three forecasting methods, the freeze rate method, the 5-year extrapolation method and the Bayesian method, are presented in this section. In the Bayesian model, results are based on the prior distribution with both shape and time series penalties. A prior distribution with only time series penalties did not change the results substantially. The main task was to forecast the completed cohort fertility rate for women still in their childbearing ages.

Figure 27 shows the fertility forecasts for Finnish cohorts born in 1964-2003 at ages 25, 30, 35 and 40. Dots in the time series represents observed age-specific fertility rates and illustrate changes in fertility timing. The upper left picture shows for example the decrease in the fertility rates at age 25 from a level of 113 live births per 1000 women for the 1969 cohort to the latest observed fertility rate of 69 live births per 1000 woman for the 1992 cohort. The horizontal line represents the freeze rate forecast and extrapolate the latest observed age-specific fertility rates into the future. This method freezes the rates of 69, 105, 74 and 24 live births per 1000 women at age 25, 30, 35 and 40 respectively. The dashed line represent the 5-year extrapolation forecast method that extrapolate the latest five years' decreasing trends observed at almost every ages five years into the future. This method expects the fertility rates to further decrease to 55, 79, 54 and 18 live births per 1000 women at age 25, 30, 35 and 40 respectively and then stay at those levels.

The light and dark grey bands illustrate the 90% and 50% posterior probability intervals from the Bayesian forecasting method. Based on the prior information, the fertility rates at ages 30 and 35 are not likely to increase or even stay at the latest observed levels, but to further decrease like the 5-year extrapolation method suggests. The future fertility rates at age 40 are then again likely to stay at the level of last observed values and the narrow probability interval tells that this forecast result is very precise. Women in their late 30s and early 40s are due to biological constrains already close to their completed family sizes. The case is completely the opposite for young women. The probability interval in the upper left picture is very wide, meaning that the fertility rates at age 25 are likely to change in any direction and that uncertainty is large.

Figure 27: Fertility forecasts for Finnish cohorts born in 1964-2003 at ages 25, 30, 35 and 40. The observed fertility rates are represented as dots and forecasts as lines. The horizontal lines represent the freeze rate forecasts, the dashed lines represents the 5-year extrapolation forecast and the light and dark grey bands are 90% and 50% posterior probability intervals from the Bayesian forecasting method.

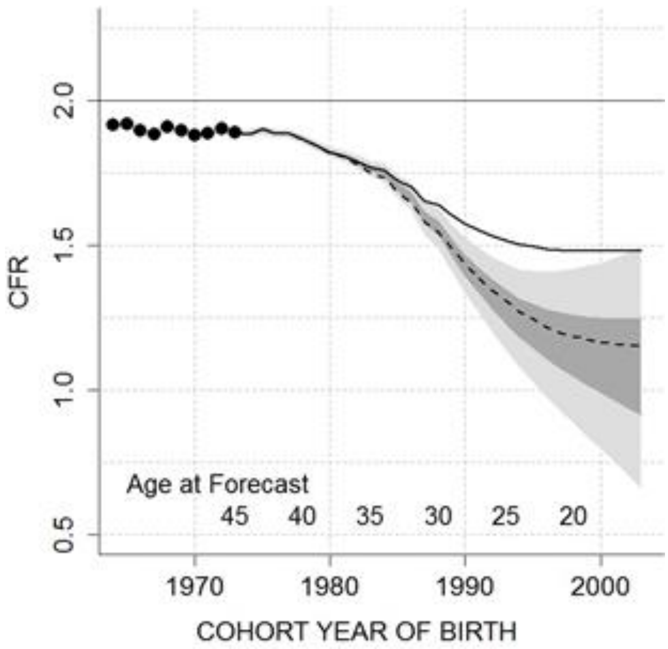


Source: Human fertility database and Statistics Finland, own forecasts

Figure 28 shows the observed and the forecasted completed cohort fertility rate (CFR) for cohorts born in 1964-2003. The latest CFR is observed for women born in 1973, since they reached age 44 in 2017 and thus have completed their fertility schedule. These women had on average 1.89 children, which is approximately the level that have remained the nearly unchanged during the last 30 years.

All three forecasting methods suggest a dramatic decrease in the completed cohort fertility rate for women who are currently in their childbearing ages. The average lifetime number of children will by all three methods and with great certainty fall below 1.80 for women currently in their late 30s and even below 1.75 for women in their early 30s. Even though the fertility rates would remain stable and not decrease further at any ages, the CFR will approach a level of 1.49 children per woman for cohorts born in the mid-90s. Since fertility rates at ages up to 37 are likely to further decline, the level of on average 1.5 children per woman by a lifetime is likely to be achieved in only 15 years. Both the Bayesian forecasting method and the 5-year extrapolation method suggest even further decline to a CFR of below 1.5 for cohorts born in the early 90s. For women currently younger than 25, the CFR is likely to both level of or increase as well as to approach an outrages low level of only 1 children per woman by a lifetime, but the forecast uncertainty is large for these women.

Figure 28: The observed and forecasted completed cohort fertility rate (CFR) in Finland for cohorts born in 1964-2003. Dots are observed fertility rates, the black line is freeze rate forecasts, the dashed line is 5-year extrapolation forecast and the light and dark grey bands are 90% and 50% posterior probability intervals from the Bayesian forecasting method.

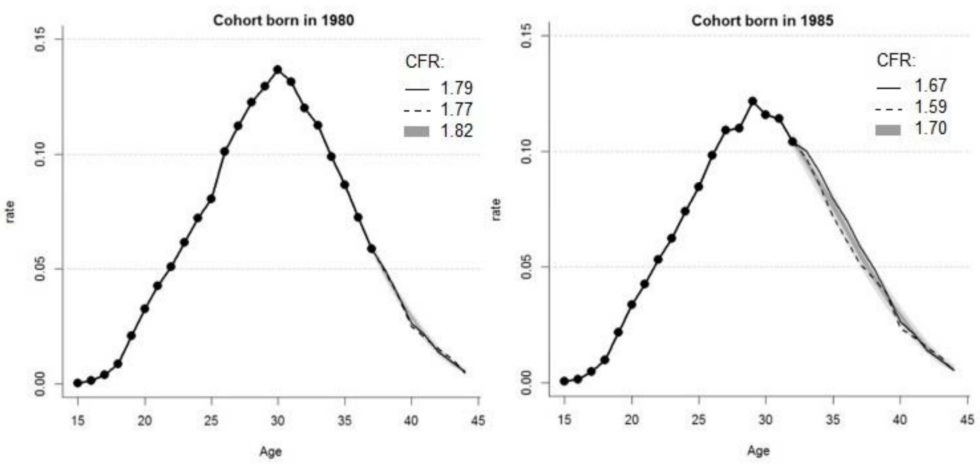


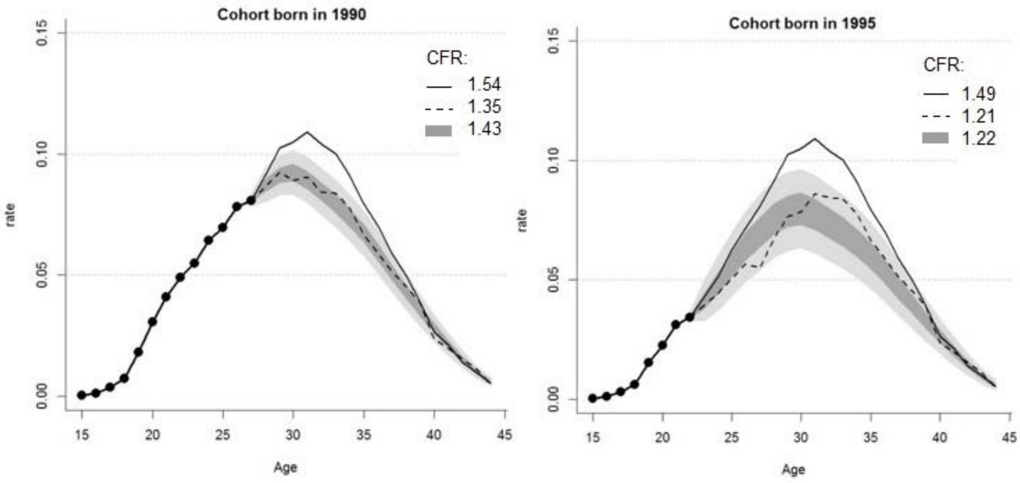
Source: Human fertility database and Statistics Finland, own forecasts

Appendix 5 shows the forecasted cohort fertility at age 49 by the 5-year extrapolation method together with simulated 95 percent confidence intervals based on the appendix of Myrskylä et al. (2013). Those results are very consistent with the results of the Bayesian forecasting method by Schmertmann et al. (2014). Figure 29 shows the observed and the forecasted fertility schedules for Finnish cohorts born in 1980, 1985, 1990 and 1995 at ages 15-44 to clarify the forecasted CFR. The fertility schedule is complete at ages 15-37 for women born in 1980 and at ages 15-22 for women born in 1995. Thus, the fertility schedules will be complete much further in the future for younger cohorts compared to older cohort, who are already close to the true CFR values. The forecast uncertainty is therefore large for younger cohorts.

For cohorts born in 1980, the completed cohort fertility rate is estimated to be around 1.8 children per women by all three forecasting methods, which is a 5 percent decrease from the latest observed CFR. When women born in 1985 reaches 44 years, their average number of children is forecasted to be 1.70 children per woman by the Bayesian forecasting method and even lower by the two other forecasting methods. Since the already observed fertility rates at ages 28-32 are so much lower for the 1985 cohort compared to the 1980 cohort, the fertility rates at ages 33-44 would have to increase dramatically during incoming years in order to catch up postponed births and the CFR to the level of the 1980 cohort, but such a dramatic increase is not likely based on prior information of past fertility schedules and time series. The situation seems even worse for younger cohorts. The completed cohort fertility rate is forecasted to be below 1.5 children per woman for cohorts born after 1990 and the probability of catching up postponed births enough in order to CFR to be higher is low.

Figure 29: Observed and forecasted fertility schedules for Finnish cohorts born in 1980, 1985, 1990 and 1995 at ages 15-44 together with the forecasted CFR by the three methods.





Source: Human fertility database and Statistics Finland, own forecasts

Based on these forecasted results, women currently in their childbearing ages will with high probability have fewer total number of children during their lifetime than women who recently completed their childbearing ages. The results shows that the decrease in the total fertility rate in 2010-2017 highly reflects an enormous quantum effect.

5 DISCUSSION

5.1 Interpretation of the main results

Fertility levels

In 2017, the total fertility rate was 1.49 children per woman in Finland, the mean age of first birth was 29.1 years and the highest age-specific fertility rate was observed at age 31 on a level of 111 live births per 1 000 women. The majority of all live births were first or second order births (41 percent and 34 percent respectively) and only one out of four live births were of third or higher birth order.

There are major differences in the fertility levels among regions in Finland but all regions experienced a clear decrease in the total fertility rate since 2010. Central Ostrobothnia experienced the highest total fertility rate of 1.96 children per woman and the lowest rate of 1.38 children per woman was observed in Uusimaa. The decreasing births is thus a widespread phenomenon in the whole country and not just concentrated to a certain area. As mentioned by Kulu et al. (2007), women in rural areas have in general more children and start their childbearing earlier than women in urban areas. This is confirmed by the results of this thesis. In 2017, the total fertility rate was 1.91 children per woman in semi-urban or rural municipalities, the mean age of first birth was 27.4 years and every third live birth was of third or higher birth order. In urban municipalities, the total fertility rate was 1.40 children per woman, the mean age of first birth was 29.6 years and only one out of five live births were of third or higher birth order. The childlessness rate among women aged 45-49 in 2017 was 21.2 percent in urban municipalities and 16.6 percent in semi-urban or rural municipalities. Women in urban areas still remain childless to a higher extent than women in rural areas, but since 2010, the childlessness rate has increased faster in rural areas.

Table 3: The total fertility rate, the mean age at first child and the childlessness rate among women aged 45-49 in 2017

	TFR	Mean age at first child	Childlessness rate
Urban	1,40	29,6	21,2
Semi-urban and rural	1,91	27,4	16,6
Total	1,49	29,1	19,9

Source: Statistics Finland, own estimates

As Jalovaara et al. (2018) found, cohort fertility has converged among different levels of education in the Nordic countries but the differences between the levels of education have remained stable in Finland. The results of this thesis showed that there are currently not any great differences in the average child rate for women among different levels of education at age 45-49, but lower educated women seem to start their childbearing earlier and get larger families to a greater extent than higher educated women. In 2016, the average child rate was 1.98, 1.86, 1.80 and 1.84 respectively for women with low, medium, high and unknown level of education. The age-specific fertility rates were highest at ages below 30 for women with low or unknown level of education and almost 30 percent of all live births were of third or higher order births for these women. For women with medium or high level of education, the highest age-specific fertility rates were observed at age 30 and above and only about 20 percent of all live births were third or higher order births.

The childlessness rate among women aged 45-49 in 2016 was below 20 percent for women with low, medium and high level of education and as high as 28.1 percent for women with unknown level of education. Since 2010, the childlessness rate did increase massively for the lowest educated women and decreased slightly for the highest educated women. The percentage of women aged 45-49 with unknown level of education with two or more children was also clearly higher in 2010 compared to recent years. One would may expect higher educated women to remain childless to a higher extent than lower educated women, which thus has been the case until a decade ago when the patterns have changed completely (Jalovaara et al. 2018). It is however women with unknown level of education that stands out in terms of a high childlessness rate nowadays.

Table 4: The average child rate and the childlessness rate for women aged 45-49 and the age of when the fertility rates did peak in 2016

	Average child rate	Peak of childbearing	Childlessness rate
Low	1,98	29	18,7
Medium	1,86	30	18,5
High	1,80	31	19,7
Unknown	1,84	27	28,1

Soure: Statistics Finland, own estimates

Postponement of births

Similarly like in many other countries, Finland is experiencing a postponement of births to older ages. In 1990, the mean age at first birth was 26.5 years, the highest age-specific fertility rate was observed at age 28 on a level of 141 live births per 1000 women and the total fertility rate was 1.78 children per woman. In 2010, the mean age of first birth was 28.3 years, the highest age-specific fertility rate was observed at age 30 on a level of 136 live births per 1000 women and the total fertility rate was 1.87 children per woman. Since 1990, the fertility rates at ages younger than 30 have overall been decreasing while the fertility rates at agers older than 30 have been increasing. Since 2010, even the fertility rates at ages 30-37 started to decrease and the decrease at younger ages became much more rapid. This has led to a continuous decline in the number of births for the last seven years and an all-time low observed period total fertility rate.

The shift in childbearing into older ages has led to an on average 8 percent lower total fertility rate compared to what would have been observed in the absence of fertility postponement. There has been a clear tempo effect in Finland in 1990-2010, meaning that women have postponed their childbearing but not reduced the number of births, and thus distorted the total fertility rate. The tempo effect is in fact also evident after 2010, since the tempo adjusted TFR is still higher than the observed TFR in this period. In the absence of fertility postponement, the total fertility rate would have been close to 1.80 instead of 1.57 in 2016. The largest tempo effects are found in first order births and the smallest in third and higher order births. This means that the small decreases in third and higher order births are due to a quantum effect while the larger decreases in first and second order births to a higher extent are due to postponed births. The smoothed tempo adjusted TFR has however been decreasing since 2010, which indicates that quantum changes can be held responsible for the rapid decrease in the total fertility rate in 2010-2017 as well.

The postponement of childbearing was more pronounced in the cities in the 2000s (Kulu et al. 2007), and this is still the case in Finland. The postponement of births can be seen in the mean age of first birth, in the age-specific fertility rates and in the tempo-adjusted total fertility rates. Since 1990, the mean age of first birth has increased with 2.9 years in urban municipalities and only with 1.5 years in semi-urban or rural municipalities. The fertility rates at ages 20-29 in semi-urban or rural municipalities have unlike urban municipalities not been decreasing but instead stayed quite stable until 2010. The overall distance between the tempo-adjusted fertility rate and the observed total fertility rate is much greater in urban municipalities compared to semi-urban or rural municipalities, meaning that there has been a more obvious tempo effect in urban municipalities. In 2016, the total fertility rate would have been close to 1.75 instead of 1.47 in urban areas and around 2.15 instead of 2.01 in rural areas in the absence of fertility postponement.

Contributions to the fertility decrease in 2010-2017

The greatest contributions to the rapid decrease in the total fertility rate from 2010 to 2017 in Finland were produced by decreases in first order births mainly by women aged 25-29. The decreases in first order births have still been massive for almost all ages, especially for women aged 19-31. This means that in comparison to 2010, there is now a greater amount of women younger than 35 that are still childless. Higher order births have however also decreased since 2010, but the contributions to the overall decrease in the total fertility rate in 2010-2017 produced by second or higher births orders have been relatively small. Thus, the main reason for the decrease is not at firsthand reduced family sizes but delayed or possibly eschewed entry to motherhood.

The trend of fast decreasing fertility rates at younger ages and particular by first order births can be observed in both urban and in semi-urban or rural municipalities. The contributions from the decreases in third or higher birth order is still much more important in semi-urban or rural municipalities compared to urban municipalities. Since 2010, the smoothed tempo adjusted TFR have also decreased faster in semi-urban or rural municipalities compared to urban municipalities. Thus, it seems like women in semi-urban or rural municipalities to a greater extent not only have delayed entry to motherhood but also reduced the number of births. Overall, the total fertility rates have decreased similarly since 2010 even though the differences between the levels remain stable. Women in urban areas postpone their childbearing to a higher extent but women in rural areas has slightly started to approach the fertility trends of women in urban areas in terms of increasing childlessness and decreasing higher order births.

The decrease in the total fertility rate in 2010-2017 has been faster for women with medium or high level of education compared to women with low or unknown level of education. The decreases in first order births by women aged 25-29 have been particularly important for women with medium or high level of education. Decreases in first order births have been slightly more important for women with medium level of education when then again decreases in higher order births have been somewhat more important for women with high level of education. For women with low level of education, the contributions produced by decreases in fertility rates are similar at all ages between 20 and 35, where decreases in first order births are important for ages below 30 and decreases in higher birth orders for ages above 30. The results differ slightly for women with unknown level of education, since the fertility rates at ages older than 30 mainly did increase.

Overall, the decrease in first order births has been massive in both urban and rural areas and among every level of education but particularly for higher educated women. The crucial question is whether these births are postponed and will be realized at older ages or whether young women eschews entry to motherhood to a higher extent than before.

Cohort fertility

The completed cohort fertility rate was forecasted to determine whether women who have postponed childbearing eventually will have fewer children. The results showed a rapid decrease in the forecasted CFR, it is likely to fall from the latest observed value of 1.89 children per woman for cohorts born in 1973 to below 1.5 for cohorts born in 1990. Since fertility rates at almost every age is likely to further decrease, cohorts who have postponed their childbearing are not likely to be able to catch up births at older ages and will therefore have fewer number of children during their lifetime. Considering the fact that cohort fertility has been fairly stable during the last thirty years, this massive decrease is surprising and reflects a substantial change in fertility behavior among women currently in their childbearing age. The decrease in the period total fertility rate in Finland in 2010-2017 therefore reflects a huge quantum effect and the result confirms the hypothesis of Rotkirch et al. (2017) that cohort fertility will start decreasing.

Furthermore, is this forecasted decrease trustworthy and if so, what could lie behind this predicted change? The Family Federation of Finland (Väestöliitto in Finnish) has true surveys followed Finnish residents childbearing intentions since 1997. They have in recent years observed a dramatic change in the average ideal and intended number of children cited by Finnish residents. This number has previously been around 2.3-2.5 children per person, but was in 2018 as low as 1.84 for residents in their 20s and 2.02 for residents in their 30s. One factor that partly explains this new trend is increasing popularity of voluntarily childlessness. The amount of childless persons who do not intend to have any children at all has been very low, around 1.5 to 4 percent out of all respondents in previous surveys. However, out of all males and females in their 20s who are currently childless, nearly one out of four declares their ideal lifetime number of children to be zero. (Berg 2018) This indeed confirms the fact that young women may not only postpone childbearing but to a much higher extent than before eschew entry to motherhood completely.

Despite the fact that Finland has exceptionally high lifetime childlessness rates compared to other European countries (Rotkirch and Miettinen 2017), the cohort fertility level has still remained fairly high and stable due to relatively high third and higher order birth rates (Jalovaara et al. 2018). Since the childlessness rate is expected to further increase and the amount of large families to decrease (Rotkirch et al. 2017), it is thus inevitable that the completed cohort fertility rate in Finland will decrease as the forecasts of this thesis suggest. If young women to a higher extent that before do choose a life without children at the same time as those who do intend children do not intend as much children as previous cohorts, it is not far-fetched that their average lifetime number of children will decrease dramatically and be at most 1.5 children per woman.

5.2 METHODOLOGICAL CONSIDERATIONS

The methods used in this thesis were demographic decomposition, tempo-adjusted total fertility rate and three different forecasting methods. The period fertility rates were calculated using Finnish administrative register data which means that all resident women and registered births in Finland were included in the analyses, not just a sample of women. Despite that the analyses were based on the total population, there could still be some uncertainty in the results, especially within small subgroups due to natural variation.

When changes in birth rates are observed, it is crucial to detect where the contributions to the changes mainly come from to be able to determine how to respond to the changes. The demographic decomposition shows the contributions produced to the total fertility rate by age and parity to detect which age groups and what parity that have produced the greatest contributions to the decrease in the total fertility rate in recent years. This thesis has the advantage of decomposing the total fertility rate by age and parity within urban and rural areas and within different levels of education and not only for the total population. The decomposition itself has the advantage of adjusting for both the age and the parity distribution among women at childbearing age in 2010 and in 2017.

The tempo adjusted total fertility rate was calculated by the method of Bongaarts and Feeney (1998). The advantage of that method is its decomposition of a change in the TFR into quantum and tempo effects. However, for the approach to be trustworthy, is requires that all age groups postpone births by exactly the same amount in one period. (Goldstein et al. 2009) In other words, this means that fertility schedules should be invariant over time at each birth order (Bongaarts and Feeney 2000), but as figure 11 did show, this has not completely been the case in the period 2010-2017 in Finland. Nevertheless, Zeng and Li (2001) calculated an adjusted TFR that allows the shape of the fertility schedule to change and showed that it did not deviate much (except in abnormal conditions) from the adjusted TFR that are based on the strict assumptions of invariant shape schedules over time. Further, another limitation with the method is the fact that it does not adjust for changing parity distribution of the female population (Kohler and Ortega 2002). Despite this limitation, more sophisticated methods that would have adjusted for changes in the parity distribution was not considered in this thesis due to the fact that the conventional TFR, that is most often used by researchers and policy makers, only adjust for the age structure but do not either adjust for the parity distribution.

The methods used for forecasting cohort fertility where the Freeze Rate method, a 5-year extrapolation method (Myrskyä et al. 2013) and a Bayesian method (Schmertmann et al. 2014). Bohk-Ewald et al. (2018) did compare 20 different cohort fertility forecasting methods, including the three forecast methods used in this thesis, and evaluated and ranked them based on their forecasting accuracy. The 20 methods consisted of parametric curve fitting methods, extrapolation methods, Bayesian approaches and fertility context-specific methods. Bohk-Ewald et al. (2018) found that out of all the 20 methods, only four methods outperformed the simple freeze rate method and among those top four methods were the 5-year extrapolation method developed by Myrskylä et al. (2013) and the Bayesian method developed by Schmertmann et al. (2014). However, despite the Bayesian method being more demanding in terms of input data, statistical techniques and computational power, it did not consistently produce more accurate forecasts compared to the more simpler 5-year extrapolation method. The 5-year extrapolation method was in fact ranked as the number one method by some of the forecast accuracy measures. To sum up, the forecasting methods used in this thesis have been shown to be among the leading forecasting method in terms of forecast accuracy. In addition, the forecasts produced by the 5-year extrapolation method and the Bayesian method did show very similar results. The forecast results of this thesis are therefore very trustworthy and match the findings of the Family Federation of Finland.

5.3 FURTHER RESEARCH

As noticed in figure 2, the decrease in the total fertility rate after 2010 in Finland is somewhat unique internationally. However, a similar decrease has also been observed in for example Norway and the US, even if their decrease is not as outstanding as in Finland. According to Dommermuth and Lappegård (2016), the fall in Norway seems to be explained by "recent decline in first birth rates and the long lasting decrease in third-birth rates" and their decomposition of the fertility rates indicated that cohort fertility may not remain stable in Norway. Updated cohort fertility forecasts for countries that have experienced a fall in the total fertility rate since 2010 could conclude whether other relatively high-fertility countries also will be experiencing a decrease in the cohort fertility level in the upcoming years as predicted in Finland.

This thesis forecasted the completed cohort fertility rate for women currently in their childbearing age, but did not make separate forecasts for women in urban and rural areas or with different level of educations partly due to data limitations. Since fertility differences have remained fairly stable among women with different levels of education while they have converged in other Nordic countries (Jalovaara et al. 2018), it would be interesting to forecast cohort fertility separately for women with different levels of education as well. Period fertility rates particularly by first order births have decreased faster for higher educated women, which could indicate that cohort fertility will decrease faster for those women compared to lower educated ones.

In addition, the main focus in this thesis was on fertility trends among women, not on fertility trends among males. Male fertility have overall gained little attention in the research literature but recent studies have also included analyses on male fertility in Finland (Nisén 2016) and overall in the Nordic countries (Jalovaara et al. 2018). While fertility usually is negatively associated with education among women, these studies confirmed that the case is completely the opposite among males in Finland. Higher educated males have higher lifetime number of children and this seems mainly to be the case due to higher childlessness rate among lower educated males (Nisén 2016). Male cohort fertility has similar like female cohort fertility also been stable during the last thirty years but clearly lower (on average 1.7 children per man) than female cohort fertility (Jalovaara et al. 2018). Since female cohort fertility is likely to decrease, it could be expected that male cohort fertility therefore will start to decrease as well.

An interesting question of great importance arises from the results of this thesis: What is the reason for the massive change in the underlying fertility level found in this thesis? As the Family Federation of Finland have noticed, the popularity of voluntarily childlessness among young people has increased dramatically in recent years. Another surprising trend they have recently noticed is that the main reasons for postponing childbearing is not anymore the lack of suitable spouse or economic instability, but such a thing as “the desire to do other interesting things” has become the number one reason for postponing births. Lifestyle reasons as well as lacking interest in children has also turned out to be the main reason for voluntary childlessness. (Berg 2018) Further research could sort out what exactly these lifestyle reasons are and where the disinterest in children comes from to be able to conclude whether society could support young people to combine their desired lifestyle with having children.

5.4 Final conclusion

The title of this thesis asked the question: Do the all-time low period fertility rates observed in Finland reflect a tempo or a quantum effect? Since period-based measures are by nature synthetic, a reduction in the total fertility rate does not necessarily reflect underlying changes in the level of fertility, it could also reflect that women are postponing but not reducing their childbearing. As mentioned by Bongaarts and Sobotka (2012), tempo and quantum changes do often occur simultaneously and it is not necessarily clear whether tempo or quantum effects should be held responsible when birth rates are decreasing. If an increase in the mean age of childbearing is observed from one period to the next while the shape of the age-specific fertility rates remain unchanged, it is considered a pure period tempo effect. The mean age at childbearing has indeed increased remarkably in Finland from 2010 to 2017, not because of an invariant shape of age-specific fertility rates moving on the age axis, but rather due to faster decreasing fertility rates at younger ages compared to older ages. Since the fertility rates did not however decrease completely proportionally at all ages, a pure period quantum effect cannot be held responsible either. The tempo-adjusted total fertility rate did also confirm the simultaneously occurrence of both period tempo and period quantum effects in the decrease in the total fertility rate in recent years.

Consequently, the possibility that women are postponing but not reducing childbearing is not enough to entirely explain the decreasing births in Finland. The fundamental goal of interest is therefore to detect a possible cohort quantum effect. Since the cohort fertility forecasts displayed a massive decrease in the completed cohort fertility rate in the upcoming years, there is indeed a pure cohort quantum effect. Hence, the importance of the period tempo effect is fading when the cohort perspective is considered. The decrease in the total fertility rate in 2010-2017 therefore reflects an enormous change in the underlying level of fertility and women currently in their childbearing age are expected to have remarkably less children compared to previous generations. Women currently in their 20s are expected to have at most 1.5 children during their lifetime, which is far below replacement level and significantly below the threshold of 1.75 children per woman as e.g. Zeman et al. (2018) consider as very low fertility.

Based on the results of this thesis, Finland is likely to depart from the “common Nordic fertility regime” in terms of not being able to keep the cohort fertility level stable close to the replacement level. Instead, the cohort fertility level in Finland is likely to approach those levels that are now observed in very low fertility countries like Germany, Italy, Japan and Spain (see e.g. Zeman 2018 for current cohort levels in low fertility countries). If such low rates are obtained in the future, population decline as well as population aging is inevitable. In that case, the need of immigration increases to prevent population decline and to satisfy the need for more labor force participation and tax payers in the future. However, increasing immigration do not solve the problem with population aging. As Kohler et al. (2006) states, "the only viable long-term strategy to limit the extent of population aging and the decline of the population size will be an increase in the level of fertility". Since voluntary childlessness has recently increased dramatically in popularity among young people in Finland (Berg 2018), this will indeed be a serious challenge for the Finnish government.

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APPENDICES

Appendix 1: The historical data set used as the prior information in the Bayesian forecasting model

Country	*n*	Birth cohorts
Austria	25	1936-1960
Bulgaria	29	1932-1960
Canada	55	1906-1960
Czechia	26	1935-1960
Estonia	17	1944-1960
Finland	37	1924-1960
France	30	1931-1960
Germany	20	1941-1960
Western Germany	20	1941-1960
Eastern Germany	20	1941-1960
Hungary	26	1935-1960
Lithuania	17	1944-1960
Netherlands	26	1935-1960
Portugal	36	1925-1960
Russia	17	1944-1960
Slovakia	26	1935-1960
Sweden	61	1900-1960
Switzerland	44	1917-1960
Great Britain	2	1959-1960
England & Wales	38	1923-1960
Scotland	31	1930-1960
Northern Ireland	2	1959-1960
USA	43	1918-1960

Source: Source: Downloaded from http://schmert.net/cohort-fertility/ on 26 Jun 2018, originally downloaded from Human Fertility Database (http://humanfertility.org) on 2 Nov 2011.

Appendix 2: Weighting procedure in the prior distribution

Appendix 2a: The search procedure for selecting the weights $w_1 \ldots w_{90}$ that adjust the contributions of each penalty term $j = 1 \ldots 90$ in the prior distribution.

1. Initialize all weight at unity: $w_1 = w_2 = \cdots = w_{90} = 1$
2. Calculate $\mathbf{K} = \sum_j w_j \mathbf{K}_j$, and its generalized Moore-Penrose inverse $\mathbf{K}^+$
3. Calculate $E^*(\pi_j|w) = \mathrm{trace}(\mathbf{K}_j \mathbf{K}^+)$ for all $j = 1 \ldots 90$
4. Update weights as $w_j^{new} = w_j \frac{E^*(\pi_j|w)}{\mathrm{target}_j}$ for all $j = 1 \ldots 90$
5. Stop if converged; otherwise return to Step 1.

Source: Appendix of Schmertmann et al. (2014)

Appendix 2b: Iterative penalty weighting.

	Schedule shapes	Freeze rates	Freeze slopes
Target value $E^*(\pi_j|w)$	27	30	30
Range of w across penalties			
Before iteration 1	1.000-1.000	1.000-1.000	1.000-1.000
After iteration 30	0.569-0.870	0.063-0.458	0.412-0.583
Range of $E^*(\pi_j|w)$ across penalties			
Before iteration 1	13.397-19.562	5.639-14.402	11.592-15.069
After iteration 30	27.000-27.000	29.998-30.001	30.000-30.001

Source: Own iterations

Appendix 3: Distribution of live births in 2017* by mother's age, parity place of residence and level of education (%)

Distribution of live births in 2017 by mother's age

-19	**20-24**	**25-29**	**30-34**	**35-39**	**40-**
1,4	12,6	29,3	34,0	18,1	4,5

Distribution of live births in 2017 by mother's parity

1	**2**	**3+**
40,6	34,0	25,3

Distribution of live births in 2017 by mother's place of residence

Urban	**Semi-urban**	**Rural**
74,1	14,6	11,3

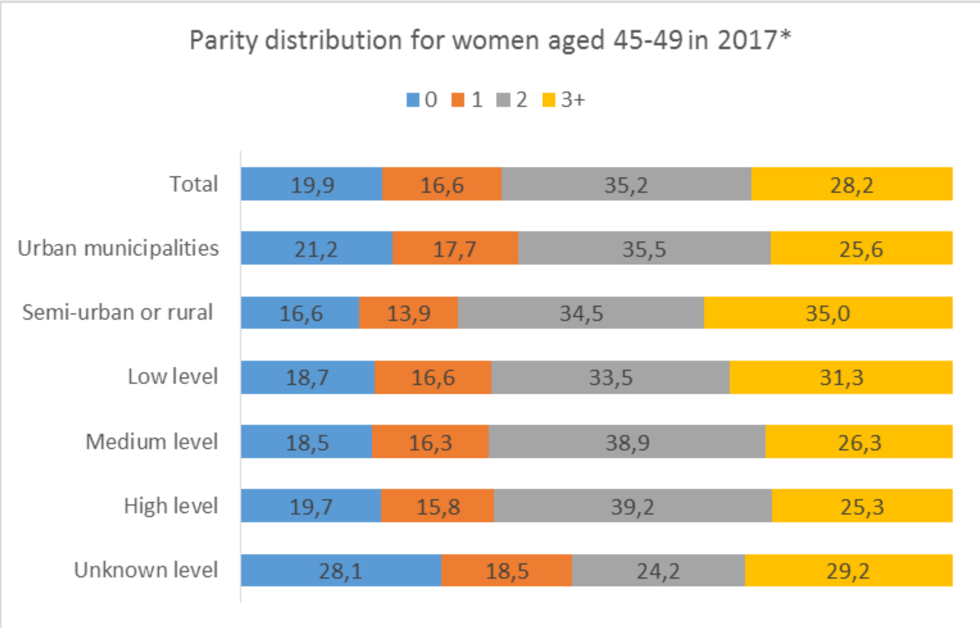
Distribution of live births in 2016 by mother's highest level of education

Low	**Medium**	**High**	**Unknown**
40,2	26,7	17,8	15,3

Source: Statistics Finland 2018, own estimates. *) in 2016 by level of education

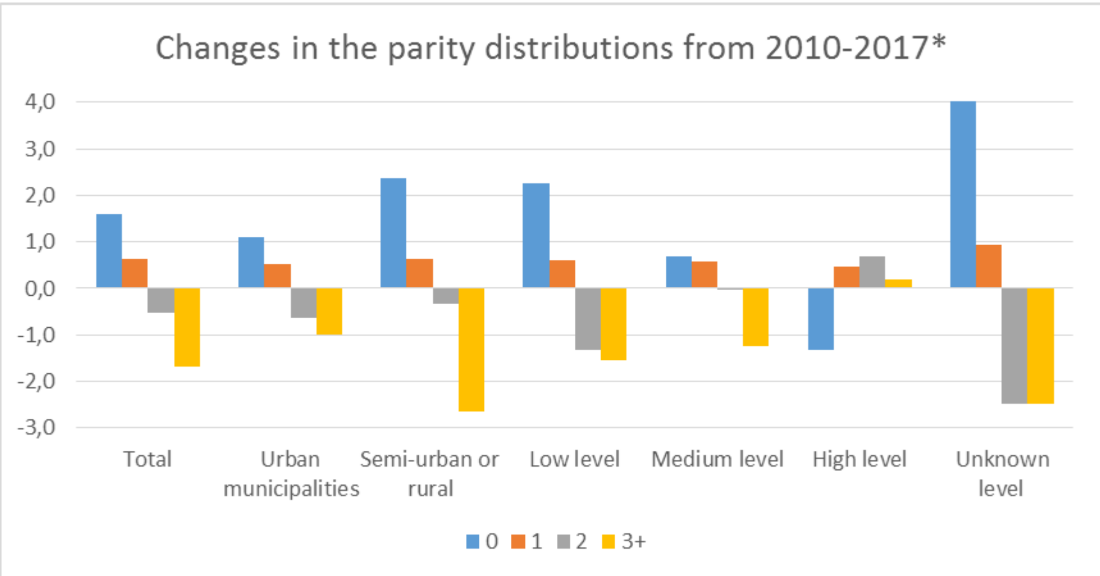
Appendix 4: Parity distribution for women (%)

Appendix 4a: The parity distribution for women aged 45-49 in 2017 within urban and rural areas and within different levels of education



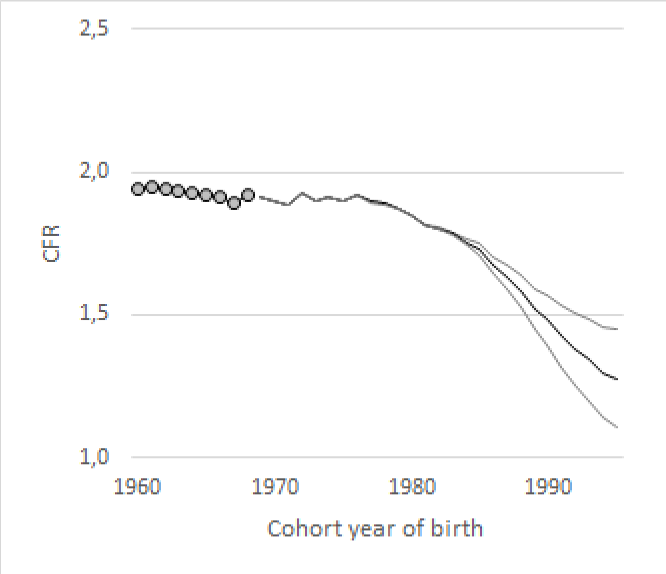
Source: Statistics Finland 2018, own estimates. *) 2016 for level of education.

Appendix 4b: Changes in the parity distributions from 2010-2017 in percentage points



Source: Statistics Finland 2018, own estimates. *) 2010-2016 for level of education.

Appendix 5: The observed and forecasted completed cohort fertility rate (CFR) and simulated 95 percent confidence interval in Finland for cohorts born in 1960-1995.



Source: Statistics Finland 2018, own forecast. Note: The fertility schedules are considered complete at age 49 and the forecast method and the simulated confidence interval are based on Myrskylä et al. (2013).