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Estimates of the Tempo-adjusted Total Fertility Rate in Western and Eastern Germany, 1955-2008

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Abstract: In this article we present estimates of the tempo-adjusted total fertility rate in Western and Eastern Germany from 1955 to 2008. Tempo adjustment of the total fertility rate (TFR) requires data on the annual number of births by parity and age of the mother. Since official statistics do not provide such data for West Germany as well as Eastern Germany from 1990 on we used alternative data sources which include these specific characteristics. The combined picture of conventional TFR and tempo-adjusted TFR* provides interesting information about the trends in period fertility in Western and Eastern Germany, above all with regard to the differences between the two regions and the enormous extent of tempo effects in Eastern Germany during the 1990s. Compared to corresponding data for populations from other countries, our estimates of the tempo-adjusted TFR* for Eastern and Western Germany show plausible trends. Nevertheless, it is important to note that the estimates of the tempo-adjusted total fertility rate presented in this paper should not be seen as being on the level of or equivalent to official statistics since they are based on different kinds of data with different degrees of quality.

Keywords: Germany · Fertility · Fertility trends · Tempo adjustment · Tempo-adjusted TFR · Bongaarts – Feeney · Total fertility rate · East-West comparison · Parity · Biological birth order · Average age at childbirth

1 Introduction

The East-West German differences in fertility trends which have been observed over many decades are probably the most frequently studied aspect of the demographic differences between Eastern and Western Germany. Above all the changes in Eastern German fertility have been frequently studied in recent years (e.g. *Dorbritz* 1992; *Menning* 1995; *Witte/Wagner* 1995; *Conrad et al.* 1996; *Beck-Gernsheim* 1997; *Dorbritz* 1997; *Sackmann* 1999; *Lechner* 2001; *Sobotka* 2002; *Kreyenfeld* 2003; *Kreyenfeld* 2009), and are regarded as the main characteristic of the "demographic shock" experienced by the population in the new Federal *Länder* after the

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political changes (*Eberstadt* 1994). The level of fertility and its changes over time are particularly important because they have the strongest long-term impact on the age structure of a population (*Luy* 2009). This is why the determinants of fertility and of childlessness in the context of the specific backgrounds of life in Western and Eastern Germany have been analysed intensively in recent years (e.g. *Dorbritz/Schwarz* 1996; *Hank* 2002; *Dornseiff/Sackmann* 2003; *Hank/Kreyenfeld* 2003; *Hank et al.* 2004; *Butterwege et al.* 2005; *Eckhard* 2006; *Boehnke* 2007; *Bernardi/Keim* 2007; *Bernardi et al.* 2008; *Arránz Becker et al.* 2010; *Pötzsch* 2010).

For most politically and socially relevant questions the absolute numbers of births are of primary interest since these determine the future numbers of kindergarten children, school pupils, students, employed persons or pensioners, albeit the size of these population groups is additionally determined by mortality and migration. Demographic fertility research, by contrast, studies primarily the relative fertility quantum in order to be able to describe changes and differences between populations and to identify the corresponding determinants and influencing factors. The demographic indicator used most frequently in the field of period analysis – i.e. the analysis of fertility conditions in a specific calendar year – is the "total fertility rate" (TFR) which is often interpreted as the "average number of children". However, it is generally difficult in the period analysis to give a specific meaning to such measures. This is only possible in the cohort perspective, in which the fertility of a real cohort is analysed year by year on a longitudinal basis. Period analysis, by contrast, summarizes the fertility of a specific calendar year using the age-specific fertility rates of all women who were between 15 and 49 years old in this calendar year. By summing up the age-specific fertility rates to the total fertility rate, a hypothetical cohort is constructed which is supposed to represent the current fertility conditions (see *Sobotka and Lutz* 2010 on the problem of the use of the period TFR for questions of political and societal relevance).

The observed or reconstructed number of births of women belonging to a certain cohort can be influenced by specific period and cohort effects. In general, these effects are not seen as distortions, but rather as causal determinants of cohort fertility and are thus of central interest of the analysis. Period analysis, by contrast, aims to describe the "pure" fertility level of a specific calendar year– the so-called "quantum of fertility" – without including any other structural factors determining or influencing the level of fertility. A classical structural factor influencing the overall fertility level is the age composition of a population, which can have a major impact on the number of births. Thus, demographic period indicators such as the TFR are calculated as age-standardised measures. (Although cohort indicators are generally calculated age-standardised as well, no comparable distortion effects of the age composition can occur here).

At the end of the 1990s, *Bongaarts and Feeney* (1998) showed that changes in the average age at childbirth occurring during a calendar year alter fertility rates and hence the TFR, a phenomenon that has been described already by *Hajnal* (1947). *Bongaarts and Feeney* (1998) referred to this alteration of the TFR as a "tempo effect" and proposed to not only standardize the total fertility rate by age, but to also adjust the TFR for tempo effects. The basic idea of Bongaarts and Feeney is that

tempo effects are also a structural factor distorting the TFR when this indicator is used to reflect the pure quantum of current fertility. An increase in the average age at childbirth during the analyzed calendar year leads to a tempo effect-caused reduction in the fertility rates, and a reduction in the average age at childbirth leads to a tempo effect-caused increase in the fertility rates. Even though the existence of such tempo effects in the period TFR is not questioned among demographers, opinions as to the need for the tempo adjustment diverge in some respects. Nonetheless, the additional use of the tempo-adjusted total fertility rate, which is symbolised by TFR*, has more and more become the standard in demographic fertility research in recent years. This can be seen in the increasing number of publications in which fertility trends and differentials are analysed not only on the basis of the conventional TFR, but also using the TFR* (e.g. *Lesthaeghe*/*Willems* 1999; *Philipov*/*Kohler* 2001; *Goldstein et al.* 2003; *Sobotka* 2003, 2004a, 2004b; *Frejka*/*Sobotka* 2008; *Goldstein et al.* 2009). The TFR* is also a part of the standard repertoire of demographic indices compiled in the "European Demographic Datasheet", published every two years by the Vienna Institute of Demography of the Austrian Academy of Sciences (available on the Internet at http://www.oeaw.ac.at/vid/datasheet/index.html).

In most of the above mentioned publications, however, information on the tempo-adjusted TFR* is missing for some European populations, including Germany. The calculation of the tempo-adjusted TFR* requires the number of births being separated not only by age of the mother but also by parity. This information was not available for unified Germany and for former West Germany until 2009 because of the statutory regulations. Prior to 2009, the parity was exclusively collected for births of married mothers, with the birth order referring solely to children of the current marriage (including pre-maritial children with the current husband). Pre-maritial children with fathers other than the mother's current husband, as well as children from previous marriages, have not been considered and thus did not enter official population statistics on parity. Only after the supplement of the Population Statistics Act in 2009 (*Bevölkerungsstatistikgesetz*/Federal Law Gazette [*BGBl*] 2007) it was possible to record the so-called "biological birth order" independently of the civil status of the mother for the whole of Germany (see *Statistisches Bundesamt* 2010).

For the new Federal *Länder* (eastern Germany), the data of the former GDR are available for the period prior to 1989. These include all births by parity and year of birth of the mother as required for tempo adjustment. After reunification, however, the birth statistics were carried out in accordance with the Federal Population Statistics Act, and thus no official data on births by biological parity is available for Eastern Germany for the period from 1989 to 2008.

This article aims to provide estimates for the TFR* in Western and Eastern Germany from the mid-1950s to the present, and hence to close – at least partly – one of the gaps in international fertility research. In order to separate births by parity as required for tempo adjustment of the TFR, we have used a variety of alternative sources for West Germany as well as for Eastern Germany from 1990 on. These contain estimates for the number or proportion of births by parity and age of the mother

for different periods, but they are based in some cases on very small population samples with questionable representativity for the overall population. Moreover, in view of the educational and family bias usually found in survey data, it cannot be ruled out that some of these data sources lead to systematic distortions in estimating parity and age at childbirth. Another inaccuracy results from the fact that the data covers different age ranges of the reproductive life span. Although the tempo-adjusted fertility rates derived from these data are rather plausible when compared to corresponding estimates for other countries with better data bases, it is important to note that the estimates presented in this paper should not be seen as being on the level of or equivalent to official statistics since they are based on different kinds of data with different degrees of quality.

The methods, and above all the data, on which our estimates of the TFR* for Germany are based are described in detail in the next section. Then we present the results for Western and Eastern Germany both in an intra-German as well as in an international comparison. Finally, we summarise the most important findings and discuss briefly interpretation-related and methodical aspects of the tempo-adjusted total fertility rate. Note that the latter issue as well as a detailed analysis of the fertility trends in Western and Eastern Germany are not the central purpose of this paper. Nonetheless, the advantages and disadvantages of the tempo-adjusted TFR* should be at least briefly summarised for those who have not followed the very detailed discussion on tempo adjustment or those who have not studied it in detail.

2 Data and methods

The conventional total fertility rate (TFR), which is published by the German Federal Statistical Office on an annual basis, is calculated from the sum of the age-specific fertility rates f(x), which are calculated by dividing the number of all births of women aged x, B(x), by the number of women aged x, P(x):

$$TFR = \sum_{\alpha}^{\beta} f(x) = \sum_{\alpha}^{\beta} \frac{B(x)}{P(x)}. \qquad (1)$$

Since all indicators in this article refer to periods, we refrain from using an additional index for the calendar year as far as possible for reasons of simplification. The parameters α and ß represent the lowest and highest ages of women's reproductive life span, which are usually defined as 15 and 49 years. When totalling the age-specific fertility rates, they all take on the same weight in the resulting TFR, so that – as has already been mentioned in the introduction – the TFR primarily constitutes an age-standardised fertility indicator.

The basic idea behind tempo adjustment of the TFR is not only to standardize for age but also for shifting effects which emerge in a calendar year when the average age of women at childbirth changes during that calendar year (see *Bongaarts/Feeney* 1998, 2006, 2010). The direction of these changes can differ between parities. Since

the parities take on different weights in the overall TFR, the tempo adjustment of the TFR according to the method of *Bongaarts* and *Feeney* (1998) is performed on a parity-specific basis. This requires separating the TFR in its parity-specific components. The TFR for a parity i is calculated by summing up the corresponding age- and parity-specific fertility rates $f(x)_i$ which differ from the age-specific fertility rates in equation (1) in that the numerator does not contain all births of women aged x, but only births of parity i, $B(x)_i$:

$$TFR_i = \sum_{\alpha}^{\beta} f(x)_i = \sum_{\alpha}^{\beta} \frac{B(x)_i}{P(x)}. \tag{2}$$

Note that these age- and parity-specific fertility rates $f(x)_i$ are no probabilities (or any related measure) of the transition of a parity i to the next parity i+1. For this purpose, the denominator of the rates should not include all x-year-old women, but only those who actually belong to the female population at risk of giving birth to a child of the i-th birth order (e.g. childless women in the calculation for parity 1). The age- and parity-specific fertility figures from equation (2) rather represent the elements of a purely formal parity-specific decomposition of the TFR as can be demonstrated easily. Subdividing the age-specific numbers of births B(x) in equation (1) into the parities $B(x)_1$ (first births), $B(x)_2$ (second births), $B(x)_3$ (third births) and $B(x)_{4+}$ (fourth and further children), leads to

$$TFR = \sum_{\alpha}^{\beta} \frac{B(x)_1 + B(x)_2 + B(x)_3 + B(x)_{4+}}{P(x)}, \tag{3}$$

which can be reformulated to

$$TFR = \sum_{\alpha}^{\beta} \frac{B(x)_1}{P(x)} + \sum_{\alpha}^{\beta} \frac{B(x)_2}{P(x)} + \sum_{\alpha}^{\beta} \frac{B(x)_3}{P(x)} + \sum_{\alpha}^{\beta} \frac{B(x)_{4+}}{P(x)}, \tag{4}$$

so that follows

$$TFR = \sum_{i=1}^{4+} TFR_i. \tag{5}$$

Tempo adjustment with the method proposed by *Bongaarts* and *Feeney* (1998) is done within the parity-specific TFR_i. Therefore, the TFR_is are divided by one minus the annual change in the average age at childbirth of parity i, r_i, so that the tempo-adjusted parity-specific TFR_i* results from

$$TFR_i^* = \frac{TFR_i}{1 - r_i} \,. \tag{6}$$

The change in the average age at childbirth of parity i can be estimated by halving the difference between the average parity-specific age at childbirth, MAB_i, in the following year and the preceding year (see *Bongaarts* and *Feeney* 1998). If we denote the analyzed calendar year with t, the estimate for $r_i(t)$ results from

$$r_i(t) = \frac{MAB_i(t+1) - MAB_i(t-1)}{2} \,. \tag{7}$$

We calculated the average parity-specific ages at childbirth MAB_i on an age-standardised basis from the age- and parity-specific fertility rates by

$$MAB_i = \frac{\sum_{\alpha}^{\beta} (x + 0{,}5) \cdot f(x)_i}{\sum_{\alpha}^{\beta} f(x)_i} \,. \tag{8}$$

In accordance with the relations expressed in equations (3), (4) and (5) the overall tempo-adjusted fertility rate TFR* results from the sum of the tempo-adjusted parity-specific TFR_i*s:

$$TFR^* = \sum_{i=1}^{4+} TFR_i^* \,. \tag{9}$$

Tempo adjustment of the total fertility rate requires the number of births to be subdivided by the age of the mothers on a parity-specific basis. The official statistics of the GDR (East Germany) recorded all births by parity and year of birth of the mother, and thus the tempo-adjusted TFR* for East Germany for the period 1955 to 1987 can be directly estimated from these data. For the new Federal *Länder* since unification in 1990 (Eastern Germany) as well as for the territory of the former Federal Republic of Germany (West respective Western Germany), official data on the biological birth order are only available since 2009. In order to carry out the parity-specific subdivision of the birth numbers necessary for the tempo adjustment of the TFR for West respective Western Germany and Eastern Germany from 1990 onwards, it was necessary to use alternative data sources:

- *Birg et al.* (1990) provided an estimate of the parity-specific subdivision of births in the Federal Republic of Germany for the years 1958 to 1985. The estimates were based on the family biographies collected in the context of the research project entitled “Labour market dynamics, family development

and generative conduct" in 1986, promoted by the DFG, which included 793 women and 783 men of the cohorts born in 1950 and 1955 from Düsseldorf, Hannover, Bochum, Gelsenkirchen, Gronau, Ahaus, Vreden and Leer. For each child of these respondents, the family biographies contain both the actual birth order and the birth order information used by the West German Statistical Office at that time. From the corresponding relative frequencies (obtained for single ages of the mothers by means of linear regression modelling), both the parity-specific births in marriage, and the non-marital births which were recorded in official statistics on a non-parity-specific basis, were transferred into an estimate of the biological parities by single age of the mother. The authors used constant parity-specific subdivisions as obtained from the project sample for both the children born in wedlock and those born out of wedlock for every year from 1958 to 1985.

- *Kreyenfeld* (2002) combined the official birth numbers for West respective Western Germany from 1985 to 1995 with parity-specific frequencies derived from the Socio-Economic Panel (SOEP) similarly to *Birg et al.* (1990). However, only the non-marital births of the SOEP samples for West/Western Germany and for foreigners (211 cases in total) were used for the subdivision into the respective birth orders by means of a time-variable multinomial logit model. As a consequence of this modelling procedure, the estimated age-specific parity distributions differ slightly from year to year, in contrast to the estimates of *Birg et al.* (1990). For marital births, *Kreyenfeld* (2002) used the official data on birth order of parents who were married to one another.

- For the years 1995 to 1999 (Western Germany) and 1995 to 2000 (Eastern Germany) we could use the data of the perinatal survey compiled and kindly made available by Dr. Manfred Voigt (University of Greifswald). This survey has been carried out since the 1980s directly in West German birth clinics with the aim of improving the quality of perinatal medicine. Participation in the survey, which was conducted by the *Bundesländer* themselves until 2000, has been obligatory for all clinics since 1995 (see *Goerke/Lack* 2000; *Kreyenfeld et al.* 2010). In contrast to official statistics, the perinatal survey includes the birth order for all births a woman has ever had. Because of the aim and the method of the survey, the perinatal survey exclusively contains births which took place in clinics, what applies to the majority of all births in Germany. Dr. Voigt was able to collect the perinatal survey data for all the Federal *Länder* with the exception of Baden-Württemberg. Despite the obligatory participation for all hospitals, the dataset for the years 1995 to 1997 contains only approx. 70 % of all 1,656,339 births registered in Germany during these years. The percentages for the single calendar years are about 65 % in 1995, 78 % in 1996 and 66 % in 1997. Nevertheless, the availability of the data for the Federal *Länder* enabled us to estimate parity-specific proportions of births by the age of the mothers for Eastern and Western Germany separately. For this purpose we used the absolute numbers without addi-

tional smoothing. Since Berlin is included as one overall unit in the perinatal survey – as in the official statistics from 2000 onwards – we excluded the capital from our analysis.

- *Kreyenfeld et al*. (2010) also used the data of the perinatal survey, which have been compiled for the whole federal territory since the beginning of the 21st Century by the German National Institute for Quality in Healthcare (*Bundesgeschäftsstelle Qualitätssicherung*), to estimate parity-specific birth numbers for the years from 2001 to 2008. But also these data are only virtually complete from 2004 onwards. Some hospitals as well as entire *Bundesländer* are missing in the years before, such as Hessen, Schleswig-Holstein and the Saarland in 2001. The authors report that 4,978,381 births are recorded (and useable) for the entire period from 2001 to 2008, corresponding to 89 % of all births registered in Germany in these years. The shares in 2001, 2002 and 2003 are however only between 62 and 85 %. *Kreyenfeld et al*. (2010) provide the parity-specific birth numbers derived from these data separately for Eastern and Western Germany, with all of Berlin being allocated to Eastern Germany. Like the data from the perinatal survey from 1995 to 1999 respective 2000 (see above), the data used by *Kreyenfeld et al.* (2010) are based solely on births which took place in hospitals. Using data from Germany's official health reporting (*Gesundheitsberichterstattung des Bundes*) and statistics of the Association for Quality in Out-of-Hospital Births (*Gesellschaft für Qualität in der außerklinischen Geburtshilfe e.V. – QUAG*), the authors found that roughly one to two percent of all births took place outside hospitals between 2001 and 2008. Although these figures include primarily higher-parity births, taking them into account only leads to negligible changes in the parity-specific subdivision derived from the data of the perinatal survey (see *Kreyenfeld et al*. 2010).

- In order to close the gap arising from the above mentioned data sources for Western Germany in the year 2000, we also analyzed the parity-specific birth numbers of official statistics for the period 1998 to 2002. As has already been described, these figures only include children born to parents who are currently married to one another including their joint pre-marital children. The quality of the TFR* estimated on the basis of these data mainly depends on the extent of deviations between the average age at childbirth of the women by the biological birth order and by the birth order in the current marriage. Analysing the new official statistics for 2009 one asserts that this extent mainly depends on the proportion of non-marital births (*Statistisches Bundesamt* 2010). The difference between the age of the mother at the first birth in the current marriage and the age of the mother at the first birth in her life was 0.9 years in Western Germany in 2009 with the proportion of extra-marital first births being 36 %. The proportion of extra-marital births was smaller among second and further births, namely between 17 % and 19 %, and the corresponding age difference was only 0.3 years. The influence of

re-marriage was weak: 93 % of first births in the current marriage in 2009 were also the first births in the life of the mother. The concordance between biological and marital birth order was even larger in second and further births. Thus, since the proportion of births of unmarried women among all live births in Western Germany in the years 1998 to 2002 was between 16 % and 21 % (*Statistisches Bundesamt* 2008, Tab. 1.1.1 to 1.1.3), the information on the marital birth order forms a relatively sound basis for estimating the TFR*. The situation for Eastern Germany is different what prohibits using the information from official statistics on the marital birth order: The proportion of extra-marital births is much larger than in Western Germany. The proportion of extra-marital births among first births was 74 % in 2009, and among second and further births it was still far above 40 %. The difference between the age at the first birth in the life of the woman and the age at the first birth in the current marriage was 2.3 years. Between second and further births, the age difference was 0.9 and 0.8 years, respectively. Furthermore, 20 % of the women had already given birth before the first child in the current marriage was born. The proportion of extra-marital births in the new Federal *Länder* in the period between 1998 and 2002 was more than twice as high as in the West, and it increased more rapidly: from 47 % in 1998 to 55 % in 2002.

Table 1 summarizes the data sources used. As far as we know, these contain the only data existing for the German population which provide the subdivision of births into first births (parity 1), second births (parity 2), third births (parity 3) and higher-order births (parity 4+) for the years 1955 to 2008. Since the case numbers in the data sources used differ from the total number of births registered in Western and Eastern Germany, the relative parity-specific subdivision of births, calculated from the data sources, was applied to the total number of births in Western and Eastern Germany as published by the statistical office. In formal terms, the age- and parity-specific numbers of births $B(x)_i$ were estimated as follows:
with B(x) denoting the official overall number of births of x-year-old women, and

$$B(x)_i = B(x) \cdot \frac{B'(x)_i}{B'(x)} \tag{10}$$

$B'(x)_i$ and $B'(x)$, respectively, denoting the number of births of parity i of x-year-old women as well as the corresponding total number of births included in the respective data source. From these age- and parity-specific birth numbers and from the numbers of living women aged 15 to 49 published by the statistical office, it was possible to derive age- and parity-specific fertility rates for single ages of the mothers which finally enabled us to estimate the parity-specific TFR_i from equation (2) as well as the parity-specific age at childbirth MAB_i from equation (8). The tempo-adjusted total fertility rates TFR* were finally calculated as shown in equation (9). For parities 1, 2 and 3 we used the tempo-adjusted TFR_1*, TFR_2* and TFR_3* (calculated

Tab. 1: Data sources used to estimate age- and parity-specific fertility rates

(a) Western Germany (former Federal Republic of Germany/old Federal *Länder*)

Data source	Period used	Basis of the parity-specific subdivision of births
Birg et al. (1990)	1958 - 1985	Marital and extra-marital births from the sample of the project entitled "Labour market dynamics, family development and generative conduct", ages 15-49
Kreyenfeld (2002)	1985 - 1995	Extra-marital births from the sample of the SOEP, marital births from official statistics, ages 15-45
Perinatal data	1995 - 1999	Births recorded in the perinatal survey in Western Germany without the Baden-Württemberg and West Berlin, ages 15-49
Official birth statistics	1998 - 2002	Births from the current marriage (without West Berlin from 2001 on), ages 15-49
Kreyenfeld et al. (2010)	2001 - 2008	Births recorded in the perinatal survey in Western Germany without West Berlin, ages 15-44
Official birth statistics	2009	All births (without West Berlin), ages 15-49

(b) Eastern Germany (former GDR/new Federal *Länder*)

Data source	Period used	Basis of the parity-specific subdivision of births
Official birth statistics of the GDR	1954 - 1988	All births, ages 15-45
Perinatal data	1995 - 2000	Births recorded in the perinatal survey in Eastern Germany without East Berlin, ages 15-49
Kreyenfeld et al. (2010)	2001 - 2008	Births recorded in the perinatal survey in Eastern Germany including West Berlin, ages 15-44
Official birth statistics	2009	All births (without East Berlin), ages 15-49

with equation 6), whereas for parity 4+ we used the conventional TFR_{4+} as recommended by *Sobotka* (2004a) in order to reduce random fluctuations.

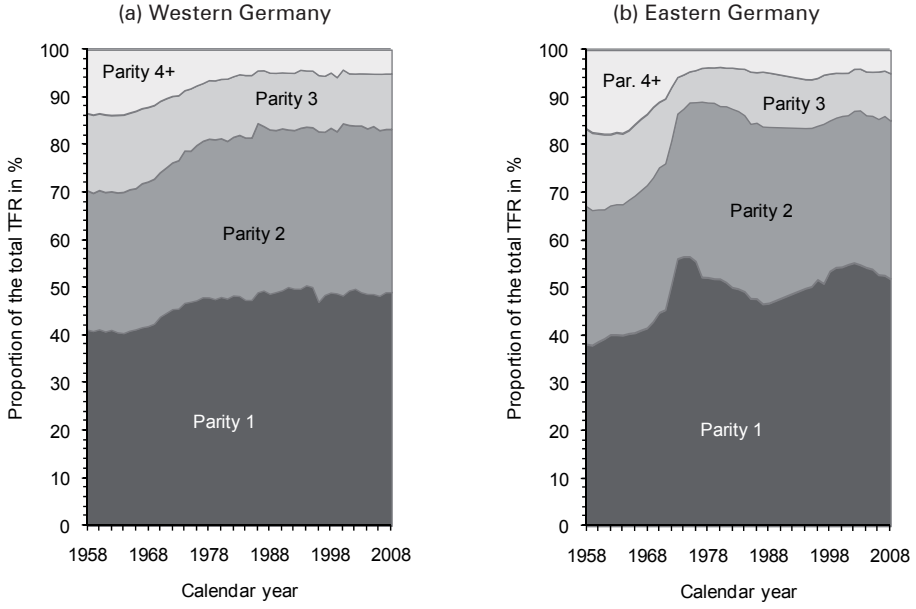
3 Results

In a first step, we subdivided the total number of births by the age of the mother for Western and Eastern Germany published by the Statistical Office of Germany into the parities on the basis of the parity distributions reconstructed from the various data sources. From these parity-specific birth numbers, we decomposed the con-

ventional total fertility rate TFR – as described in the previous section – into parities 1, 2, 3 and 4+. The corresponding estimates for TFR_1, TFR_2, TFR_3 and TFR_{4+} for each calendar year can be found in Annex 1.

Figure 1 shows the proportions of the parity-specific TFR_i from 1958 to 2008 calculated from these data. Although the time trends of the parity-specific proportions of the TFR reveal interesting differences between Western and Eastern Germany, both parts of the country resemble each other in the fact that total fertility is mainly determined by parities 1 and 2. All in all, first and second born children account for 70 % (from the end of the 1950s until the 1960s) to 80-85 % (since the 1970s in Eastern Germany and since the 1980s in Western Germany) of the total number of live births in the analyzed period. The proportions of parity 3 remain largely constant in both Western and Eastern Germany, whilst births of fourth and higher order have clearly become less significant since the 1970s in both parts of Germany and are of only minor significance for total fertility. With regard to the tempo effect component in the conventional TFR it is therefore of primary relevance how the average age at childbirth of mothers of first and second children has changed in the analyzed calendar years.

Fig. 1: Proportions of parity-specific TFR_is in the conventional total fertility rate TFR in Western and Eastern Germany, 1958-2008

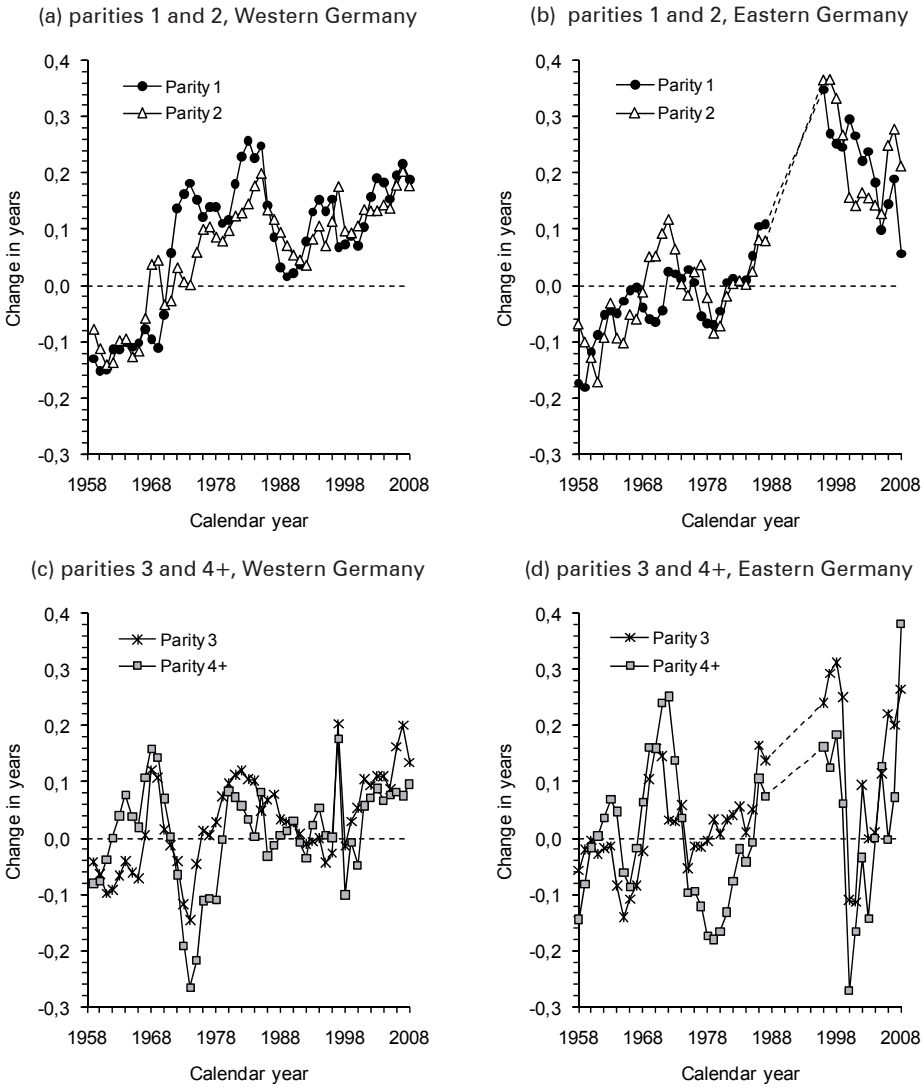


Notes: Data basis of the estimates for Western Germany for the years 1958-1985 *Birg et al.* (1990), 1986-1995 *Kreyenfeld* (2002), 1996-1999 perinatal survey, 2000 official statistics (marital births), 2001-2008 *Kreyenfeld et al*. (2010); data basis of the estimates for Eastern Germany for the years 1954-1988 official statistics of the GDR, 1995-2000 perinatal survey, 2001-2008 *Kreyenfeld et al.* (2010); the missing calendar years 1989-1994 for Eastern Germany were estimated by means of linear interpolation of the values for 1988 and 1995; the parity-specific TFR_i for single calendar years can be found in Annex 1.

Figures 2a to 2d present the annual changes in the average parity-specific age at childbirth r_i for the same observation period estimated from the age- and parity-specific numbers of births. The values for parity 1 in Western Germany (black dots in Fig. 2a) are to be found exclusively in the negative range until the beginning of the 1970s. This means that the average age of women giving birth for the first time is continuously decreased during these years. The situation is similar for the average age at childbirth of parities 2 (shown in Fig. 2a by white triangles) and 3 (star signature in Fig. 2c). Consequently, one can presume that tempo effects increased the conventional TFR in the years of the baby boom. The changes in the average age of the mothers of children of fourth and higher order (grey squares in Fig. 2c) show a trend in contrast to parities 1 and 2 between the mid-1960s and the beginning of the 1970s. Because of the minor significance of parity 4+ for total fertility, this can only result in a slight reduction of the tempo effects caused by parities 1, 2 and 3. From the 1970s to the end of the 1990s, all parities show an almost permanent annual increase in the average age at childbirth in Western Germany, albeit with varying intensities. Above all in parity 1, the annual changes are more than 0.1 years in most calendar years, with the maximum value of 0.26 being reached in 1983. Only in the second half of the 1980s the values for r_1 are around zero. Since the early 1990s, there is a rise in the annual increase again, with an overall upward trend until the last year of observation. The changes in the other parities are very similar over the entire period. In the last years of the observation period, the annual change in the average age at childbirth among parities 1 to 3 is between 0.15 and 0.20 years, so that the TFR in Western Germany was influenced most by tempo effects in the 1970s and early 1980s as well as since the early 1990s.

In Eastern Germany, the values for r_i of all parities fluctuate around zero from the mid-1960s until the end of the 1980s (see Figs. 2b and 2d). The few exceptions relate to parities 2, 3 and 4+ for a short time around 1970 and to parity 4+ at the end of the 1970s and at the beginning of the 1980s. All in all, the conventional TFR in Eastern Germany should be more or less unaffected by tempo effects in this period. Since unification, the trends have changed considerably. Unfortunately, for the years between 1987 and 1996 the change in the average age at childbirth cannot be estimated. However, the r_i values derived for the years from 1996 to 2000 are – above all for parities 1 and 2 – very high and much higher than in Western Germany. The dashed interpolated lines in Figures 2b and 2d between 1987 and 1996 are included to provide an impression of the massive changes which occurred in the ages at childbirth among Eastern German mothers during the 1990s. These lines cannot be used to estimate the r_i values for the single years of this period, which could indeed have been rather above the level of 1996 particularly in the first half of the 1990s. However, they indicate that the extremely low TFR of Eastern Germany in this period is caused to a considerable degree by tempo effects. From the beginning of the 20th century on the annual change in the average age at childbirth returns to a level of around 0.2 years among parities 1 and 2, and is hence similar to the West German level. The fluctuations are larger in parities 3 and 4+ with many of the single values being around zero. However, as can be seen in Figure 1b, the changes in the ages at

Fig. 2: Annual changes in the average parity-specific age at childbirth r_i in Western and Eastern Germany, 1958-2008



Notes: Data basis of the estimates for Western Germany for the years 1959-1984 *Birg et al.* (1990), 1985 combination *Birg et al.* (1990)/*Kreyenfeld* (2002), 1986-1994 *Kreyenfeld* (2002), 1995 combination *Kreyenfeld* (2002)/perinatal survey, 1996-1998 perinatal survey, 1999-2001 official statistics (marital births), 2002-2007 *Kreyenfeld et al*. (2010), 2008 combination *Kreyenfeld et al*. (2010)/official statistics (all births); data basis of the estimates for Eastern Germany for the years 1958-1987 official statistics of the GDR, 1996-1999 perinatal survey, 2000-2001 combination perinatal survey/*Kreyenfeld et al.* (2010), 2002-2007 *Kreyenfeld et al.* (2010), 2008 combination *Kreyenfeld et al.* (2010)/official statistics (all births).

childbirth of the mothers of third and further children have only a minor influence on the magnitude of the tempo effects.

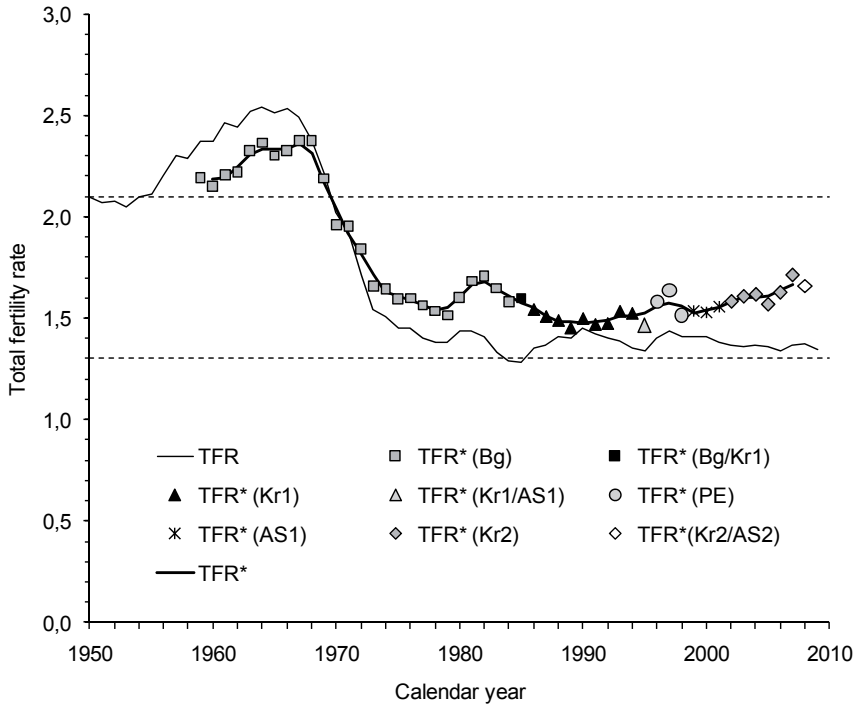
The estimated annual changes in the parity-specific age at childbirth can be used to adjust the TFR_is for tempo effects according to the method proposed by *Bongaarts* and *Feeney* (1998), and the resulting TFRi*s can then be cumulated to the tempo-adjusted total fertility rate TFR* (the values for the TFR_i* and the total TFR* can be found for the single calendar years in Annex 2). Figure 3 shows the corresponding estimates for Western Germany in comparison to the conventional TFR (thin line). All in all, the estimates for the tempo-adjusted TFR* derived from the various data sources (designated in Fig. 3 by different symbols) show a coherent overall trend.

Since tempo adjustment with the method of *Bongaarts* and *Feeney* (1998) can generally lead to distinct annual fluctuations (and here additionally the combination of different data sources), more robust results are obtained when averaging the tempo-adjusted TFR* for three calendar years (see *Goldstein et al.* 2009). The resulting estimates for the TFR* of Western Germany can be found in Table 2a. The thick black line in Fig. 3 represents the corresponding trend of the TFR* which reflects the expectations that have already been outlined in connection with the trends in the annual changes in parity-specific ages at childbirth. The TFR* is slightly below the conventional TFR from the late 1950s to the mid-1960s because the age at childbirth was falling at that time. This shows that the increase in the TFR at the beginning of the baby boom in the 1950s was not only caused by the actual increase in fertility but also to a slight degree by tempo effects. Similar results were shown for instance for the USA (*Bongaarts/Feeney* 1998). At the end of the 1960s and at the beginning of the 1970s, practically no differences can be found between the TFR and the TFR*.

Since the early 1970s, the TFR* in Western Germany has been higher than the conventional TFR. Whilst the TFR stagnated between 1.3 and 1.4 after the fertility decline between the second half of the 1960s and the mid-1970s, the TFR* declined less in the 1970s, and at the beginning of the 1980s the TFR* increased slightly to about 1.7. The following years show a subsequent decrease in the TFR* that persisted until 1990. Since then, the tempo-adjusted total fertility rate shows a more or less continuous increase, reaching almost 1.7 in the last year of the observation period (2008). All in all, although the TFR* is far from the replacement level of 2.1 children per woman (upper dashed line in Fig. 3), it lies – in contrast to the conventional TFR – clearly above the level of "lowest-low fertility", which *Kohler et al.* (2002) defined as 1.3 children per woman (lower dashed line in Fig. 3).

The differences between the conventional TFR and the tempo-adjusted TFR* also correspond to the expectations for Eastern Germany outlined above on the basis of the estimated annual changes in the average parity-specific age at childbirth. In Figure 4 the corresponding estimates are, again displayed for the single years and the trend in the three-year average of the TFR* (the respective values can be found in Tab. 2b, as well as in Annex 2). It can be seen that tempo effects also led to a slight increase in the total fertility rate during the 1950s in Eastern Germany which is indicated by the somewhat lower values of the TFR* in comparison to the TFR.

Fig. 3: Estimates of the tempo-adjusted total fertility rate TFR* in Western Germany from various data sources, 1950-2010



Notes: The abbreviations in brackets refer to the data basis for the estimate of the TFR*, Bg = *Birg et al.* (1990), Kr1 = *Kreyenfeld* (2002), Kr2 = *Kreyenfeld et al.* (2010), PE = perinatal survey, AS1 = official statistics (marital births), Bg/Kr1 = combination *Birg et al.* (1990)/*Kreyenfeld* (2002), Kr1/PE = combination *Kreyenfeld* (2002)/perinatal survey, Kr2/AS2 = combination *Kreyenfeld et al.* (2010)/official statistics (all births); the trend line of the TFR* is calculated from a three-year moving average (values for the mid-calendar years can be found in Tab. 2); the parity-specific TFR_i*s for the single calendar years can be found in Annex 2.

In the subsequent years until the mid-1980s, the annual changes in the mothers' average age at childbirth were too small to lead to significant tempo effects. Consequently, there are virtually no differences between the TFR and the TFR* in this period. This changes in the last years prior to reunification during which the TFR* in Eastern Germany rises in contrast to the decreasing TFR because of the increasing age at childbirth, similar to what can be observed for Western Germany at the end of the 1970s.

Although we have only few estimates for the TFR* in the 1990s because of the available data sources, these estimates illustrate to what degree the conventional TFR (and the actual birth numbers) were affected by changes in the mean age at childbirth in Eastern Germany. Whereas the conventional TFR was only 1.04 in 1997, the estimated tempo-adjusted TFR* is 1.47. Equally to what has been done in Fig-

Tab. 2: Estimates of the tempo-adjusted total fertility rate TFR* in Western and Eastern Germany, 1950-2010 (three-years averages)

(a) Western Germany

1950-1959		1960-1969		1970-1979		1980-1989		1990-1999		2000-2009	
Year	TFR*	Year	TFR*	Year	TFR*	Year	TFR*	Year	TFR*	Year	TFR*
1950	--	1960	2.18	1970	2.03	1980	1.60	1990	1.47	2000	1.54
1951	--	1961	2.19	1971	1.92	1981	1.66	1991	1.48	2001	1.56
1952	--	1962	2.25	1972	1.82	1982	1.68	1992	1.49	2002	1.58
1953	--	1963	2.30	1973	1.71	1983	1.65	1993	1.51	2003	1.60
1954	--	1964	2.33	1974	1.63	1984	1.61	1994	1.51	2004	1.60
1955	--	1965	2.33	1975	1.61	1985	1.57	1995	1.52	2005	1.61
1956	--	1966	2.34	1976	1.59	1986	1.55	1996	1.56	2006	1.64
1957	--	1967	2.36	1977	1.57	1987	1.51	1997	1.58	2007	1.67
1958	--	1968	2.31	1978	1.54	1988	1.48	1998	1.56	2008	--
1959	--	1969	2.17	1979	1.55	1989	1.48	1999	1.53	2009	--

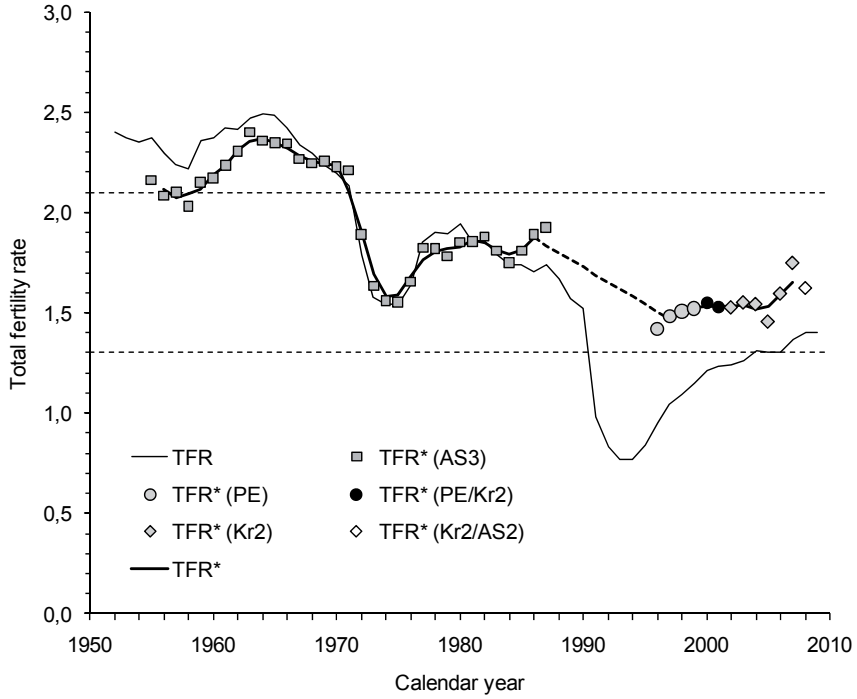
(b) Eastern Germany

1950-1959		1960-1969		1970-1979		1980-1989		1990-1999		2000-2009	
Year	TFR*	Year	TFR*	Year	TFR*	Year	TFR*	Year	TFR*	Year	TFR*
1950	--	1960	2.18	1970	2.23	1980	1.83	1990	--	2000	1.53
1951	--	1961	2.24	1971	2.11	1981	1.86	1991	--	2001	1.53
1952	--	1962	2.31	1972	1.91	1982	1.85	1992	--	2002	1.53
1953	--	1963	2.35	1973	1.69	1983	1.81	1993	--	2003	1.54
1954	--	1964	2.37	1974	1.58	1984	1.79	1994	--	2004	1.52
1955	--	1965	2.35	1975	1.59	1985	1.81	1995	--	2005	1.53
1956	2.12	1966	2.32	1976	1.68	1986	1.87	1996	--	2006	1.60
1957	2.07	1967	2.29	1977	1.77	1987	--	1997	1.47	2007	1.65
1958	2.09	1968	2.26	1978	1.81	1988	--	1998	1.50	2008	--
1959	2.12	1969	2.24	1979	1.82	1989	--	1999	1.52	2009	--

Notes: -- no estimates available; values for the TFR* calculated from the three-year moving average of the estimates for the single calendar years (see Annex 2).

ure 2b, the dashed sections of the line for the tempo-adjusted TFR* in Figure 4 are only included to give an impression of the fertility conditions prevailing in the first half of the 1990s. In fact, the TFR* could have also been below this line during these years as indicated by the estimate for the single year 1996. From 1997 to 2005, the tempo adjusted TFR* ranged relatively constant around 1.5. Whether the increase in the TFR* in the last years of the observation period as indicated by the estimates from 2006 onwards reflects an actual trend can only be said once the data for the next years become available.

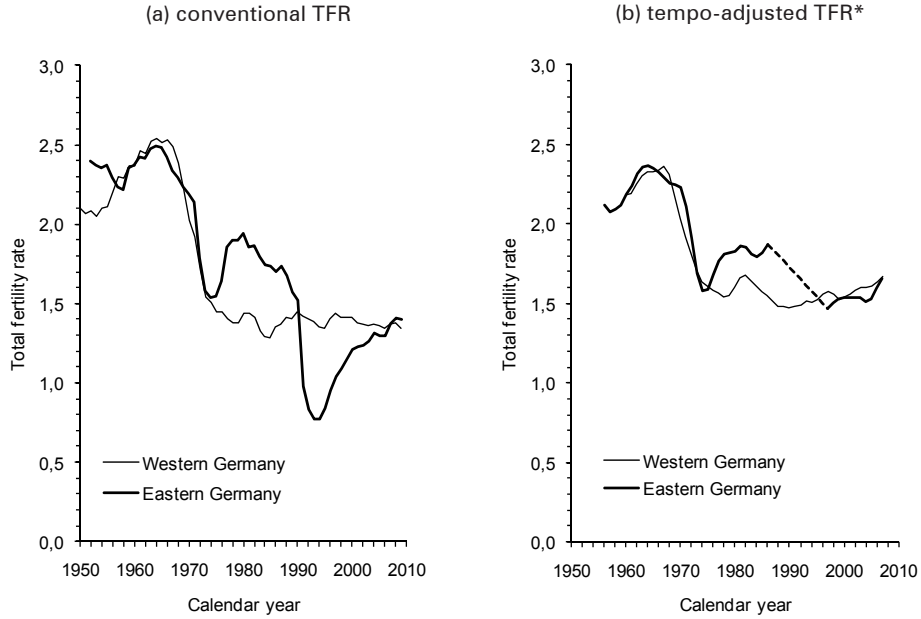
Fig. 4: Estimates of the tempo-adjusted total fertility rate TFR* in Eastern Germany from various data sources, 1950-2010



Notes: The abbreviations in brackets refer to the data basis for the estimate of the TFR*, AS3 = official statistics (GDR), PE = perinatal survey, Kr2 = *Kreyenfeld et al.* (2010), PE/Kr2 = combination perinatal survey/*Kreyenfeld et al.* (2010), Kr2/AS2 = combination *Kreyenfeld et al.* (2010)/official statistics (all births); the trend line of the TFR* is calculated from the three-year moving average (values for the mid calendar years can be found in Tab. 2); for the calendar years 1987-1996, the trend for the TFR* in Eastern Germany (years without estimate) was completed by linear interpolation of the values for 1986 and 1997 (dashed line); the parity-specific TFR_i*s for the single calendar years can be found in Annex 2.

A direct East-West comparison of fertility trends in Germany is presented in Figure 5 according to the conventional TFR and the tempo-adjusted TFR*. The trends in the conventional TFR can be found in Figure 5a and the trends in the tempo-adjusted TFR* can be found in Figure 5b. Interestingly, both variants of calculation show the same phases in which the total fertility rate is higher in Eastern or Western Germany. However, the differences in the tempo-adjusted TFR* in the two parts of Germany are smaller in each phase (and since the second half of the 1990s almost negligible). (Note once more that the dashed sections in the line of the TFR* for Eastern Germany are no real estimates, but represent the interpolated connection between the estimates for 1986 and 1997.) Besides this, the graphical West-East comparison of the total fertility rate by means of the two calculation variants provides one more important result: fertility had virtually disappeared at the end of the

Fig. 5: Total fertility rate in Western and Eastern Germany according to the conventional TFR and the tempo-adjusted TFR*, 1950-2010

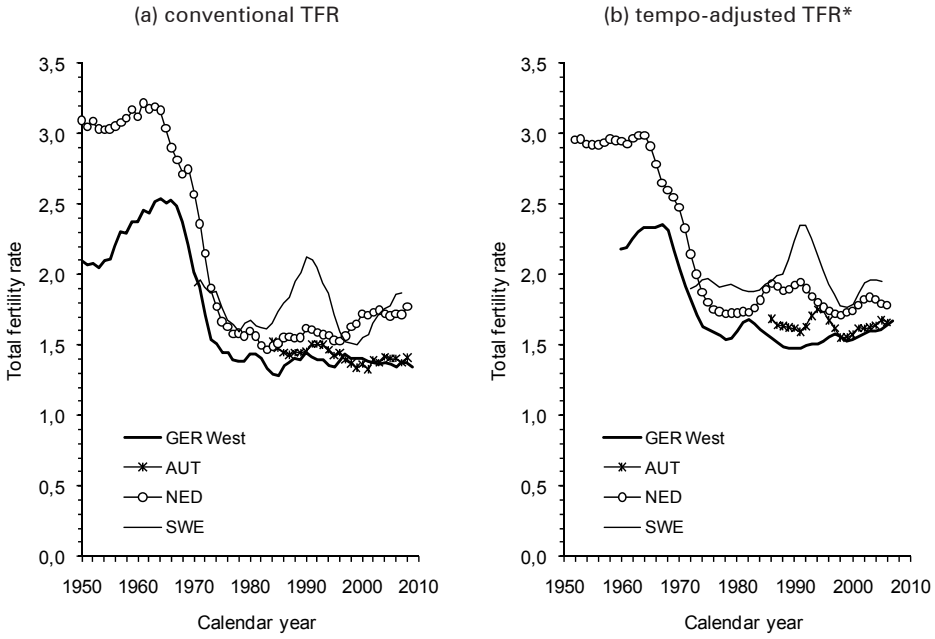


Notes: Values for the tempo-adjusted TFR* from the three-year moving average of the estimates for the single calendar years (see Tab. 2); for the calendar years 1987-1996, the trend for the TFR* in Eastern Germany (years without estimate) was completed by linear interpolation of the values for 1986 and 1997 (dashed line).

observation period. This holds for both versions of the total fertility rate, namely the conventional TFR and the tempo-adjusted TFR*.

Finally, Figure 6 (Western Germany) and Figure 7 (Eastern Germany) show the trends in the TFR as well as in the TFR* in comparison to three other western and eastern European populations for which the corresponding values could be calculated from the Human Fertility Database (HFD) (the TFR* for these populations was calculated analogously to our estimates for Western and Eastern Germany, i.e. using the tempo-adjusted TFR_i* for parities 1, 2 and 3 and the conventional TFR_i for the higher parities, presented by means of three-year moving averages). Equally to what has been done in Figure 5, the graphs on the left-hand side show the conventional TFR and the graphs on the right-hand side show the tempo-adjusted TFR*. The figures are intended to enable us to evaluate the degree to which our estimates of the TFR* for Western and Eastern Germany derived from data sources of different quality can be regarded as plausible. It can be assumed that populations with comparable demographic conditions and trends also show similar trends in tempo effects. This, however, is a more intuitive concept rather than real empirical evidence, More so if one takes into consideration that despite the common features

Fig. 6: Total fertility rate in Western Germany in comparison to other Western European populations according to the conventional TFR and the tempo-adjusted TFR*, 1950-2010



Notes: Values for the tempo-adjusted TFR* for Western Germany (GER West) reflect the three-year moving average of the estimates for the single calendar years (see Tab. 2); values for Austria (AUT), the Netherlands (NED) and Sweden (SWE) calculated with data from the Human Fertility Database (HFD), three-year moving averages.

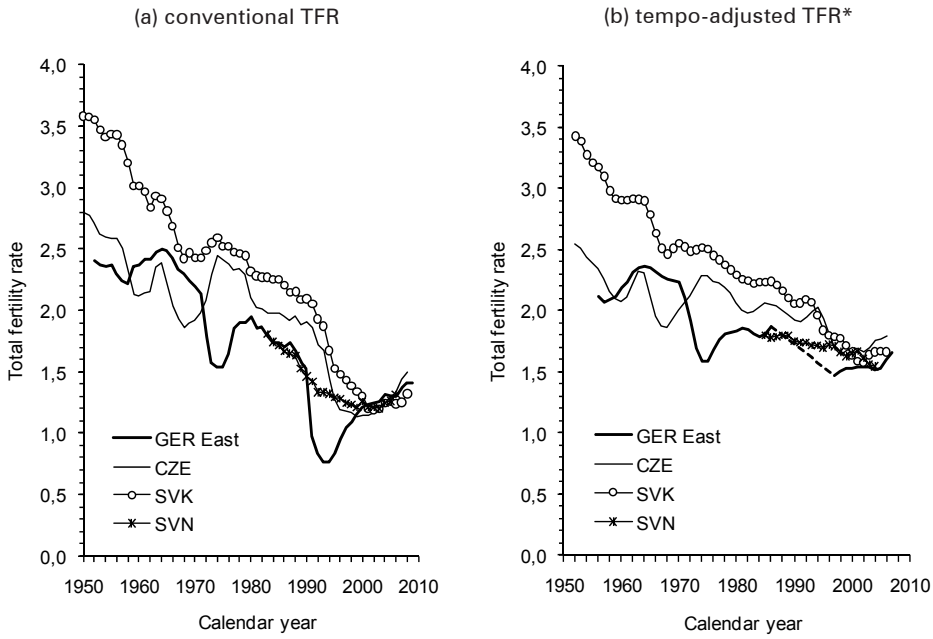
there are also historic and socio-structural differences between the two populations under consideration.

The trends of the conventional TFR in Western Germany, Austria, the Netherlands and Sweden shown in Figure 6a reflect the already known fact that the West German fertility level is located at the low end of the range in other western European populations. Austria is comparable to Western Germany with regard to the level and trend of the TFR since the 1980s (the HFD provides data for Austria only since this time). In Sweden and in the Netherlands, the TFR has increased in the last ten years, in contrast to the stagnation observed in Western Germany and Austria, where it ranges around the level of 1.8 to 1.9 in most recent years. Figure 6b reveals that the estimates for the TFR* of Western Germany are also close to the corresponding values of Austria, for which age- and parity-specific birth numbers of the total population are published directly by the national statistical office (*Statistik Austria*). This finding holds for the mid-1990s onwards. In the years before, at around 1990, the Austrian TFR* shows a strong fluctuation which is not visible in the conventional TFR. All in all, the estimates for the TFR* of Western Germany fit well and plausible into the picture of the Western European populations. Only in the 1980s and early

1990s the estimates for the TFR* seem somewhat too low. An interesting result is that in the most recent years the differences in the total fertility rate between Western Germany and Austria, on the one hand, and Sweden and the Netherlands, on the other, are much smaller when the TFR is tempo adjusted.

Figure 7 also includes one population which seems suitable for comparison with Eastern Germany in order to judge the plausibility of our tempo-adjusted estimates. Roughly since 1980, Slovenia shows a similar trend in the conventional TFR compared to that of Eastern Germany. In the 1990s, however, both differ when no fertility changes comparable to those in Eastern Germany occurred in Slovenia (see Fig. 7a). The two other populations, from the Czech and Slovak Republics, exhibit a much higher TFR until the mid-1990s, but show similar changes in the fertility level as the East German population in the first half of the 1990s (albeit without recovery after the baby bust). The comparison of the estimates for the East German tempo-adjusted TFR* with the corresponding figures for the three other populations in Figure 7b also shows that the estimates for Eastern Germany seem highly plausible.

Fig. 7: Total fertility rate in Eastern Germany in comparison to other eastern European populations according to the conventional TFR and the tempo-adjusted TFR*, 1950-2010



Notes: Values for the tempo-adjusted TFR* for Eastern Germany (GER East) reflect the three-year moving average of the estimates for the single calendar years (see Tab. 2); the trend for the TFR* in Eastern Germany for the calendar years 1987-1996 (years with no estimate) was completed by linear interpolation of the values for 1986 and 1997 (dashed lines); values for the Czech Republic (CZE), the Slovak Republic (SVK) and Slovenia (SVN) are calculated with data from the Human Fertility Database (HFD), three-year moving averages.

There are only minor differences in comparison to the values for Slovenia in the 1980s as well as since the beginning of the 21st century. During the 1990s, the much less pronounced fertility reduction shown by the TFR* in comparison to the conventional TFR fits the examples of the Czech and Slovak Republics very well. Both experienced declines in the conventional TFR similar to those occurring in Eastern Germany during this period.

4 Discussion

As already mentioned in the introduction, the main aim of the work for this article was the compilation of a time series of estimates for the tempo-adjusted total fertility rate in Western and Eastern Germany. To achieve this, we used a variety of data sources from which age- and parity-specific birth numbers could be derived to serve as basis for estimating the tempo-adjusted TFR*. It was possible to construct a complete time series for Western Germany for the years from 1960 to 2007. For Eastern Germany, however, it was not possible to provide such a complete time series. We were able to present estimates (by means of three year averages) for the years 1956 to 1986 and for 1997 to 2007 (the estimates for single calendar years cover the years 1959-2008 for Western Germany and the years 1955-1987 as well as 1996-2008 for Eastern Germany).

Although the idea behind Bongaarts and Feeney's tempo approach (not only for fertility but also for all other demographic events) as well as the arguments of the critics are described in *Luy* (2010), we should add a few remarks with regard to the interpretation and correct attribution of the tempo-adjusted time series presented in this paper. Particularly the question of the interpretation of the tempo-adjusted total fertility rate is not easy to answer, and has already led to a number of misunderstandings in the corresponding demographic literature. The advantage of the conventional TFR is its clear definition and interpretation as the sum of the age-specific fertility rates observed in a given calendar year. In order to explain the meaning of the TFR* as intended by Bongaarts and Feeney, it is necessary to describe this indicator in a broader context.

Independent of the calculation variant (conventional or tempo-adjusted), the aim of the calculation of the total fertility rate for a period is to provide a cross-sectional measure of a population's current fertility. Therefore, only women who are aged between 15 and 49 in the calendar year under observation, i.e. women hence belonging to 35 different cohorts, are considered. The current fertility of these women is influenced to differing degrees by the current political and societal framework and their own reproduction histories. In order to obtain a better understanding of a period measure, one might imagine that the current age-specific fertility conditions are used to construct a scenario for a hypothetical population. All the women of this hypothetical population would realise precisely the given age-specific fertility at any time. In such a scenario, all female cohorts would have the same final average number of children, which equals the average number of children of all women

aged between 15 and 49 living in each calendar year. Demographers refer to such a scenario as a "stable population".

A real population whose current fertility is to be characterised by the total fertility rate is naturally never stable. Consequently, period indicators derived in the logic of the stable population always have to be regarded as purely hypothetical. The idea behind Bongaarts and Feeney's tempo approach is based on the fact that the number of births and the number of women aged between 15 to 49 living in a specific calendar year do not originate from a stable population. Imagine a rather simple exemplary case in which each woman has exactly one child, gives birth at exactly the same age, and that the times of the births are evenly distributed over the year. In this scenario, the sum of the age-specific fertility rates as an indicator of the current fertility would also be exactly one child per woman in any given calendar year. If, however, the age at which the women give birth to their child continually increases (so that a change in birth timing takes place, but not in birth quantum), the cohorts of women being in reproductive ages in a calendar year would have their children over a longer period than one year. In this case, all women living in a specific calendar year would still realise one birth during their lives, but the average value derived from the age-specific fertility rates for this year would be lower than one.

Bongaarts and Feeneys' approach for characterising the fertility of a specific calendar year takes into account that the current fertility of a real population does not originate from a situation in which the age at childbirth of all cohorts currently living remains unchanged. The idea is hence to adjust the time frames of the birth times of the newborns and of the cohorts of mothers (i.e. the numerators and denominators of the age-specific fertility rates) to capture the current birth quantum of the currently living women. The adjustment relates exclusively to the above described expansion effect of the birth period resulting from the increase in the age at childbirth, assuming that the fertility quantum remains unchanged despite the age shift (analogously, when the age at childbirth declines, the reduction effect of the shorter childbirth period would be adjusted for).

In a stable population, the total fertility rate of a calendar year can be regarded as the average number of children born during the life course of all female cohorts currently living. In these terms, the conventional period TFR (i.e. the observed total fertility rate of a specific calendar year) can also be interpreted as the average number of children born by the female cohorts living at the same time in the hypothetical population in the course of their reproductive life span. The prerequisite is that these female cohorts realise exactly the age-specific fertility rates observed in the period, i.e. without changes in birth quantum and birth timing. The tempo-adjusted TFR* is to be equivalently interpreted as the average number of children who are born to the hypothetical female cohorts living at the same time in the course of their reproductive life span if these female cohorts realise the birth quantum of the period observed, defined by the age-specific fertility rates, but with changes in birth timing. When we reduce the interpretation to the single hypothetical cohort usually used, then the TFR* does not reflect the age-specific fertility rates observed in the period, but the age-specific fertility rates adjusted for changes in the birth timing during the observed year (see also *Lesthaeghe/Willems* 1999).

Besides the aspects of birth quantum and birth timing, the age distribution of the parity-specific fertility rates by the age of the women is also relevant with regard to the tempo adjustment according to the Bongaarts and Feeney formula used in this article. It becomes evident from equation (6) that the tempo adjustment is exclusively based on the change in the average age at childbirth of the parities. Thus, the Bongaarts and Feeney formula implies that the distribution of the age-specific fertility rates remains constant when shifting with age. Most of the methodical critics of tempo adjustment focus on this feature of the Bongaarts and Feeney method (see e.g. *van Imhoff/Keilman* 2000; *Kohler/Philipov* 2001; *van Imhoff* 2001; *Yi/Land* 2001). In real populations, the changes in the average age at childbirth are indeed accompanied by variance changes which also exert an influence on the number of children born in a calendar year. Thus, the increase in the average age at childbirth can be caused by both an increase in age-specific fertility in the higher reproductive age and by a fall in the fertility rates among younger women (in the first case, the fertility quantum would increase in the long term; in the latter it would fall). Consequently, very different changes in the age distribution of the parity-specific fertility rates can lead to identical changes in the average age at childbirth, and hence to an identical tempo adjustment with the Bongaarts and Feeney formula. Such cases are not rare and can also be observed in the German population during the calendar years analysed in this paper.

Theoretically it is possible to extend the tempo adjustment to include the effect of changes in the age distribution of the parity-specific fertility rates as proposed by *Kohler* and *Philipov* (2001). In practice, however, feasibility reaches its limit here in most cases because of the detailed nature of the data required. It is therefore important to note that the tempo adjustment with the Bongaarts and Feeney formula is merely an approximation of the intended adjustment of the total fertility rate (see *Luy* 2010 for details). However, the criticism of the non-consideration of variance effects can be countered by two arguments: The first concerns the relative significance of changes in the average age at childbirth and in the age distribution of the age-specific fertility rates for the numbers of births occurring in a specific calendar year. As *Dinkel* (1989) has shown by simulations, changes in the average age at childbirth have a much larger impact on the birth numbers than changes in the variance of the fertility distribution. It is not likely that the non-consideration of variance changes leading to an incorrect direction of the tempo adjustment with the Bongaarts and Feeney formula occurs frequently, albeit its absolute extent can indeed be distorted. The second argument is that the conventional TFR does not at all account for changes in birth timing. Consequently, also *Kohler* and *Philipov* (2001) concluded that an adjustment of the total fertility rate with the Bongaarts and Feeney formula is better for the analysis of period fertility than completely excluding tempo adjustment.

This discussion, however, is not aimed to ascertain which measure is better suited to characterise period fertility. One should not forget that the TFR and the TFR* are both pure period indicators, and hence both solely reflect hypothetical average birth numbers. In case of the conventional TFR, this hypothetical average birth number is based on the *observed fertility rates* of a calendar year, and in the

case of the tempo-adjusted TFR* on the *estimated birth quantum* of the women living in this calendar year. The latter cannot be measured, but only modelled, which is certainly a weakness of the TFR* compared to the conventional total fertility rate. Ultimately, the two indicators are based on somewhat different reference quantities. For the analysis of period fertility it is thus most informative to use them parallel and supplementing one another, as it was done in all the papers listed in the introduction.

Regarding the empirical results presented in this article, it can be stated that the two fertility indicators – the conventional TFR and the tempo-adjusted TFR* – identify different phases in fertility trends in Western and Eastern Germany. In both parts of the country, the TFR* is lower than the TFR until the end of the 1960s. This is a consequence of the decline in the average age at childbirth, in particular with regard to the first and second births. The age of the women at the birth of their children rises markedly in Western Germany in the 1970s and 1980s. As a consequence, the tempo-adjusted TFR* is on average almost 0.18 higher than the conventional TFR during the years from 1971 to 1987. In the former GDR, by contrast, the age at childbirth remained relatively constant in this period, so that the tempo-adjusted TFR* and the conventional TFR do not differ significantly. Since the beginning of the 1990s, the average age at childbirth of Western German women rises once more after a brief phase of relative stability. This trend causes an increasing deviation between the estimated TFR* and the conventional TFR in Western Germany. In Eastern Germany, we can only presume that the difference between the two indicators was particularly large in the first half of the 1990s. This is suggested by several indicators pointing towards a rapid increase in the age at childbirth of Eastern German mothers. An idea of the extent of this difference is provided by the estimates for the second half of the 1990s. The difference between the tempo-adjusted TFR* and the conventional TFR in the years 1997-1999 is between 0.37 and 0.43. In the years from 2000 to 2007, the TFR* in Eastern Germany is on average 0.28 higher than the conventional TFR.

Hence, the combined picture of the conventional TFR and the tempo-adjusted TFR* provides interesting results with regard to the trends in period fertility in Western and Eastern Germany, which were not analysed in detail in this paper. This applies above all to the West-East differences in the overall trend and the massive tempo effects in Eastern Germany during the 1990s. Since 2009 it is possible to analyse level and trends of fertility in Germany with tempo-adjusted fertility rates on the basis of parity-specific data for all births from official statistics. For the period prior to this we have compiled the best possible estimates. Even if these estimates are not comparable with the data of official statistics in qualitative terms, the data presented in this paper enables researchers to include the population of Western and Eastern Germany in future research on international trends in tempo-adjusted period fertility.

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Annex 1: Estimated subdivision of the conventional total fertility rate TFR for Western and Eastern Germany into the parity-specific TFR_is, 1954-2009

	Western Germany					Eastern Germany				
Year	TFR_1	TFR_2	TFR_3	TFR_{4+}	TFR	TFR_1	TFR_2	TFR_3	TFR_{4+}	TFR
1954	--	--	--	--	2.10	0.93	0.71	0.36	0.35	2.35
1955	--	--	--	--	2.11	0.93	0.71	0.37	0.35	2.35
1956	--	--	--	--	2.20	0.88	0.68	0.37	0.36	2.26
1957	--	--	--	--	2.30	0.85	0.66	0.36	0.36	2.21
1958	0.94	0.67	0.37	0.31	2.29	0.85	0.65	0.36	0.37	2.21
1959	0.97	0.69	0.39	0.33	2.37	0.89	0.67	0.38	0.41	2.35
1960	0.97	0.69	0.38	0.32	2.37	0.90	0.65	0.37	0.41	2.33
1961	1.00	0.72	0.40	0.34	2.46	0.95	0.66	0.38	0.43	2.40
1962	1.00	0.71	0.39	0.34	2.44	0.97	0.66	0.36	0.43	2.42
1963	1.02	0.74	0.41	0.35	2.52	0.99	0.68	0.37	0.43	2.47
1964	1.02	0.75	0.41	0.35	2.54	0.99	0.69	0.37	0.44	2.51
1965	1.02	0.75	0.40	0.34	2.51	1.00	0.70	0.36	0.42	2.48
1966	1.04	0.75	0.41	0.33	2.53	0.98	0.70	0.36	0.38	2.42
1967	1.03	0.75	0.39	0.31	2.49	0.96	0.69	0.35	0.34	2.34
1968	0.99	0.72	0.37	0.29	2.38	0.95	0.69	0.34	0.31	2.30
1969	0.93	0.67	0.34	0.26	2.21	0.96	0.68	0.33	0.27	2.24
1970	0.88	0.61	0.30	0.22	2.02	0.98	0.67	0.30	0.24	2.19
1971	0.86	0.59	0.28	0.20	1.92	0.97	0.66	0.29	0.22	2.14
1972	0.78	0.53	0.24	0.17	1.71	0.90	0.54	0.19	0.14	1.79
1973	0.70	0.48	0.21	0.15	1.54	0.88	0.48	0.12	0.09	1.58
1974	0.70	0.48	0.19	0.13	1.51	0.87	0.48	0.11	0.08	1.54
1975	0.68	0.46	0.19	0.12	1.45	0.87	0.50	0.10	0.07	1.54
1976	0.68	0.47	0.18	0.11	1.45	0.90	0.55	0.11	0.07	1.64
1977	0.67	0.46	0.17	0.10	1.40	0.96	0.68	0.13	0.07	1.85
1978	0.66	0.46	0.17	0.09	1.38	0.99	0.70	0.14	0.07	1.90
1979	0.65	0.46	0.17	0.09	1.38	0.98	0.70	0.14	0.07	1.89
1980	0.69	0.48	0.18	0.09	1.44	1.01	0.70	0.16	0.07	1.94
1981	0.69	0.48	0.19	0.09	1.44	0.95	0.69	0.15	0.07	1.85
1982	0.68	0.47	0.18	0.08	1.41	0.93	0.70	0.16	0.07	1.86
1983	0.64	0.45	0.17	0.07	1.33	0.89	0.67	0.16	0.07	1.79
1984	0.61	0.44	0.17	0.07	1.29	0.85	0.65	0.16	0.07	1.74
1985	0.61	0.44	0.17	0.07	1.28	0.83	0.64	0.19	0.08	1.73
1986	0.66	0.48	0.15	0.06	1.35	0.81	0.63	0.18	0.08	1.70
1987	0.67	0.47	0.16	0.06	1.37	0.81	0.65	0.20	0.08	1.74
1988	0.69	0.49	0.17	0.07	1.41	0.78	0.62	0.19	0.08	1.67
1989	0.69	0.48	0.17	0.07	1.40	--	--	--	--	1.57
1990	0.71	0.49	0.17	0.07	1.45	--	--	--	--	1.52
1991	0.71	0.47	0.17	0.07	1.42	--	--	--	--	0.98
1992	0.70	0.47	0.17	0.07	1.40	--	--	--	--	0.83
1993	0.69	0.47	0.17	0.06	1.39	--	--	--	--	0.77

Annex 1 (continuation)

	Western Germany					Eastern Germany				
Year	TFR_1	TFR_2	TFR_3	TFR_{4+}	TFR	TFR_1	TFR_2	TFR_3	TFR_{4+}	TFR
1994	0.68	0.45	0.16	0.06	1.35	--	--	--	--	0.77
1995	0.67	0.45	0.16	0.06	1.34	0.42	0.28	0.09	0.05	0.84
1996	0.66	0.50	0.17	0.08	1.40	0.49	0.31	0.09	0.06	0.95
1997	0.70	0.49	0.17	0.08	1.44	0.53	0.35	0.11	0.05	1.04
1998	0.69	0.49	0.16	0.07	1.41	0.58	0.35	0.11	0.05	1.09
1999	0.69	0.48	0.16	0.08	1.41	0.62	0.36	0.11	0.06	1.15
2000	0.68	0.51	0.16	0.06	1.41	0.66	0.38	0.11	0.06	1.21
2001	0.68	0.48	0.15	0.07	1.38	0.68	0.39	0.11	0.06	1.23
2002	0.68	0.47	0.15	0.07	1.37	0.69	0.40	0.11	0.05	1.24
2003	0.67	0.48	0.15	0.07	1.36	0.69	0.41	0.11	0.05	1.26
2004	0.67	0.48	0.16	0.07	1.37	0.71	0.42	0.12	0.06	1.31
2005	0.66	0.48	0.15	0.07	1.36	0.70	0.42	0.12	0.06	1.30
2006	0.65	0.47	0.16	0.07	1.34	0.69	0.43	0.13	0.06	1.30
2007	0.67	0.47	0.16	0.07	1.37	0.72	0.46	0.13	0.06	1.37
2008	0.67	0.47	0.16	0.07	1.37	0.73	0.47	0.14	0.07	1.40
2009	0.67	0.45	0.15	0.07	1.35	0.72	0.48	0.14	0.07	1.40

Notes: -- no estimates available; data basis of the estimates for Western Germany for the years 1958-1985 *Birg et al.* (1990), 1986-1995 *Kreyenfeld* (2002), 1996-1999 perinatal survey, 2000 official statistics (marital births), 2001-2008 *Kreyenfeld et al.* (2010), 2009 official statistics (all births); data basis of the estimates for Eastern Germany for the years 1954-1988 official statistics of the GDR, 1995-2000 perinatal survey, 2001-2008 *Kreyenfeld et al.* (2010), 2009 official statistics (all births); deviations between the sum of the parity-specific TFRi and the total TFR are caused by rounding errors.

Annex 2: Estimated subdivision of the tempo-adjusted total fertility rate TFR* for Western and Eastern Germany into the parity-specific TFR_i*s, 1954-2009 (annual values)

	Western Germany					Eastern Germany				
Year	TFR_1*	TFR_2*	TFR_3*	TFR_{4+}*	TFR*	TFR_1*	TFR_2*	TFR_3*	TFR_{4+}*	TFR*
1954	--	--	--	--	--	--	--	--	--	--
1955	--	--	--	--	--	0.82	0.67	0.31	0.26	2.16
1956	--	--	--	--	--	0.81	0.60	0.32	0.27	2.08
1957	--	--	--	--	--	0.80	0.61	0.33	0.30	2.10
1958	--	--	--	--	--	0.72	0.60	0.34	0.33	2.03
1959	0.86	0.64	0.37	0.30	2.19	0.75	0.61	0.37	0.38	2.15
1960	0.84	0.62	0.36	0.30	2.15	0.81	0.58	0.37	0.40	2.17
1961	0.87	0.63	0.36	0.33	2.20	0.87	0.56	0.36	0.43	2.23
1962	0.90	0.63	0.36	0.34	2.22	0.92	0.60	0.36	0.44	2.31
1963	0.92	0.68	0.38	0.36	2.32	0.94	0.66	0.36	0.47	2.40
1964	0.93	0.69	0.40	0.38	2.37	0.95	0.63	0.34	0.46	2.35
1965	0.92	0.66	0.38	0.35	2.30	0.97	0.63	0.32	0.40	2.35
1966	0.94	0.68	0.38	0.34	2.33	0.97	0.67	0.33	0.35	2.34
1967	0.96	0.71	0.40	0.35	2.38	0.96	0.65	0.32	0.33	2.27
1968	0.91	0.75	0.43	0.35	2.37	0.92	0.68	0.33	0.33	2.24
1969	0.84	0.71	0.38	0.30	2.19	0.91	0.71	0.36	0.33	2.26
1970	0.84	0.59	0.30	0.24	1.96	0.92	0.71	0.36	0.29	2.23
1971	0.91	0.57	0.27	0.20	1.95	0.93	0.73	0.34	0.29	2.21
1972	0.90	0.55	0.23	0.16	1.84	0.92	0.62	0.20	0.19	1.88
1973	0.84	0.49	0.18	0.12	1.66	0.90	0.52	0.12	0.11	1.63
1974	0.86	0.48	0.17	0.10	1.64	0.88	0.48	0.12	0.08	1.56
1975	0.80	0.49	0.18	0.10	1.59	0.89	0.49	0.10	0.06	1.55
1976	0.78	0.52	0.19	0.10	1.60	0.91	0.56	0.11	0.06	1.65
1977	0.77	0.52	0.17	0.09	1.56	0.91	0.71	0.13	0.07	1.82
1978	0.76	0.50	0.17	0.08	1.53	0.92	0.69	0.14	0.06	1.82
1979	0.73	0.50	0.19	0.09	1.51	0.92	0.64	0.15	0.06	1.78
1980	0.78	0.53	0.20	0.10	1.60	0.96	0.66	0.16	0.06	1.85
1981	0.84	0.55	0.21	0.10	1.68	0.95	0.67	0.16	0.06	1.86
1982	0.88	0.54	0.20	0.09	1.71	0.94	0.70	0.17	0.07	1.88
1983	0.87	0.52	0.19	0.08	1.65	0.89	0.67	0.17	0.07	1.81
1984	0.79	0.54	0.18	0.07	1.58	0.86	0.65	0.17	0.07	1.74
1985	0.81	0.55	0.18	0.07	1.60	0.87	0.66	0.20	0.07	1.81
1986	0.76	0.55	0.17	0.06	1.54	0.91	0.68	0.22	0.09	1.89
1987	0.74	0.54	0.17	0.06	1.51	0.91	0.70	0.23	0.09	1.92
1988	0.71	0.54	0.17	0.07	1.49	--	--	--	--	--
1989	0.70	0.52	0.17	0.07	1.45	--	--	--	--	--
1990	0.73	0.52	0.18	0.07	1.50	--	--	--	--	--
1991	0.74	0.50	0.17	0.07	1.47	--	--	--	--	--
1992	0.76	0.48	0.17	0.06	1.47	--	--	--	--	--
1993	0.79	0.51	0.16	0.06	1.53	--	--	--	--	--

Annex 2 (continuation)

	Western Germany					Eastern Germany				
Year	TFR_1*	TFR_2*	TFR_3*	TFR_{4+}*	TFR*	TFR_1*	TFR_2*	TFR_3*	TFR_{4+}*	TFR*
1994	0.80	0.50	0.16	0.06	1.52	--	--	--	--	--
1995	0.72	0.52	0.15	0.07	1.47	--	--	--	--	--
1996	0.78	0.57	0.16	0.08	1.58	0.75	0.49	0.12	0.07	1.42
1997	0.75	0.60	0.21	0.10	1.64	0.72	0.55	0.15	0.06	1.48
1998	0.74	0.54	0.16	0.06	1.51	0.78	0.52	0.16	0.07	1.51
1999	0.75	0.56	0.16	0.06	1.53	0.83	0.49	0.14	0.06	1.52
2000	0.74	0.57	0.16	0.06	1.53	0.93	0.46	0.10	0.05	1.55
2001	0.75	0.58	0.17	0.06	1.55	0.93	0.45	0.10	0.05	1.53
2002	0.80	0.55	0.17	0.07	1.58	0.88	0.47	0.12	0.05	1.52
2003	0.82	0.55	0.17	0.07	1.61	0.90	0.48	0.11	0.05	1.55
2004	0.82	0.56	0.17	0.07	1.62	0.87	0.50	0.12	0.06	1.54
2005	0.78	0.55	0.17	0.07	1.57	0.78	0.48	0.14	0.07	1.45
2006	0.80	0.57	0.19	0.08	1.63	0.80	0.57	0.16	0.06	1.59
2007	0.85	0.59	0.20	0.08	1.71	0.89	0.63	0.16	0.07	1.75
2008	0.83	0.57	0.18	0.08	1.66	0.78	0.60	0.18	0.11	1.62
2009	--	--	--	--	--	--	--	--	--	--

Notes: -- no estimates available; data basis of the estimates for Western Germany for the years 1959-1984 *Birg et al*. (1990), 1985 combination *Birg et al.* (1990)/*Kreyenfeld* (2002), 1986-1994 *Kreyenfeld* (2002), 1995 combination *Kreyenfeld* (2002)/perinatal survey, 1996-1998 perinatal survey, 1999-2001 official statistics (marital births), 2002-2007 *Kreyenfeld et al.* (2010), 2008 combination *Kreyenfeld et al.* (2010)/official statistics (all births); data basis of the estimates for Eastern Germany for the years 1955-1987 official statistics of the GDR, 1996-1999 perinatal survey, 2000-2001 combination perinatal survey/*Kreyenfeld et al.* (2010), 2002-2007 *Kreyenfeld et al.* (2010), 2008 combination *Kreyenfeld et al.* (2010)/official statistics (all births); total TFR* calculated from $TFR_1^* + TFR_2^* + TFR_3^* + TFR_{4+}$ (see section on data and methods).

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