*Демографическое обозрение / Demographic Review*
*2024;11(4) 4-43 DOI: https://doi.org/10.17323/demreview.v11i4.24288*

# The intensity of fertility decline is increasing worldwide: Is a low fertility trap increasingly likely?

*Pavel Kishenin (pkishenin@hse.ru),*
*HSE University, Russia.*

*Angelina Zinina (ai.zinina@hse.ru),*
*HSE University, Russia.*

*Tatyana Maksimova (tmaksimova@hse.ru),*
*HSE University, Russia.*

***Abstract:*** *The paper examines mainstream theoretical concepts of low fertility existing in demography, with particular attention to types and models of fertility convergence. The aim is to assess the increasing likelihood of the low-fertility trap model compared to other models of fertility convergence. To do that, we review major theoretical concepts of lowest-low fertility in demography, describe the types and models of fertility convergence, and evaluate the potential consequences of a low-fertility trap scenario.*
*The analysis is based on the Institute for Health Metrics and Evaluation (IHME) international database covering more 200 countries and dependent territories. We examined trends in the total fertility rate (TFR) and estimated tempo-adjusted TFRs using the Bongaarts-Feeney method for 2020-2025, and analyzed projected TFRs and completed cohort fertility as estimated by leading international organizations performing long-term demographic projections (IHME, IIASA and the UN Population Division).*
*Our findings show that since the early 2010s, all countries of the world have experienced a marked acceleration in the decline of period TFR. In more countries demographically modernizated, part of this decline can be attributed to the increase in the age at childbearing (tempo-effect), but there is also evidence of a decline in the intensity of childbearing itself (quantum-effect). Together, these patterns point to a sharp increase in the probability of a low-fertility trap.*
*Recent rounds of projections by IHME, IIASA, and the UN Population Division (2023-2024) increasingly incorporate the low-fertility trap model in forecasting the future of fertility in all countries of the world. This suggests that the low-fertility trap scenario may represent the most likely trajectory among models of fertility convergence.*

***Keywords:*** *fertility, low-fertility trap, theories of low fertility, models of fertility convergence, long-term demographic projections, IHME database.*

***Funding:*** *This research paper uses the results of projects carried out under the Fundamental Research Program of the HSE University.*

***For citation:*** *Kishenin P., Zinina A., & Maksimova T. (2024). The intensity of fertility decline is increasing worldwide: Is a low fertility trap increasingly likely?. Demographic Review, 11(4), 4-43.*
*DOI: https://doi.org/10.17323/demreview.v11i4.24288*

## Introduction

The future population of the Earth depends primarily on what is the most likely mode of population reproduction, a question which remains highly controversial. Some experts believe that a significant decrease in the population is inevitable due to long-term low fertility (Lutz, Scherbov, Gietel-Basten 2013); others foresee a slight decrease in the population due to moderately low fertility throughout the 21st and first half of the 22nd centuries (Vollset et al. 2020); still others consider possible a stabilization of the planet's population at around 9-10 billion people and a rapid return to fertility at the level of population instant-replacement (United Nations 2020).

The key question raised in this study is how much fertility could decline around the world. Determining the limits of the world's population and the potential for human depopulation directly depends on understanding which of the hypothetically possible models of fertility convergence will be realized in the future. Based on the research of a number of experts (Coleman, Rowthorn 2011; Lutz, Scherbov, Gietel-Basten 2013; Vollset et al. 2020), this article puts forward the hypothesis that fertility data in recent years already indicate a significant acceleration in the rate of decline in fertility and the potential for the realization of the low fertility trap model. This also leads to a second hypothesis, that the main international organizations doing long-term demographic forecasting in their latest analytical reports and forecasts take into account a sharp increase in the likelihood of such a demographic scenario. Confirmation or refutation of these hypotheses is important, since the low fertility trap leads to a number of negative and positive consequences for which state and public institutions must prepare.

In demographic forecasts up to the end of the 2010s – beginning of the 2020s, the main hypotheses (Anderson 2014; Kishenin 2023) most often included assumptions about the stabilization in all countries of the period total fertility rate (*the total fertility rate of hypothetical cohort, PTFR*) and the completed cohort fertility rate (*the total fertility rate of birth cohort*, *CCFR*) at the level of 1.25-1.75 children per woman with a slow and gradual long-term return of fertility to the level of population instant-replacement (2.05-2.15 children per woman). However, in the last two or three years, as data on the acceleration of the rate of decline in fertility has appeared, forecasts have increasingly turned towards the possibility of realizing the *low-fertility trap hypothesis*, i.e. a decrease in fertility to very low values (*lowest-low fertility*), to PTFR (*fictitious low fertility trap*) or CCFR (*actual low fertility trap*) indicators remaining steadily and in the long term at levels below 1.25-1.30 children per woman.

Already now, in a number of countries and territories in East and Southeast Asia[1] (Macau, Hong Kong, Singapore, South Korea, Taiwan, North Korea and the urban population of the PRC) with a lower level of gender equality in the family and household sphere compared to European and North American countries[2] (Hou, Ma, Huang 2008; Kan, Hertog 2017), there is a decrease in the desired and ideal number of children in the direction of increasing the prevalence of reproductive intentions to limit oneself to one child. Under the influence of this and other factors

[1] Countries and territories in East and South-East Asia have the largest time gap between men and women for childcare and household.

[2] The emphasis here is on gender inequality in the family and domestic sphere, as it includes inequalities in the distribution of household responsibilities and therefore a greater burden on women’s time budgets, which directly affects fertility.

(the second demographic transition, aging of the age profile of fertility, increasing population density, etc.), there is a prospect of maintaining PTFR at a very low level of 0.60-0.80 children per woman with the continuation of the aging of motherhood and 0.80-1.10 children per woman in the context of the eventual end of such aging (Demeny 2015).

In this article, based on PTFR data for a wide range of countries of the world, presented in the research and projections of the Institute for Health Metrics and Evaluation (IHME)[3] for 2005-2025 in the version of February-March 2024, the adjusted total fertility rate was calculated using the Bongaarts-Feeney method (*tempo-adjusted total fertility rate, taTFR*) in order to determine the contributions of aging fertility and intensity of childbearing (*tempo- and quantum effects dimensions of fertility*). The paper compares these indicators in terms of the dynamics of absolute and relative values.

To confirm the assumption about taking into account the low fertility trap model in demographic projections, we analyzed data from various PTFR projection variants for the period 2025-2100 of IHME, from the SSP-1, SSP-2 and SSP-5 variants of the International Institute for Applied Systems Analysis (IIASA) forecast of December 2023, and from the low and median fertility variants of the World Population Prospects 2024 revision of the UN Population Division. They include a decrease in PTFR to levels of 0.60-1.45 children per woman by country, as well as the idea that a long-term return of fertility to the level of population instant-replacement is either impossible or will occur much later: previous ideas that the decline in the desired and ideal number of children will stop between 1.70 and 2.00 children per woman clearly do not correspond to the actual dynamics of both real dynamics of fertility and the expected number of children.

An important limitation of the study is the low quality of data for many developing countries, in particular for states and territories with the highest fertility. It should also not be forgotten that fertility forecasts take into account, in one way or another, a variety of theoretical concepts both on the determinants of low and very low fertility, and on the types and models of fertility convergence. To demonstrate a possible scenario of fertility decline according to the actual low fertility trap model, the authors describe the calculation of the CCFR forecast of the IIASA SSP-5 variant based on data on age-specific fertility rates.

## Theoretical explanations for very low fertility

The decline in fertility began in the second half of the 18th century in Western and Northern Europe, but in most countries of the world, a decline in fertility was recorded only in the second half of the 20th century and continues to this day. According to estimates by the UN Population Division, in demographically developed countries of the world, the fertility rate had reached 2.8 children per woman since 1950 to 1960 year, but by 2010 the values had decreased to 1.58 (United Nations 2020; United Nations 2022). In the 1990s and 2000s, fertility in the countries of Southern, Central and Eastern Europe fell to very low levels, amounting to less than 1.3 children per woman (Anderson 2014: 65). PTFR became significantly lower in all countries compared to the mid-20th century (Kohler, Billari, Ortega 2002), although the dynamics of the indicator often undulated. For example, in the 1980s, PTFR increased in Eastern and Central Europe, while it declined in Northern, Western and Southern Europe, which was followed by

[3] For more information on the Institute for Health Metrics and Evaluation (ICME) and its databases, see: https://www.healthdata.org/about

opposite trends in the 1990s.

Population projections by major international organizations in the 1990s and early 2000s (Lutz 1996; United Nations 2004; World Bank, Eurostat 2010) suggested that future fertility levels would gradually approach the replacement level, when PTFR takes on values of 2.06–2.15 children per woman (Anderson 2014). In the late 2000s and early 2010s, the vast majority of demographically developed countries and territories, as well as individual developing countries (mainly with a rapid increase in the population structure of such groups for which demographic modernization would be lagging - for example, the countries of Central Asia, Israel, a some states in Oceania and sub-Saharan Africa), were looking at stabilization or even a slight increase in PTFR, but this was a temporary phenomenon caused by the slowdown in the aging of fertility (Wilson 2011), as can be easily seen from the CCFR data (Kishenin 2023: appendices, table A2).

The decline of fertility to very low values is associated with a number of factors (Poston 2018):

- the second demographic transition and the aging of fertility;
- modernization of society, which led not only to a decrease in fertility below the level of simple population replacement, but also to a parallel increase in individual autonomy and the transformation of family relations (*family transition*) (Dalla Zuanna, Micheli 2004);
- urban transition and growth in population density;
- gender transition and a lagging decrease in gender inequality in society and the family, which resulted in the phenomenon of the *feminist paradox* (McDonald 2000).

One of the signs of the second demographic transition (Sobotka 2017) was a change in the usual norms and values of family formation, expressed in a shift in the average age of the mother at the birth of a child in general and in lower birth orders (first and second children, to a lesser extent third children) to later ages (Sobotka 2017). Postponing the birth of children for several years helps to achieve stability in the labor market, accumulate resources to provide for children, and buy housing, often not leading to the same significant decrease in CCFR as in PTFR (Sobotka, Matyziak, Brzozowska 2019: 14). The reason for this is that women do not have time to leave active reproductive age, the range of reproductive age itself increases (Bloom, Canning 2007) and the use of assisted reproductive technologies expands (Lazzari et al. 2023).

The decrease in PTFR levels in demographically developed countries is associated not only with the aging of fertility of the native population, but also with the role of migrants - coming mainly from countries with a delayed demographic transition in fertility, in demographically developed countries their PTFR is significantly overestimated due to the effect of fictitious rejuvenation of fertility, i.e. the rapid disappearance of higher order births, which leads to a nominal decrease (or stagnation) in the average age of the mother at the birth of a child as a whole with an actual increase in the average age of the mother at the birth of the first and second children (Sobotka 2018). Although the fictitious rejuvenation of fertility leads to a temporary overestimation of PTFR and some other fertility indicators of hypothetical cohorts, the fertility of female birth cohorts among migrants decreases quite quickly to the levels of the native population (Schoen 2022).

An important role in reducing fertility to very low values is played by the socio-economic modernization of society (Livi-Bacci 2017). An increase in the standard of living, expanded access to education and career opportunities, and individualization of the life course have contributed to both a decrease in fertility due to the ability to control reproductive behavior and an increase in personal autonomy, as well as family transition as a process of modernization of the family and marriage, expressed in the freedom to choose family and marital relations and the pluralism of forms of family and marriage (Anderson, Kohler 2015: 383). At the same time, in a society after economic modernization, any decrease in the standard of living or in female employment under the pretext of social conservatism leads to an additional decrease, rather than an increase, in fertility (Neyer, Lappegård, Vignoli 2013).

The *contraceptive revolution* of the 1960s contributed to an increase in the proportion of women willing to combine work and family (Bernstein, Jones 2019), which is reflected in *preference theory* (Hakim 1998). This theory states that the growth of human capital in turn leads to an increase in the proportion of women who are able to completely or almost completely control their sexual and reproductive behavior, and hence the possibility of very low fertility through only planned and desired pregnancies and children (Rindfuss, Choe, Brauner-Otto 2016: 294). Thus, the increase in the possibility of reproductive control due to the availability of a choice of the number of children that corresponds to the reproductive intentions of the parents, has additionally accelerated the decline in fertility (de Silva, Tenreyro 2017: 223).

An important factor in the accelerating decline in fertility is the continuing growth in urbanization in almost all countries: thus, with rare exceptions, in rural areas fertility is higher compared to urban areas, and among the urban population, the lower the fertility, the larger the city or urban agglomeration (Adhikari, Lutz, KC 2023). The attractiveness of urban areas is due not only to a more comfortable standard of living for the population, but also to a higher level of median wages, which is to some extent offset by the high costs of housing and raising children. Lower fertility in urban areas, in fact, is also associated with the transition to a more modernized lifestyle from a social and economic point of view, which is accompanied in particular by an increase in the education of the entire population as a whole and, above all, an increase in female education (De Silva, Tenreyro 2017: 221). An increase in population density also plays a significant role (Vollset et al. 2020), which, all other things being equal, contributes to either a fall in the fertility rate or its stabilization at ultra-low values.

An equally important feature of demographic modernization is that demographically developed countries with a high level of income and high gender egalitarianism of society have fertility rates in hypothetical and birth cohorts higher than countries with a lower level of gender equality (Bloom, Kuhn, Prettner 2023: 14), a phenomenon referred to as the *feminist paradox*. Despite the fact that gender equality makes it possible to stabilize fertility at a higher level, PTFR is below the level of simple replacement even in demographically developed countries with a high degree of egalitarianism, and in countries with a high level of gender inequality, fertility falls even faster and often to extremely low values.

Similar dynamics of PTFR and CCFR in connection with changes in gender inequality also take place in more demographically modernized developing countries, which leads demographers to the idea of the universality of this relationship (Mazzuco, Keilman 2020). It is precisely the reduction of gender inequality, including through expanding the availability of female education and reducing the double burden on women's time budgets through a more equal distribution of family and household labor between spouses with the participation of third parties (relatives at earlier stages and public and state institutions at later stages of the demographic transition in fertility), that may become the key to long-term stabilization of fertility (Neyer, Caporali, Gassen 2017; United Nations 2024a).

The decline in fertility below the instant-replacement level has led to attempts to implement active pro-natalist policies in a number of countries (Schleutker 2013). By 2018, 66% of European and about 40% of Asian countries had at least once introduced measures to prevent a further decline in fertility or to stabilize it (Bergsvik, Fauske, Hart 2021: 914). Studies show that such policies lead to an increase in PTFR due to timing translations in the birth calendar, but do not cause an increase in CCFR, and in some cases even a slight additional decrease in CCFR has been noted due to the inhibition of gender and family transitions (Botev 2015; Bergsvik, Fauske, Hart 2021).

It should be noted that researchers have repeatedly called for caution in using PTFR as an indicator of the effectiveness of population policy (Beaujouan 2020; Hellstrand, Nisén, Myrskylä 2020: 3), due to the sensitivity of this indicator to changes in the distribution of births over time, which "increases the TFR if women have children at increasingly earlier ages, and decreases it if they postpone childbearing to later reproductive ages" (Sobotka, Lutz 2011).

Using fertility rates of birth cohorts allows us to eliminate the influence of timing translations. For demographically developed countries, four types of geographic changes in CCFR levels can be distinguished (Hellstrand et al. 2021), with a tendency for a more intense decline in regions that began the demographic transition in fertility earlier:

1. countries of Western (Bongaarts, Sobotka 2012) and Northern Europe (Hellstrand, Nisén, Myrskylä 2020), the USA (Guzzo, Hayford 2023), Canada, Australia and New Zealand;
2. countries of Southern Europe, including the Balkan states (Čipin, Zeman, Međimurec 2020);
3. countries of Central and Eastern Europe (Myrskylä, Goldstein, Cheng 2013);
4. East and Southeast Asian countries (Frejka 2017: 97-102; Jones 2019; Hwang 2023).

The cohort method for studying fertility is also used to analyze the dynamics of CCFR in countries in Africa, Asia (except East and Southeast Asia), Oceania and Latin America (Alders, de Beer 2004; Bricker, Ibbitson 2019; Reiter, Goujon, KC 2022; Whittaker 2022), which was largely the result of increasing levels of female education (Durowaa-Boateng, Yildiz, Goujon 2023: 14).

During the demographic transition, there was initially a divergence of fertility across countries: in some countries, fertility began to decline, while in others it remained at a fairly high level. However, later on, the decline in fertility in these countries proceeded at a faster pace, which allowed allows us to talk about the convergence of fertility levels in different countries.

## Types and models of fertility convergence

It is necessary to distinguish between types and models of convergence. The types of convergence determine (Dorius 2008: 520) how close to each other the PTFR and CCFR values between countries will be in the future. Convergence models allow us (Reher 2019) to predict at what levels and for which groups of countries convergence will occur in the future.

Among the types of fertility convergence, the classic distinction is between weak and strong convergence (Andreson 2014). Weak convergence assumes a difference of more than 5% in the PTFR (fictitious weak convergence) or CCFR (actual weak convergence) between countries with minimum and maximum fertility for these indicators. Strong convergence implies a difference of less than 5% (Castiglioni, Dalla-Zuanna, Tanturri 2020). It is also possible to consider beta- and sigma-convergence of fertility (Rindfuss, Choe 2015). The idea of beta-convergence is that, in countries with a higher PTFR and CCFR, the rate of decline in fertility is higher than in those countries where the initial level of the analyzed PTFR and CCFR was lower: for example, countries of Eastern and Central Europe compared to Northern and Western Europe. Sigma-convergence describes how fertility gradually declines in countries with lower PTFR and CCFR values, and as a result of the demographic transition, countries with beta-convergence of fertility should show lower values than countries with sigma-convergence for both PTFR and CCFR, but for CCFR the difference should be somewhat smaller (Wilson 2011: 376).

Convergence models explain fertility change depending on the historical-geographical and socio-economic group in the context of earlier or later demographic and social modernization to which a country belongs, as well as on the assumption as to the level at which fertility will stabilize in the future (Gietel-Basten, Sobotka, Zeman 2014). There are five models of fertility convergence: global return to population instant-replacement, long-term return to population instant-replacement, global equilibrium of moderately low fertility, long-term equilibrium of moderately low fertility, and a low-fertility trap.

The *model of global return to population instant-replacement* consists in the establishing of demographic equilibrium: stabilization of PTFR and CCFR at the level of population instant-replacement as social and economic modernization continues (Vollmer, Strulik 2015: 34). It is assumed that in countries with fertility above the level of simple population replacement, PTFR will decrease, and in countries where fertility has fallen below the level of population instant-replacement, there will be a return to initial values in the second half of the 21st century. This model of convergence has practically ceased to be considered in modern demographic discourse due to an obvious contradiction with empirical reality (Anderson 2014).

The second model - a *long-term return to population instant-replacement* – describes a situation in which demographically developed and more modernized developing countries, whose PTFR and CCFR have now fallen below the level of population instant-replacement, will return by 2050-2150 to a fertility rate of 2.06-2.15 children per woman, while in less demographically modernized developing countries, fertility will continue to decline to levels characteristic of modern demographically developed countries, and then return to population instant-replacement by analogy with the first group of countries (Bourgeois-Pichat 1994; Poston 2018).

An essential point of this fertility convergence model is that countries with an increasing share of population groups with lagging demographic modernization (Caswell, Vindenes 2018), such as the countries of Central Asia, French Guiana, Mayotte, Fiji or Israel, should see a complete cessation of the decline in PTFR and CCFR (Poston 2018). Thus, despite the active social and economic development of Israel, in the period from 1994 to 2017 the PTFR value gradually stabilized in the range between 2.9 and 3.1 children per woman (Okun 2013: 478), but since 2018, PTFR has begun to decline rapidly and is expected to reach 2.6 children per woman in 2024. If the current dynamics are maintained, PTFR will fall to 1.9 children per woman by 2035 and to 1.2 by 2050, and in birth cohorts, to 1.6 children per woman in cohorts born in the late 1990s, since the indicators of reproductive intentions (ideal number of children, desired number of children, expected number of children) have become equal in almost all groups at levels previously characteristic only of migrants from the former USSR (Okun, Shifris 2024). Based on such dynamics of PTFR and CCFR in Israel and a similar situation in the other countries and territories listed above, we can conclude that the probability of this model being realized is low (Kishenin 2023: 84).

The *model of global equilibrium of moderately low fertility* predicts that fertility in developing countries with PTFR above 1.75 children per woman during all or part of the 21st century (Gietel-Basten, Scherbov 2020) will gradually decrease to the level of developed countries, where the PTFR level will remain at the level of 1.25-1.75 children per woman for a long time (Sobotka, Matyziak, Brzozowska 2017: 10), as a result of which CCFR will gradually stabilize around these values in all countries (Winkler-Dworak, Pohl, Beaujouan 2024).

The fourth convergence model, consisting in a *long-term equilibrium of moderately low fertility,* complements the third model. Thus, in the most developed countries, those with a high level of income and low level of gender and social inequality, the PTFR and CCFR values will remain at the level of 1.25-1.75 children per woman (Vollmer, Strulik 2015). Fertility rates in countries with lagging demographic and social modernization will remain at the level of 1.0-1.5 children per woman until the end of the 21st – first half of the 22nd century (Kishenin 2023: 85). Researchers who adhere to this model and want to find ways to find a balance between the existence of familiar social institutions and a high standard of living point to the need to adjust social security for people of retirement age by raising the retirement age due to the ongoing aging of the population (Keilman 2019: 25).

The fifth model is the *low-fertility trap model,* based on the corresponding hypothesis assuming a decrease in fertility in developed and developing countries below critically low values for a long time: PTFR and CCFR below 1.25-1.30 children per woman (Lutz, Skirbekk 2005: 701).

This hypothesis includes de facto three smaller hypotheses (Rindfuss, Choe 2016). The first one examines the demographic problem of declining fertility in hypothetical and birth cohorts: the share of mothers without children, or with one or two children, increases, but the share of mothers with three or more children decreases, due to the fact that indicators of the realization of reproductive intentions are, for the first time in history, close to or slightly lower than the reproductive intentions themselves. The second hypothesis is sociological: each new cohorts of children is guided by the number of children that were in their parental family, or by the number that are in their social environment now. The third and last hypothesis is related to economic changes: births will gradually be postponed to older ages, since the younger generation will want an increase in the level of income to start a family and have children. At a young age, achieving the desired level of economic security will be increasingly difficult, which may lead to the birth of a statistically significantly smaller number of children than expected according to reproductive intentions (Lutz, Skirbekk, Testa 2006: 177–180).

It is worth noting that many experts have suggested that stabilizing the PTFR and CCFR values at a level of 1.3–1.6 children per woman may be optimal both for modern society (with a smaller population, states will be able to pay more attention to increasing the level of education of their citizens and the degree of development of healthcare (Lutz, Scherbov, Gietel-Basten 2013: 1155–1156)), and for the environmental burden of humanity on the environment (Sanderson, Lutz, Scherbov 1996; Bloom, Kuhn, Prettner 2023: 3). Before the rapid decline in fertility in recent years, it was the third and fourth convergence models that were considered the most likely in demographic fertility projections (Lutz, Butz, KC 2014; Kishenin 2023), but now researchers are increasingly turning to the low-fertility trap hypothesis.

A low fertility trap does not mean that fertility will remain so low forever (Sobotka 2017: 31). Two types of fertility traps are distinguished. An *actual low-fertility trap* assumes a decrease in CCFR to values below 1.25-1.30 children per woman in more than one female birth cohort, which in theory should lead to a long-term or permanent low-fertility trap. A *fictitious low-fertility trap* is a decrease in PTFR below 1.25-1.30 children per woman: such a trap may be temporary, since the decrease in PTFR can be explained by the effects of aging fertility (Ediev 2013). The actual low-fertility trap can be especially acute when there is a discrepancy between, on the one hand, persistent high gender inequality and patriarchal social norms (Jalovaara et al. 2019), and, on the other, a high level of female education and part-time or full-time female employment, while at the same time, a decrease in female employment and in the availability of female education in the late stages of the demographic transition no longer restores fertility to the level of instant-replacement, but leads to an even deeper decline in fertility (see the examples of Iran and the UAE (Reiter, Goujon, KC 2022)).

Currently, more than thirty countries and territories of the world have a PTFR below 1.3 children per woman. East and Southeast Asia have ultra-low fertility rates (South Korea, Taiwan, Hong Kong, Macau, and Singapore), with PTFRs below 0.9 children per woman in 2023, including around 0.6 in Macau, and around 1.0 on average in China, but in some areas, such as Beijing and Shanghai, the PTFR has already dropped to 0.5 children per woman, as in the provinces of Manchuria (Hwang 2023; United Nations 2024a). Surveys show that in East Asian countries, the average ideal number of children (social norm of fertility) currently ranges from 1.4 to 1.7 children per woman and continues to decline smoothly (Brinton et al. 2018; Jones 2019: 7). This process of fertility decline was predicted by researchers about a decade ago (Lutz, Scherbov, Gietel-Basten 2013: 1155), and further implementation of this forecast suggests that ultra-low fertility may be established throughout the world with PTFR values of 0.6-1.0 children per woman (in some countries and territories, PTFR may fall to extremely low values of 0.3-0.5 children per woman for some time) and CCFR at the level of 0.75-1.15 children per woman.

According to this forecast, such low fertility may be observed for several centuries, which will lead to a reduction in the planet's population by 2200 to 1.8-2.6 billion people, and by 2300 it will return to the population of the Earth characteristic of the pre-demographic transition, i.e. to 300-500 million people (Coleman, Rowthorn 2011; Lutz, Scherbov, Gietel-Basten 2013), which, however, may have favorable consequences for reducing the environmental burden on the planet (IHME 2020), slowing down climate change (Lutz, Pachauri 2023) and alleviating the acute problem of depletion of non-renewable energy and other mineral resources (Lutz, Scherbov, Gietel-Basten 2013).

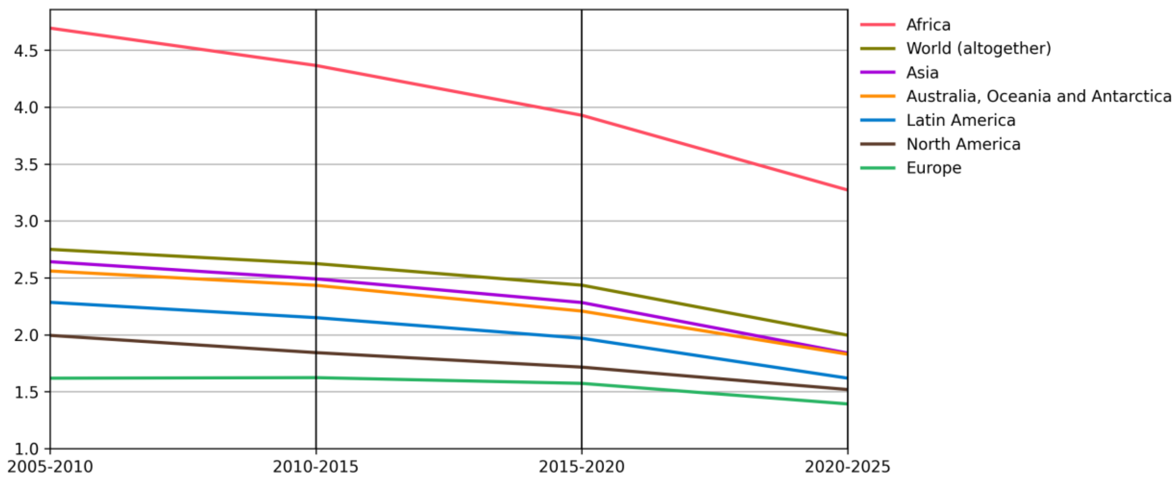
In a situation where humanity does not know how to effectively implement pro-natalist policies to restore fertility to the level of population instant-replacement (IHME 2024a), when it is even unknown whether fertility falling to unprecedented low values is not a compensatory reduction in the number of our biological species in order to maintain a balance with the environment (Wilson 2013; Vollmer, Strulik 2015), it is worth taking active steps to support the preservation of economic growth of states, especially in terms of continuing to grow per capita GDP at purchasing power parity (PPP) and median per capita income PPP (van Dalen, Henkens 2020: 7). Another challenge posed by the low-fertility trap is the impact on the pension system and the social security system in general, the impact on the labor market due to an increase in the proportion of people of retirement age and a shortage of certain specialists of working age (Wilkins 2019: 25).

## Results

### *PTFR trends for 2020-2025*

Let's consider the PTFR dynamics for 2005-2025 in the study of the Institute for Health Metrics and Evaluation (IHME) (Table A1 in the Appendix). The graph (Figure 1) for the twenty-year observation period from 2005-2010 to 2020-2025 clearly shows a downward trend in PTFR across all regions of the world and the world as a whole. In absolute values, the fastest rate of decline in PTFR is observed in African countries: from 4.694 children per woman in 2005-2010 to 3.271 in 2020-2025. The coefficient falls slightly more slowly in Asian countries (from 2.641 to 1.839 children per woman) and Latin America (from 2.284 to 1.618 children per woman), as well as in Australia, Oceania and Antarctica (from 2.560 to 1.829 children per woman). The PTFR in absolute values decreases slightly more slowly in North America and the countries of the European region: from 1.994 children per woman to 1.518 and from 1.623 to 1.392 children per woman in 2005-2010 and 2020-2025, respectively.

**Figure 1. PTFR dynamics by world regions, 2005-2025, children per woman aged 15-54**



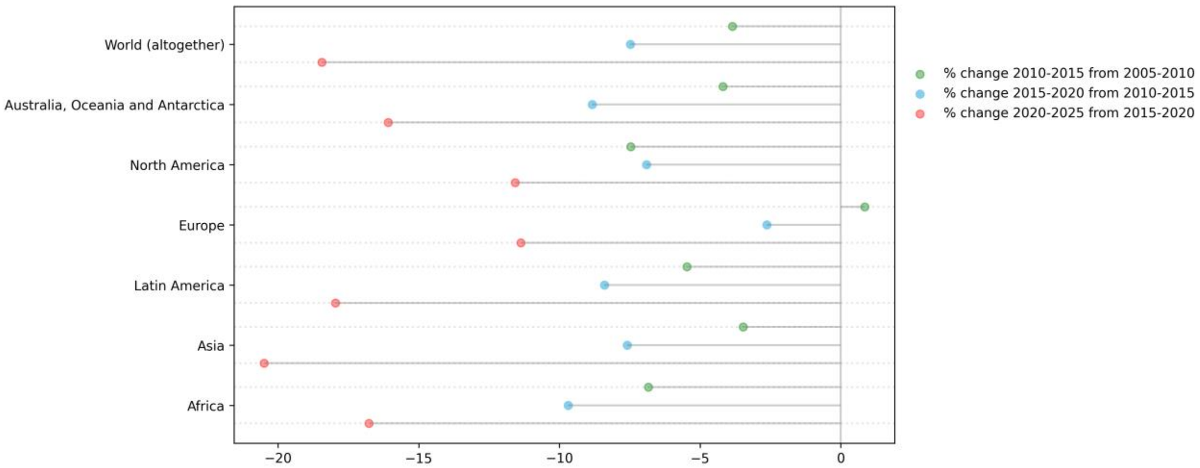

*Source: IHME data. Visualization in Python (using matplotlib and pandas packages).*

The relative change in PTFR in 2015-2025 shows a clearly expressed trend towards an acceleration of fertility decline in all regions of the world and in the world as a whole: in each subsequent five-year period, the rate of fertility decline increases, expressed as a percentage of PTFR changes in the analyzed period compared to the value in the previous five-year period (Figure 2).

However, in the more demographically developed regions of the world, some exceptions to the general trend were observed in the late 2000s and early 2010s. In Europe in 2010-2015, compared to 2005-2010 there was a slight increase in PTFR (by 0.9%), and in North America in 2015-2020, compared to 2010-2015 the rate of fertility decline somewhat slowed down (IHME 2021). In 2020-2025, the fastest decline in fertility is in Asia, slightly outpacing even African countries, as well as countries in Australia, Oceania and Antarctica, and Latin American countries (IHME 2024b).

It is important to note that the absolute and relative dynamics of PTFR by regions of the world and the world as a whole demonstrate a clear acceleration in the rate of decline in fertility both in less demographically modernized regions of the world and at the same time in regions with a higher level of gender inequality, lower female employment and lower prevalence of female education.

**Figure 2. Relative change in PTFR by regions of the world, 2005-2025, % change in children per woman aged 15-54**




*Source: Authors' calculations based on IHME data. Visualization in Python (using the matplotlib package).*

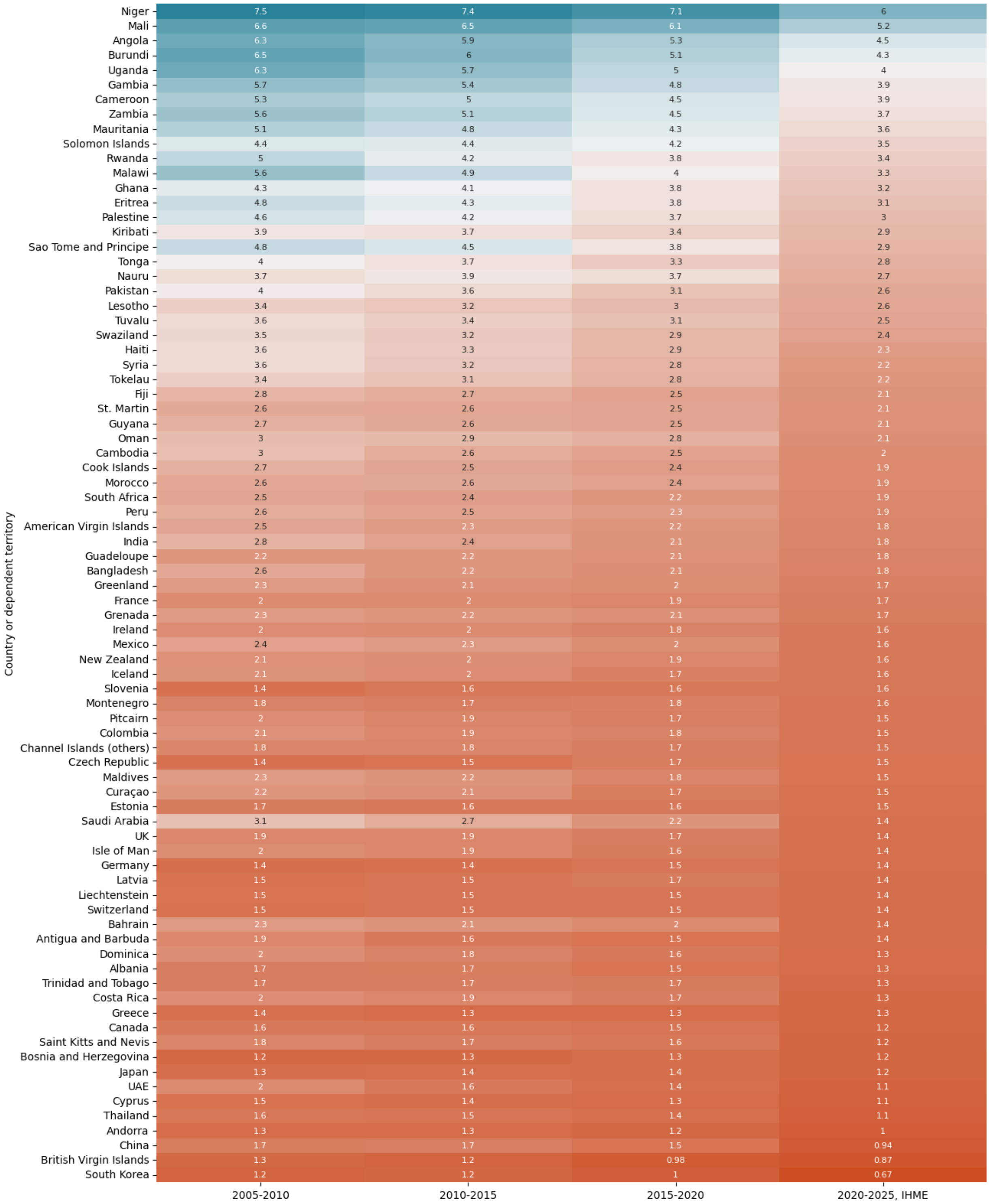
Let's move from the global dynamics of PTFR to a more detailed examination of data for individual countries of the world (Table A1 in the Appendix). To illustrate, we present PTFR for 240 countries and dependent territories of the world on a heat map (Figure 3). On the heat map, the highest values are indicated by colder shades, and the lower PTFR values are indicated by warmer shades, according to IHME data. The heat map, as well as the illustrations by regions of the world, clearly demonstrates the trend of declining fertility worldwide from 2005 to 2025, with an increase starting around the mid-2010s.

In 2005-2010, the highest PTFR value was in Niger (7.55 children per woman), and the lowest was in Macau (0.93), a special administrative region of the PRC; by the period 2020-2025, there is a decrease in the absolute value of PTFR in almost all countries and dependent territories in the world, including the above-mentioned: in Niger to 6.01 children per woman, and in Macau to 0.56. The heat map shows that by 2020-2025, in most countries and dependent territories, the PTFR value is at the level of 1.2-1.8 children per woman.

In several countries, contrary to the overall picture of declining PTFR and accelerating decline in fertility, there is an increase and short-term fluctuations in PTFR.

Thus, in Uzbekistan, over the period from 2005-2010 to 2020-2025, PTFR increased from 2.49 children per woman to 3.16, and in Kazakhstan, at the same time, from 2.48 to 2.87 (although in Kazakhstan in 2020-2025 there was almost no growth in PTFR compared to 2015-2020). The likely reason is timing shifts due to a combination of fictive rejuvenation (in Uzbekistan, but not Kazakhstan), the beginning of the second demographic transition, and a change in the heterogeneous composition of the population in favor of a temporary increase in the share of the population with higher reproductive behavior (Pelletier 2021): the PTFR of first and second children has exceeded 1 in both countries, but the PTFR of higher birth orders is rapidly falling (Kan 2023).

**Figure 3. Heat map of PTFR for selected countries and territories, 2005-2025, children per woman aged 15-54**




*Source: IHME data. Visualization in Python (using matplotlib and seaborn packages).*

In a number of Central and Eastern European countries, there was a short-term increase in the PTFR value in the late 2000s and the first half of the 2010s (IIASA 2018), which has now been replaced by a decline. This phenomenon is also associated with the effects of timing translations in the birth calendar, namely the rapid aging of the fertility rate in the 1990s and 2000s (Lutz et al. 2018). For example, in Hungary in 2005-2010 there were 1.31 children per woman, in 2010-2015 1.35, and in 2015-2020 1.53. At the same time, in 2011-2012 In Hungary, the existing system of tax incentives for parents was expanded (Cook, Iarskaia-Smirnova, Kozlov 2023: 7): therefore, the increase in PTFR in Hungary most likely occurred due to the effect of timing shifts in the birth calendar. Similar processes were characteristic of Poland, Russia (Zakharov 2024), Belarus, Ukraine and a number of other countries.

Germany can also be used as an example: in 2005-2010, the PTFR value was at the level of 1.36 children per woman, in 2010-2015 1.43, and in 2015-2020 1.55. The increase in the PTFR value in Germany can be explained by reverse timing shifts similar to those in Central European countries, when PTFR quickly increases after a period of long and intensive aging of the fertility rate (Sobotka 2018), which is what happened in Germany.

The relative change in PTFR in 2005-2025 by country (Table A1 in the Appendix) also indicates a more intense decline in fertility, but there are differences in rates. The fastest rate of decline in PTFR is in Asian countries. In 2020-2025, compared to the previous five-year period, PTFR falls most rapidly (from -50.6 to -29.6%) in such Asian countries and dependent territories as Macau, Hong Kong, China, the Philippines, South Korea, Saudi Arabia, Bahrain, Kuwait and Taiwan.

For example, South Korea is one of the countries with ultra-low fertility: PTFR fell from 1.16 children per woman in 2005-2010 to 0.67 in 2020-2025. Taiwan has a similar situation: PTFR fell from 1.05 children per woman in 2005-2010 to 0.79 in 2020-2025. The only relatively rich Asian country with a positive PTFR growth is Kazakhstan (+0.6% in 2020-2025 and +7.8% in 2015-2020), a situation which was explained earlier.

High rates of fertility decline are also observed in countries in Africa, Latin America, Australia, Oceania and Antarctica. Among the African countries in 2020-2025 the fastest rate of decline in PTFR is in Tunisia (-26.0%) and Ethiopia (-25.9%). Thus, over the period from 2005 to 2025, the PTFR in Ethiopia declined at a rate of approximately -20% every five years: in 2005-2010 the PTFR value was 5.62 children per woman, in 2010-2015 4.74, in 2015-2020 3.58, and in 2020-2025 2.65 children per woman. The leaders in the decline in fertility among Latin American countries in 2020-2025 compared to 2015-2020 are Argentina (-39.1%) and Uruguay (-35.3%). Fertility is falling rapidly in Samoa (-31.4% in 2020-2025): PTFR fell from 4.46 children per woman in 2005-2010 to 2.37 in 2020-2025. The situation is less rapid in the countries of North America and Europe: in most countries and territories, fertility is declining at a slower pace, and North Macedonia even shows a slight increase in PTFR (+ 0.9%).

Consequently, from the dynamics of PTFR, we can conclude that the rate of decline in fertility is accelerating from 2015 to 2025 in all countries of the world.

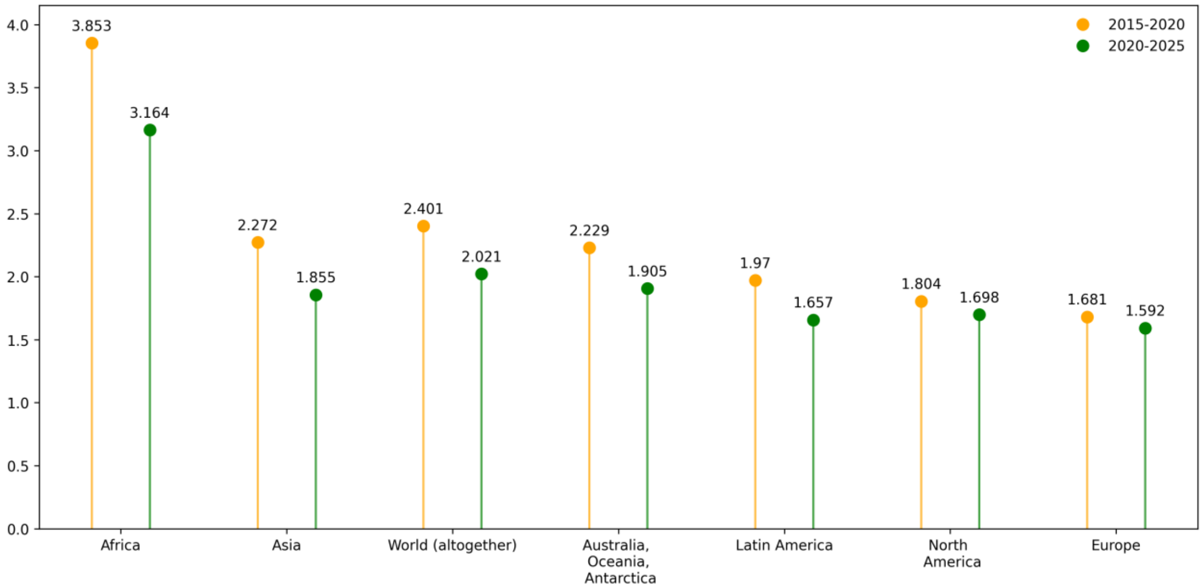
***Adjustment of PTFR for 2020-2025 using the Bongaarts-Feeney method***

The PTFR indicator has a number of significant shortcomings: it does not take into account changes in the mean age of the mother at birth or changes in birth order patterns, and is sensitive to short-term fluctuations in the birth calendar (Sobotka, Lutz 2011; Keiding et al. 2021).

Based on IHME data on age-specific fertility rates by birth order and mean age of the mother at birth by birth order in one-year periods (with a transition to five-year periods), tempo-adjusted total fertility rates using the Bongaarts-Feeney method (taTFR) were calculated. This indicator takes into account shifts in the birth calendar, which allows for the decomposition of PTFR changes using the Bongaarts-Feeney method into the effects of timing translations (*tempo-effect*) and fluctuations in the real intensity of childbearing (*quantum-effect*) by adjusting PTFR by birth order by an amount equal to the average age of the mother at the birth of a child of a given order (Bongaarts, Feeney 1998).

According to taTFR (Figure 4), as well as PTFR, from 2005 to 2025, a long-term trend towards a decrease in fertility is also observed in all regions and countries of the world (Table A2 of the Appendix). In absolute terms, taTFR has fallen the most in African countries (from 3.85 children per woman in 2015-2020 to 3.16 in 2020-2025), and the least in European countries (from 1.68 children per woman in 2015-2020 to 1.59 in 2020-2025). If we compare with PTFR values, we can see that in European countries PTFR in 2020-2025 compared to the previous five-year period fell by -11.4%, and taTFR only by -5.3%. This indicates that a significant part of the decline in PTFR in Europe (about 53.5%) in recent years is explained by the aging of fertility. Similar processes are taking place in almost all countries and territories of the world with a low PTFR value, although it is in Europe that this phenomenon is on the largest scale.

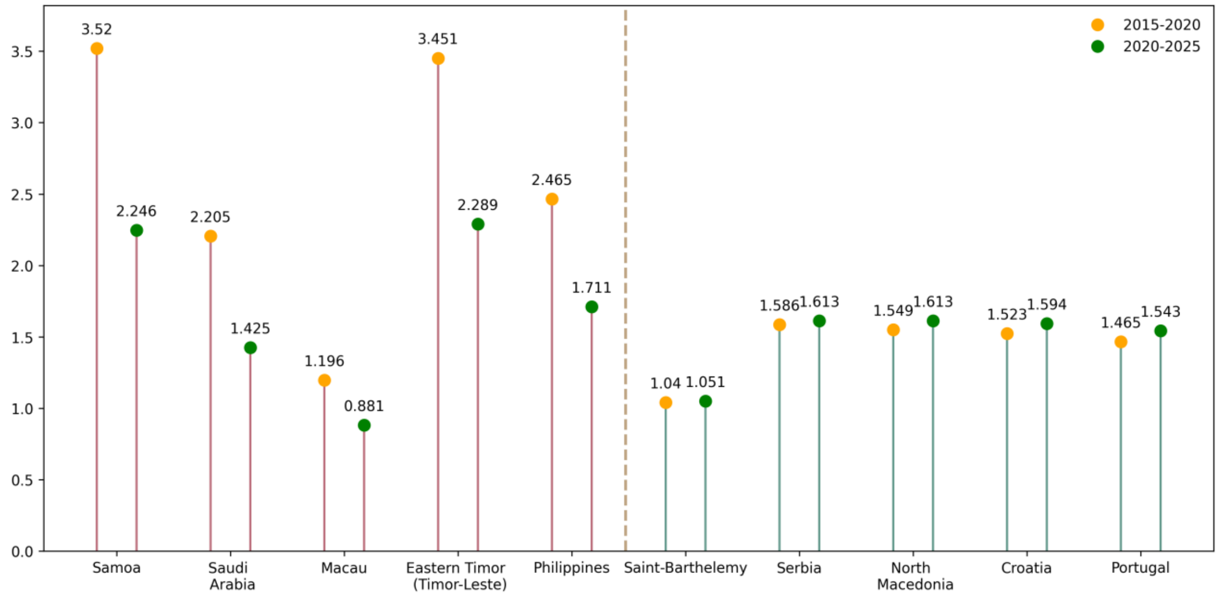
**Figure 4. taTFR by world region, 2015-2025, children per woman aged 15-54**




*Source: Authors' calculations based on IHME data. Visualization in Python (using the matplotlib package).*

Let us consider the impact of timing shifts in the birth calendar for individual countries and dependent territories of the world (Tables A1 and A2 in the Appendix; Figure 5). The largest change in taTFR in relative terms between 2015-2020 and 2020-2025 occurred in Asia and Oceania: in Samoa (-36.2%), Saudi Arabia (-35.4%), Macau (-34.7%), East Timor (-33.7%) and the Philippines (-30.6%). Period PTFR is declining faster in African countries, but the relative change in taTFR shows that fertility is falling fastest in Asian countries, which have the highest burden on women's time budgets and the least equality in the family and household sphere, including in raising and caring for children (IHME 2024a).

**Figure 5. taTFR for the five countries with the largest and smallest declines, 2015-2025, children per woman aged 15-54**




*Source: Authors' calculations based on IHME data. Visualization in Python (using the matplotlib package).*

In a number of countries and territories, mainly in Europe, between 2020 and 2025 there was an increase in taTFR (Figure 5): in Portugal (+5.4%), Croatia (+4.7%), North Macedonia (+4.1%), Serbia (+1.7%), Saint Barthélemy (+1.1%) and Romania (+0.7%), which means a slight increase in the real intensity of childbearing.

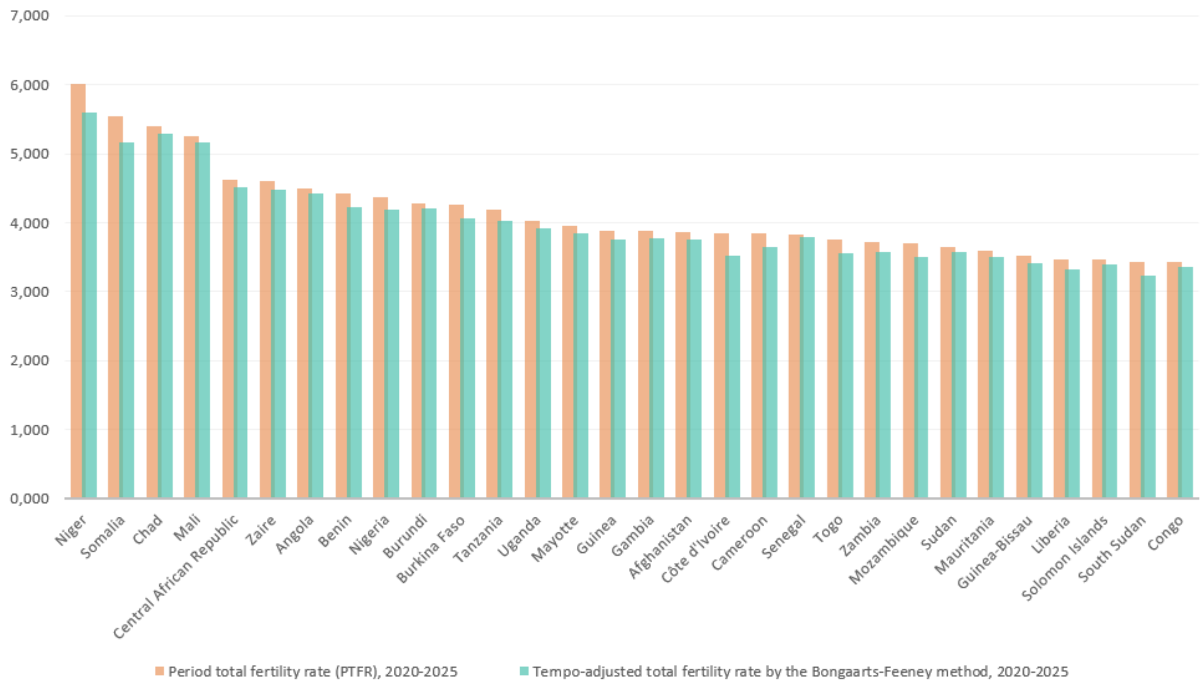
The PTFR of these countries and dependent territories most often falls: in Portugal from

2010-2015 to 2015-2020 there was a growth of +6.5%, and in the next five-year period there was a fall of -1.4%, in Croatia there was a fall of -2.4% (the change in 2015-2020 compared to 2010-2015) and -3.1% (the change in 2020-2025 compared to 2015-2020), in North Macedonia there was a fall of -5.2% and a small growth of +0.9%, in Serbia there was a growth of +3.9% and a fall of -5.5%, in Saint Barthelemy there was a fall of -15.6% and -3.8% in each respective five-year period, and in Romania there was a growth of +12.1%, which was followed by a fall of 6.2%. Such jumps in PTFR are explained by new significant waves of ageing fertility. Similar trends are observed in the vast majority of other demographically developed countries where there is no nominal growth in taTFR, for example in the Scandinavian countries (Jalovaara et al. 2019) and the Baltics, in France, the Czech Republic, Britain, Germany, the Netherlands, Belgium, etc. It should also be noted that CCFR in these countries usually falls rather slowly, and for some cohorts it hardly decreases at all (Hellstrand et al. 2021).

It is worth noting that taTFR, unlike PTFR, in many countries and dependent territories remains at a level of at least 1.25 children per woman. At the same time, in Macau, Hong Kong, South Korea, Singapore, Taiwan and several countries and dependent territories located in the Caribbean, there is a drop in taTFR below 1.25 children per woman, which may indicate the failure to realize reproductive intentions (the expected, wanted and ideal number of children remains at a level of about 1.5 children per woman and slightly lower, but the actual indicators of the realization of reproductive intentions are quite low). Many authors assume (Lutz, Scherbov, Gietel-Basten 2013; Jones 2019) that the fertility rate in the countries of East and Southeast Asia will continue to decline in the future at least until the early 2030s.

In countries with a high PTFR, the tempo-adjusted total fertility rate by the Bongaarts-Feeney method is usually lower than the PTFR value (Figure 6). For example, in Niger, the PTFR in 2020-2025 was equal to 6.01 children per woman, and taTFR was at the level of 5.59 children per woman; in Angola PTFR was equal to 4.50 and taTFR to 4.41 children per woman. This clearly indicates that the real fertility rate is lower than the PTFR value due to the fictitious rejuvenation of fertility.

**Figure 6. PTFR and taTFR for 30 countries with the highest PTFR, 2020-2025, children per woman aged 15-54**




*Source: IHME data and authors' calculations based on IHME data. Visualization in Python (using the matplotlib package).*

It is worth paying attention to the ratio of taTFR and PTFR (Table A2 in the Appendix). In most countries and dependent territories in 2020-2025, taTFR is either higher than PTFR or slightly lower (the ratio of adjusted PTFR to PTFR is at the level of 97-99%). A similar picture was observed in 2015-2020, but it should be noted that the ratio of taTFR to PTFR increased in 2020-2025: in 2015-2020 the minimum ratio was 85.8% (Reunion), and the maximum was 122.6% (Cayman Islands), and in 2020-2035 the minimum ratio was 89.7% (Guam) and the maximum was 158.7% (Macau). This indicates an additional decrease in PTFR due to timing shifts in the birth calendar, suggesting that the decrease in the real intensity of childbearing was somewhat lower than it seems from the dynamics of PTFR values.

The analysis of PTFR and taTFR showed a decline in fertility in all countries of the world. Part of the decline can be explained by the aging of fertility (*tempo-effect*), but in parallel with this, in almost all countries of the world there is a decrease in the real intensity of childbearing (*quantum-effec*t), which allows us to talk about a high probability of the low-fertility trap scenario.

Let us now move on to considering the forecasts of the main international organizations for the past two years, showing the indicated scenarios of the low fertility trap, true or fictitious.

## Fertility forecast data in the context of the low fertility trap

In March 2024, IHME released a new population projection for countries and dependent territories from 2022 to 2100 (IHME 2024a). The fertility projections are based on data from 1950 to 2021: mixed-effects regression models and space-time Gaussian process regressions were built to pool data from 8,709 state-years of civil registration and sample registration (Keiding et al. 2021), 1,455 surveys and censuses, and 150 other sources used to derive age-specific fertility rates (ASFRs) for one- and five-year age groups 15–54 years (IHME 2024b). ASFRs were summed to obtain PTFR estimates.

To project future fertility to 2100, the Institute for Health Metrics and Evaluation (IHME) used CTFR in completed cohorts at ages 50 and 55 as the key modeled variable (the projection uses the abbreviation CCF50/CCF55, i.e. the average number of children born by age 50/55 to women in a given birth cohort), which provides more stable and accurate fertility estimates than direct PTFR modeling (Ševcíková et al. 2016). CCF50 modeling was performed using an ensemble approach with different numbers of covariates (Cheng, Lin 2010), the MR-BRT (meta-regressions of Bayesian hierarchical models with regularized moving average) toolkit, and first-order autoregression for the residual term (more details on the projection methodology can be found in (IHME 2024a)).

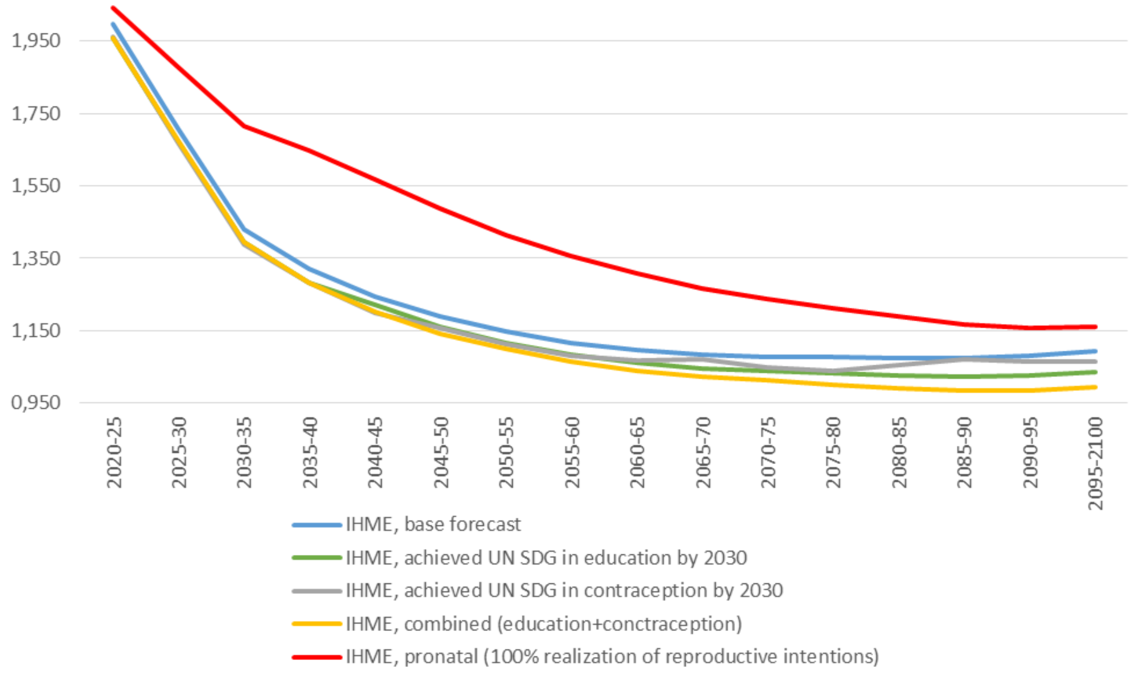
The *reference scenario* is an estimate of the most likely future fertility given the model of past fertility, covariate projections, and historical relationships between covariates and fertility. In addition, projections were prepared for several alternative scenarios in each country/dependent territory, region, and the world as a whole: achieving the UN Sustainable Development Goal (SDG) on education by 2030 (*Education SDG scenario*); achieving the SDG on contraception by 2030 (*Contraceptive met need scenario*); the two previous scenarios together (*Combined scenario (Education+Contraceptive)*) and the variant of creating maximum conditions for reducing biological, social, and economic barriers to having children with the rates of realization of reproductive intentions reaching 100%, i.e., the level of reproductive intentions themselves (*Pronatal scenario*). For the world as a whole, they can be found in more detail in Figure 7.

The uncertainty associated with the past data and the assessment of the quality of the model is addressed by specifying 95% confidence intervals of uncertainty (UI) and the subsequent 95% Bayesian credible intervals (CI). Thus, the forecast variants covered allow us to estimate the probability space of the ASFR, PTFR and CCFR values up to 2100 (IHME 2024b).

It is worth noting that in all variants of the IHME-2024 forecast, the fictitious low fertility trap scenario is realized in PTFR, and at the CCFR level-an actual low fertility trap with the possible realization of a long-term equilibrium model of moderately low fertility for the countries and territories of Western, Northern and Central Europe, the USA, Canada, Australia, New Zealand and Israel (with the exception of the Education SDG scenario and Combined scenario (Education + Contraceptive), since they assume the realization of a true low fertility trap for all countries of the world).

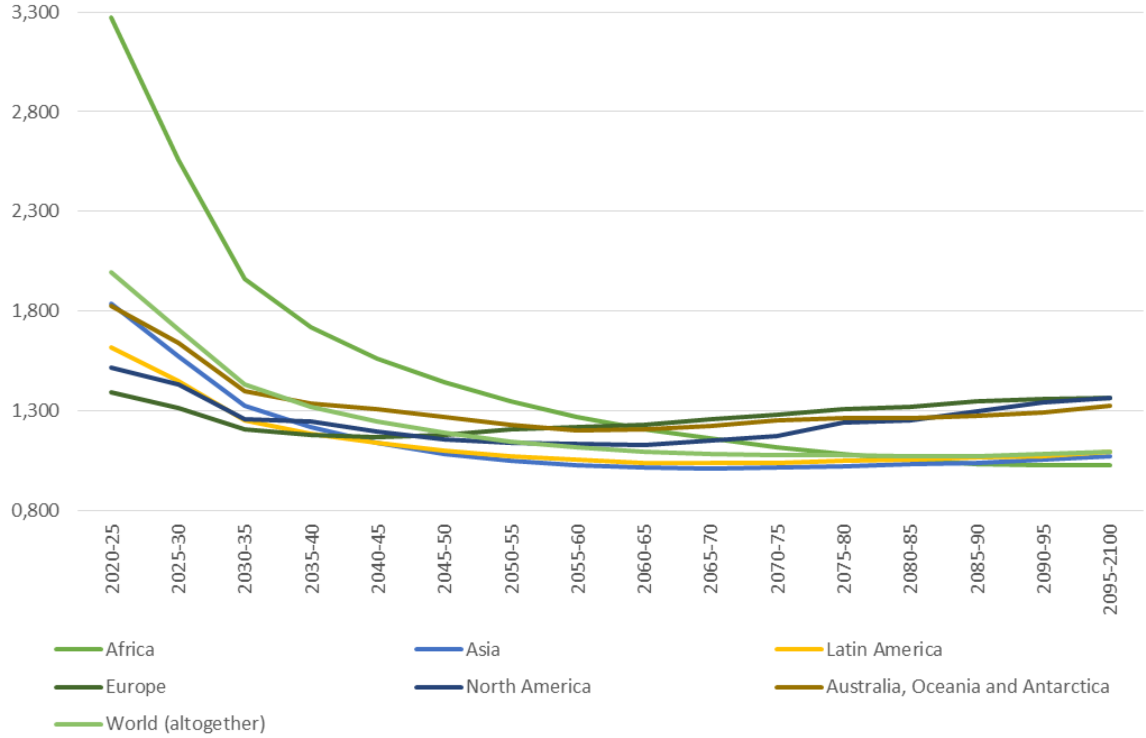
In terms of world regions, the reference scenario is based on IHME data for 2020-2025 and suggests a decline in fertility for regions with incomplete demographic modernization and stagnation for demographically developed countries, as demonstrated in Figure 8.

**Figure 7. PTFR for IHME 2024 forecast variants, from 2020-2025 to 2095-2100, children born per woman aged 15-54**




*Source: IHME data. Visualization in Excel.*

**Figure 8. PTFR according to the IHME-2024 Reference scenario for the main regions of the world, from 2020-2025 to 2095-2100, children per woman aged 15-54**




*Source: IHME data. Visualization in Excel.*

A similar situation will be observed in the context of PTFR dynamics for individual countries and dependent territories of the world (table A3 of the Appendix). Already in 2025-2030, PTFR values will be in the range from 0.61 children per woman in Macau to 4.81 in Niger, and in the first half and mid-2040s PTFR will fall below the level of population instant-replacement everywhere. By 2050-2055, PTFR will range from 0.65 children per woman in the British Virgin Islands to 1.77 in Niger, in 2075-2080 from 0.79 in Equatorial Guinea to 1.45 in the Czech Republic, and by 2095-2100 from 0.75 in Somalia to 1.45 in the Czech Republic with a lower 95% Bayesian credible interval of 0.33 children per woman in Bhutan to 1.25 children per woman in the Netherlands and an upper 95% Bayesian credible interval of 0.96 children per woman in Jamaica and Somalia to 1.81 in the Czech Republic and Estonia.

**Table 1. Main variants of the IIASA-2023 demographic projection in the context of the probability scenario distributions used for fertility, mortality, migration and human capital (education + contraception + gender inequality), 2020–2100**

| Process/Variant | SSP-1 | SSP-2 | SSP-3 | SSP-4 | SSP-5 |
|---|---|---|---|---|---|
| *Demographics* | | | | | |
| Fertility | Very low for developing countries and low for developed countries | Low | High | Median | Very low for all countries |
| Mortality | Very low | Low | Median | Median | Very low |
| Migration | Median | Median | Median | High | Median |
| *Human capital* | | | | | |
| Education | High for developing countries and very high for developed countries | Median | Low | Median | High for all countries |
| Contraception and sex education | High for developing countries and very high for developed countries | Median | Low | Median | High for all countries |
| Gender inequality | Median for developing countries and low for developed | Low | High | Moderately high | Median for all countries |

*Source: (Lutz 2009; KC et al. 2024).*

In December 2023, the International Institute for Applied Systems Analysis (IIASA) published the first data on a new round of population projections (KC et al. 2023). In January 2024, the IIASA population projection report (KC et al. 2024) was also released, including a detailed section on fertility, and a complete database for all population projection variants (IIASA 2024). Unlike the forecast made in the summer of 2022, this one does not analyze data for all countries and dependent territories of the world (278 in IIASA-2022), but only for 200 countries and territories with a population of more than 100 thousand people as of January 1, 2023, while the remaining countries and dependent territories are given in a separate line "Other countries and territories".

The IIASA-2023 demographic projection, following the logic of the previous projections, contains five main variants presented in the table, including hypotheses on the level of fertility, mortality, migration and human capital factors (the prevalence of education, in particular female education; the availability of contraception and the degree of development of sex education programs; the level of gender inequality; all projections are based on a variant of high growth in urbanization indicators around the world).

The main variants in terms of the probability of their realization, measured through the limited probability space estimation tool in Bayesian network analysis (Billari, Graziani, Melilli 2014; KC et al. 2024), are SSP-1 (48.38%), SSP-2 (25.95%) and SSP-5 (24.39%), while the variants SSP-3 (0.06%) and SSP-4 (1.22%) are more of an analytical forecast variant than a realistic one (Lutz 2009; KC et al. 2024).

To construct the fertility forecast itself, IIASA also applies Bayesian hierarchical models, a methodological approach first proposed and applied to forecasting here (Lutz 1996; Sanderson, Lutz, Scherbov 1996). All forecast variant are constructed for five-year periods and five-year age groups.

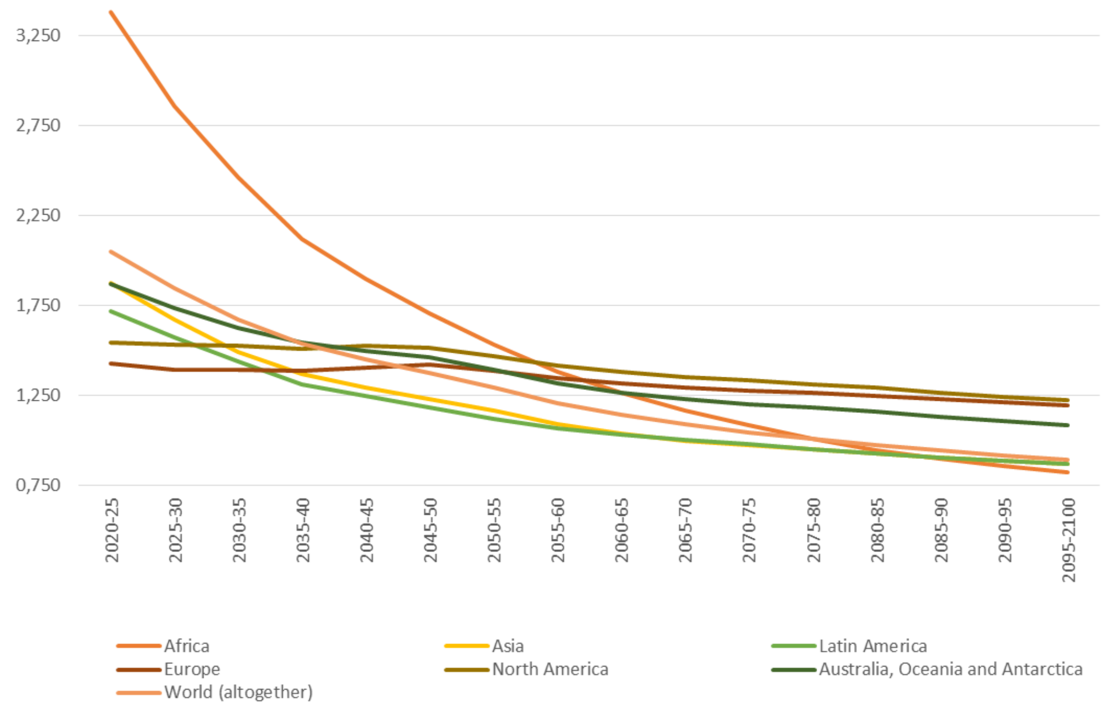
For the first and second levels of the model, the four groups of the above-mentioned human capital indicators are used. Two methods are used to forecast the values of these indicators for 2025-2100: LASSO regression and multilevel time series analysis. Then, using these two methods, the third level of the Bayesian hierarchical model is constructed - a forecast of the ASFR value for the 200 countries and territories of the world being analyzed. Only then can the ASFR indicators be interpreted in the logic of hypothetical and birth cohorts, i.e. as PTFR and CCFR (Schmertmann et al. 2014). As the initial data for 1950-2025, the indicator values are taken from the IIASA 2018 and 2022 surveys (IIASA 2018) and the UN (United Nations 2022), while for individual countries and indicators other data sources are used (KC et al. 2024:

20-26). The IIASA-2023 forecast for assessing the quality of the models contains data on the lower and upper 97.5% Bayesian credible intervals (CI), but, more importantly, differentiation by education and income (IIASA 2024) and the first-ever differentiation for urban and rural populations (Adhikari, Lutz, KC 2023).

If we turn to the SSP-1 forecast for PTFR by world regions (Figure 9), we can see, as in the baseline IHME-2024 forecast, the implementation of a fictitious low-fertility trap for all regions, but Europe and North America could stabilize fertility at a slightly higher level due to greater development of human capital, and Australia and Oceania find themselves in an intermediate position between developed and developing regions (Africa, Asia, Latin America).

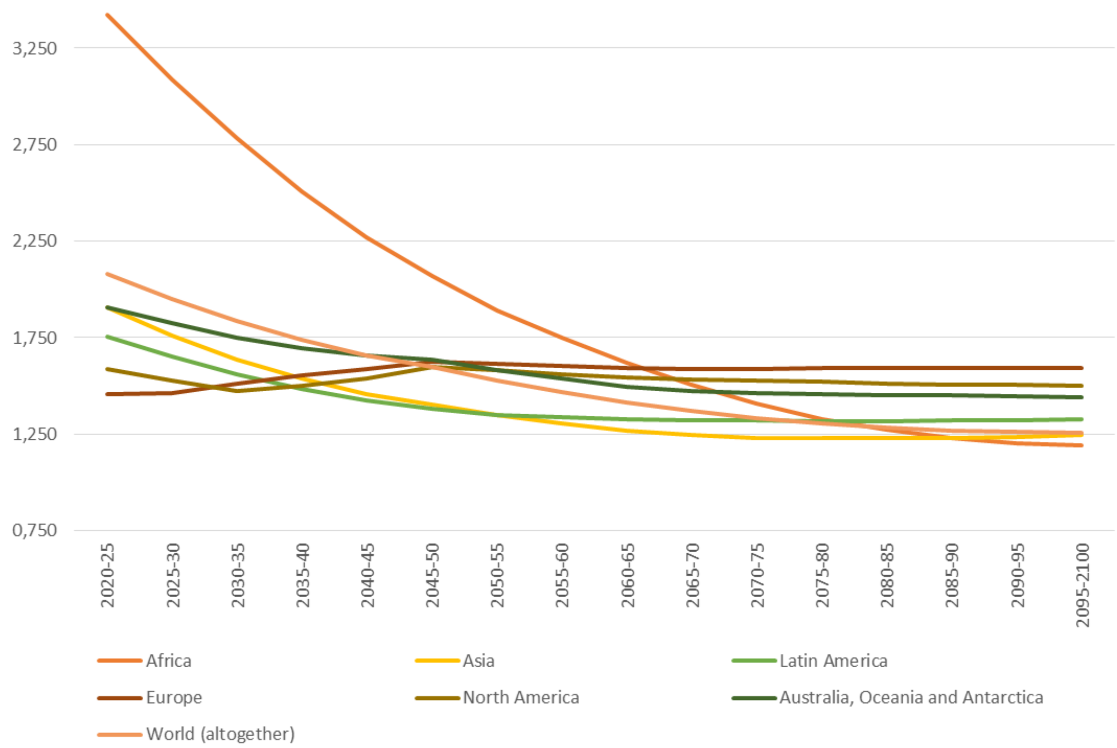
The SSP-2 forecast for PTFR (Figure 10) assumes the realization of a long-term equilibrium model of moderately low fertility.

**Figure 9. PTFR according to SSP-1 IIASA-2023 for the main regions of the world, from 2020-2025 to 2095-2100, children per woman aged 15-49**




*Source: IIASA data. Visualization in Excel.*

**Figure 10. PTFR for IIASA-2023 SSP-2 for the main regions of the world, from 2020-2025 to 2095-2100, children per woman aged 15-49**

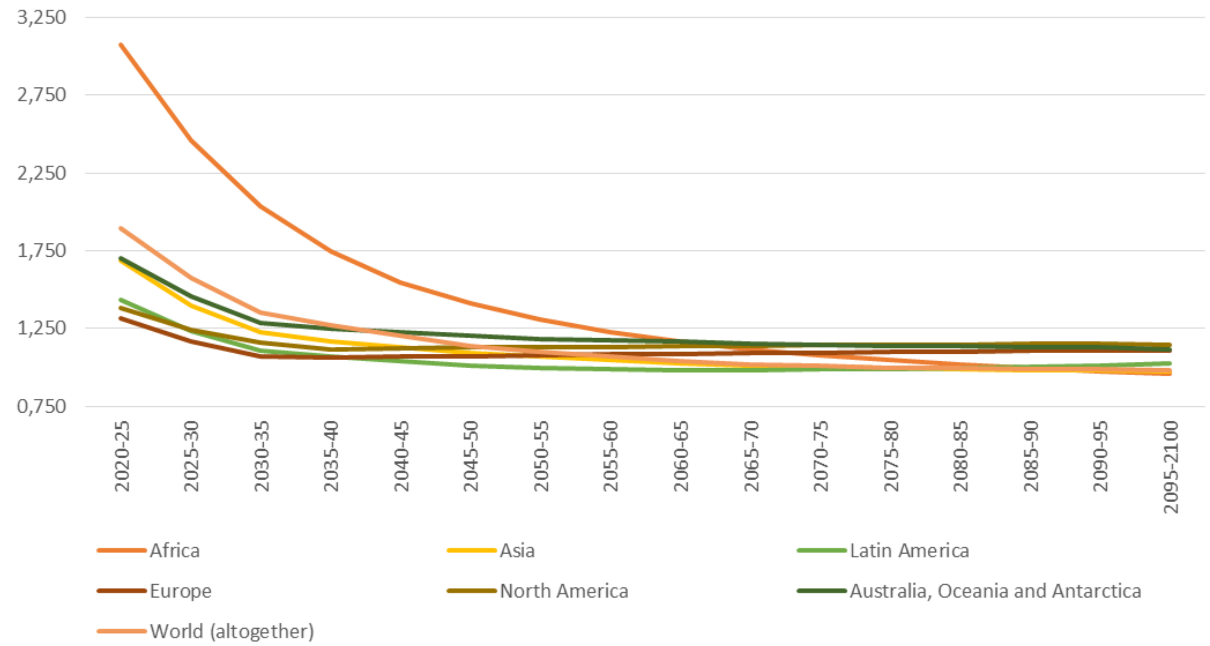



*Source: IIASA data. Visualization in Excel.*

According to SSP-2, by the end of the 21st century PTFR in Europe will stabilize in the range of 1.55-1.60 children per woman, in North America and Australia and Oceania at levels of 1.4-1.5, in Latin America at 1.30-1.35, in Asia and the world as a whole at between 1.25 and 1.30, and in Africa in the range of 1.15-1.20. Both the SSP-1 and SSP-2 variants provide for CCFR dynamics of 1.5-1.7 children per woman for demographically developed countries and 1.30-1.55 for countries that have not completed demographic modernization; the difference in the convergence models for PTFR is explained by small differences in the dynamics of the values of human capital indicators and, as a consequence, in different variants of the development of the second demographic transition and, in particular, a smaller aging of the fertility rate in the SSP-2 variant (Lutz, Pachauri 2023).

The SSP-5 variant (Figure 11) is a sub-variant of the development of the SSP-1 forecast, which, however, provides as a scenario hypothesis the absence of a difference between the dynamics of fertility and human capital growth for developed and developing countries, which, in theory, leads to the stabilization of the fertility rate in developed countries at the same levels or close to the values of developing countries.

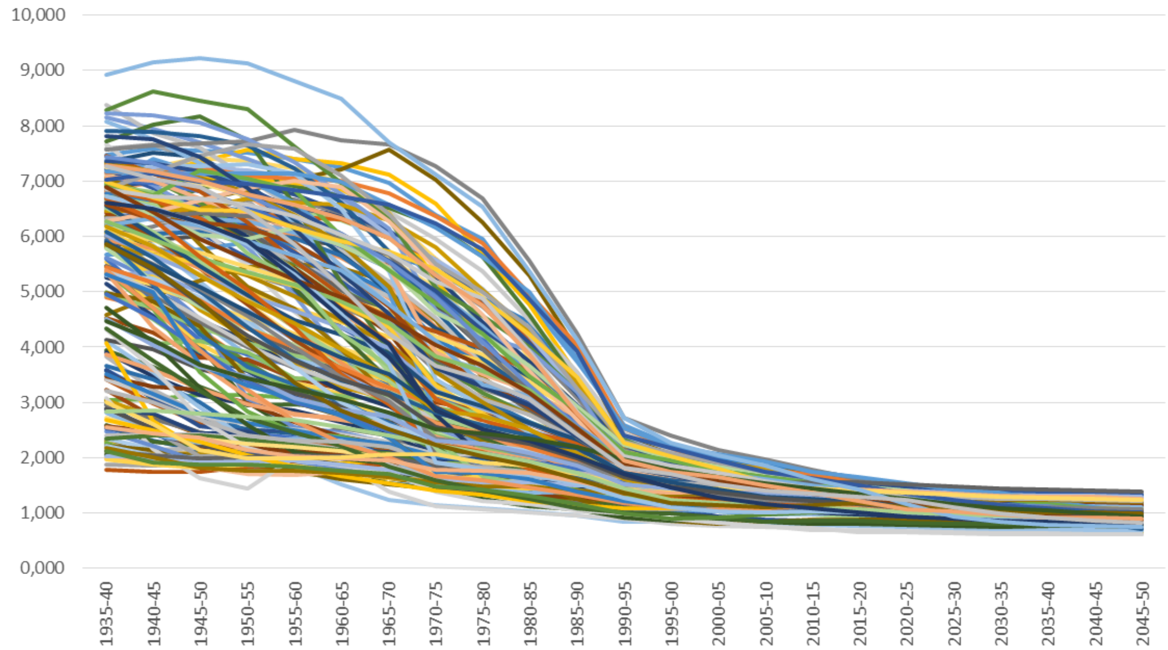
**Figure 11. PTFR for IIASA-2023 SSP-5 for major regions of the world, from 2020-2025 to 2095-2100, children per woman aged 15-49**




*Source: IIASA data. Visualization in Excel.*

This variant assumes that all countries and territories according to PTFR will see a fictitious low fertility trap. In Europe, North America, Australia and Oceania by the end of the century, PTFR is on average about 1.0-1.1 children per woman, and in other regions of the world 0.80-1.05. SSP-5 also includes the realization of actual low-fertility trap: cohorts born in 2030-2050 should have a completed cohort fertility rate between 0.6 and 1.3 children per woman (Figure 12).

**Figure 12. CCFR for IIASA-2023 SSP-5 for countries and dependent territories with a population of over 100,000 people, from 1935-1940 to 2045-2050 year of birth of mothers, children per woman aged 15-49**




*Source: Authors' calculations based on IIASA data. Visualization in Excel.*

PTFR dynamics for individual countries and dependent territories of the world for the SSP-1 variant (table A4 of the Appendix) are as follows. In 2020-2025, PTFR will range from 0.61 children per woman in Macau to 6.04 in Niger, falling below the instant-replacement level in all countries of the world by the early 2050s; by this time, PTFR will range from 0.78 children per woman in China to 2.38 in Niger, in 2075-2080 from 0.67 in Haiti to 1.53 in Iceland, and by 2095-2100 from 0.56 in Haiti to 1.42 in Iceland with a lower 97.5% Bayesian credible interval from 0.32 children per woman in Ethiopia and Haiti to 1.11 in Denmark, and an upper 97.5% Bayesian credible interval from 0.66 children per woman in Haiti and Somalia to 1.64 in Iceland.

For the SSP-2 forecast scenario (Table A5 in the Appendix), the values are: in 2020-2025, PTFR will be from 0.63 children per woman in Macau to 6.08 in Niger, falling below the replacement level in the latter countries in the second half of the 2060s. By 2050-2055, PTFR will range from 0.77 children per woman in Saudi Arabia to 3.33 in Niger, in 2075-2080 from 0.83 in Saudi Arabia to 1.79 in Niger, and by 2095-2100 from 0.95 in the Philippines to 1.74 in Sweden with a lower 97.5% Bayesian credible interval from 0.52 children per woman in Ethiopia to 1.41 in Sweden and an upper 97.5% Bayesian credible interval from 1.14 children per woman in Haiti to 2.00 in Iceland and 2.01 in Latvia.

For the SSP-5 forecast variant (table A6 in the Appendix), the values are as follows. In 2020-2025 PTFR will range from 0.55 children per woman in Macau to 6.04 in Niger, falling below the replacement level in all countries by the early 2050s, as in the SSP-1 option. By this time the PTFR will range from 0.67 children per woman in North Korea (DPRK) to 2.38 in Niger, in 2075-2080 from 0.57 in North Korea to 1.34 in Mayotte, and by 2095-2100 from 0.50 in North Korea to 1.12 in Iceland with a lower 97.5% Bayesian credible interval from 0.32 children per woman in Ethiopia and Haiti to 0.87 in Latvia and an upper 97.5% Bayesian credible interval from 0.57 children per woman in North Korea to 1.31 in Latvia.

For comparison, we also provide data on CCFR for the SSP-5 variant (Table A7 in the Appendix), within the framework of which the actual low-fertility trap is realized. CCFR for women born in 1985-1990 will be from 0.95 children per woman in Hong Kong to 4.25 in Niger, for women born in 2020-2025 from 0.66 in Macau to 1.54 in Somalia, and for women born in 2045-2050 from 0.61 in Macau and 0.62 in Singapore to 1.37 in Denmark and 1.38 in Iceland.

On July 11, 2024, the United Nations Population Division published the twenty-eighth World Population Prospects (WPP-2024) report. It presents (United Nations 2024b) population estimates and demographic data for 237 countries and dependent territories, world regions and the world as a whole. WPP-2024 contains data from 1950 to 2023 (1,910 national censuses, 3,189 sample surveys, as well as information on current civil registration, in particular on birth and death registration) and a projection from 2024 to 2100.

In projecting future fertility and mortality levels, Bayesian probabilistic methods were used, reflecting the uncertainty of the projections based on the historical variability of changes in each indicator. This method takes into account the past experience of each country and also reflects the uncertainty of future changes based on the past experience of other countries in similar circumstances (United Nations 2024a).

The WPP-2024 forecast contains both deterministic and probabilistic variants: in total, about 10 thousand probabilistic forecasts were modeled for each country and territory, three main deterministic variants (median fertility, low fertility and high fertility), and a number of analytical deterministic scenarios (for example, a variant of constant fertility, a variant without teenage pregnancies, i.e. zero fertility in women under 20, etc.). For the median fertility variant, Bayesian credible intervals (CI) are also indicated at statistical significance levels of 80 and 95%.

Although the UN Population Division draws attention to the special significance of the medium fertility variant, it also contains a number of shortcomings, which have long been pointed out by various researchers (Lutz 2009; Anderson 2014; Pelletier 2021; IHME 2024a), as mentioned both in the WPP-2024 methodology itself (United Nations 2024a) and in the previous version of WPP-2022 (United Nations 2022):

1. data on demographic indicators, and in particular on PTFR, in WPP reports are most often not the most up-to-date, since, due to administrative regulations, the most recent information from current records, the latest national censuses and sample surveys, primarily DHS and MICS, are taken into account with a lag of 1-2 years; in this case, the forecast is based not on a separate forecast of ASFR, and then obtaining PTFR and/or CCFR, but on the primary forecast of PTFR followed by secondary forecasting of ASFR without direct forecasting of CCFR, which, however, can be obtained analytically from the ASFR tables for one-year or five-year age groups;
2. as the main scenario assumption, the median fertility variant is based on a model of differentiation of countries by the dynamics of PTFR depending on the level of its value in the last year with actual data - PTFR for countries with low fertility (in WPP-2024 this is 1.55-1.60 children per woman) begins to grow directly from the first forecast year (in this case, 2024); for countries with fertility slightly above, but below the level of instant-replacement, a hypothesis is introduced about stagnation of PTFR values with a

tendency to a slight decrease in the long term in the second half of the 21st century; and only for countries with fertility above the level of simple reproduction of the population is it assumed that the trend towards an intensive decrease in the PTFR value will persist due to the continuation of the active stage of the demographic transition in fertility;

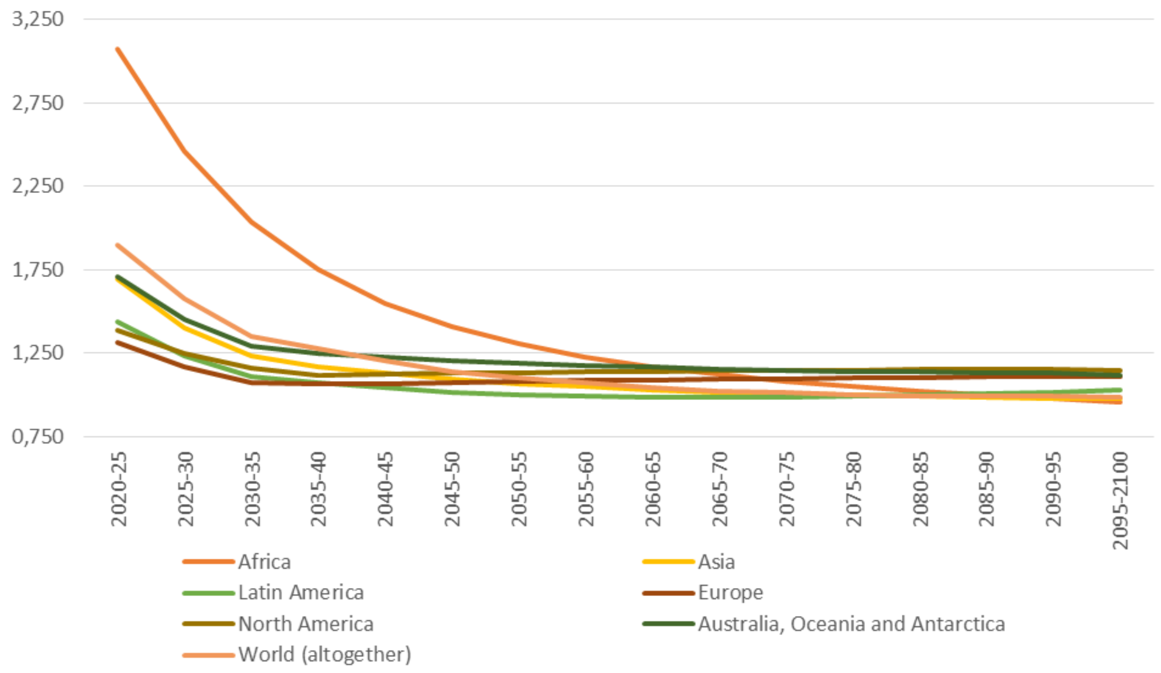
3. the above differentiation model is based on the hypothesis of strong convergence (Anderson 2014) of PTFR values between all countries of the world - in WPP-2024, the range of convergence in the overwhelming majority of countries by the end of the century should be, according to the median variant, between 1.60 and 1.80 children per woman with subsequent stabilization around 1.70-1.75 (United Nations 2024a);
4. the logic of constructing forecasts includes putting in place a specific fertility convergence model (Pelletier 2021) - a model of general equilibrium of moderately low fertility for both female hypothetical and birth cohorts, although convergence for birth cohorts should be more similar to the IIASA and IHME forecasts (Kishinin 2023) due to the assumption of the UN Population Division about the cessation of fertility aging in the most demographically modernized countries of the world and the idea that subsequent stages of the second demographic transition will not follow (Wilson 2013).

These problem areas of the median fertility variant WPP-2024 (and previous versions of WPP) inevitably lead to the need for a more detailed consideration of the low fertility variant as more likely to be realized for most or even all countries and dependent territories of the world (Pelletier 2021; Kishenin 2023). This assumption is confirmed by the most recent data from current records (in most countries with well-established records of births, the dynamics of fertility more likely correspond to the low fertility variant or are between the low and median fertility variants, approaching the trends of the low fertility variant), and by sample surveys from DHS and MICS: of these, released in 2022-2024 surveys, a PTFR value at the level of the low fertility variant of WPP-2024 or even lower is demonstrated by such countries as Nigeria (MICS Nigeria 2021-2022) at 4.2 children per woman, Tanzania (DHS Tanzania 2022) at 3.9, Ethiopia, Liberia, Guinea, Senegal (DHS Senegal 2023) at 3.6, Vanuatu, the Democratic Republic of the Congo (former Zaire (DHS DRC 2023-2024)) at 4.6, Cambodia, Guatemala, Bolivia, Samoa (Western Samoa), Nauru, etc.

The low fertility scenario assumes the realization of the fictitious low fertility trap scenario for all regions of the world by PTFR (Figure 13) and the actual low fertility trap by CCFR.

The resulting picture is similar to the baseline version of the IHME-2024 forecast: in the countries of Europe, North America, Australia and Oceania, the PTFR value will stabilize at between 1.00 and 1.15 children per woman by the end of the 21st century, and between 0.90 and 1.00 in the countries of Africa, Asia and Latin America. CCFR for cohorts of women born in the 2040s turns out to be at levels of 1.15-1.35 children per woman for Europe, 1.15-1.25 for North American countries, 0.85-1.25 for Australia and Oceania, 0.90-1.10 for Latin America, and 0.80-1.05 for Asian and African countries (except Japan and Israel, with rates in the region of 1.15 children per woman).

**Figure 13. PTFR for the low fertility variant of the UN Population Division WPP-2024 for the main regions of the world, from 2020-2025 to 2095-2100, children per woman 15-49 years**



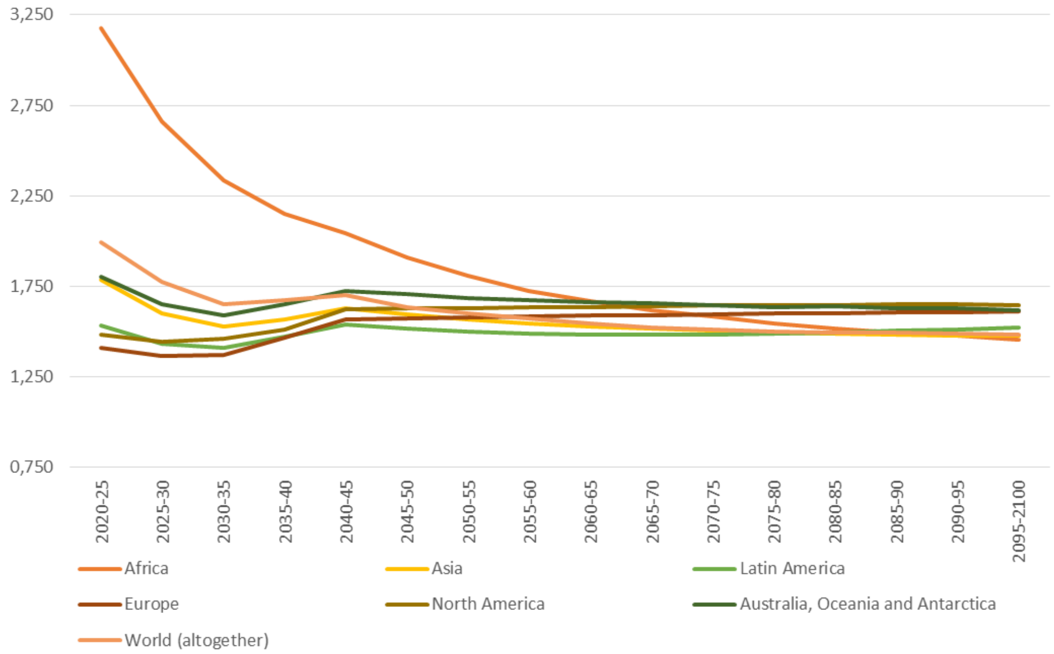

*Source: UN WPP-2024 data. Visualization in Excel.*

For individual countries and dependent territories (Table A8 of the Appendix): in 2020-2025, PTFR will be from 0.43 children per woman in Macau to 5.67 in Niger, falling below the level population instant-replacement in the latter countries by the end of the 2030s – beginning of the 2040s. By 2050–2055, the PTFR will range from 0.44 children per woman in Macau to 1.82 in Mayotte, in 2075–2080 from 0.58 in the Vatican to 1.22 in Kazakhstan and 1.23 children in Mayotte, and by 2095–2100 from 0.57 in the Vatican to 1.22 in France with a lower 95% Bayesian credible interval of 0.24 children per woman in Macau to 1.02 in France. Compared to WPP-2022 (United Nations 2022), the PTFR forecast has decreased by an average of 0.12 children per woman, and by 0.25-0.30 in some countries in Africa and Oceania.

The WPP-2024 median fertility variant is on average (except for the first few five-year periods to smoothly combine the forecast variants) 0.5 children per woman higher in PTFR (Figure 14).

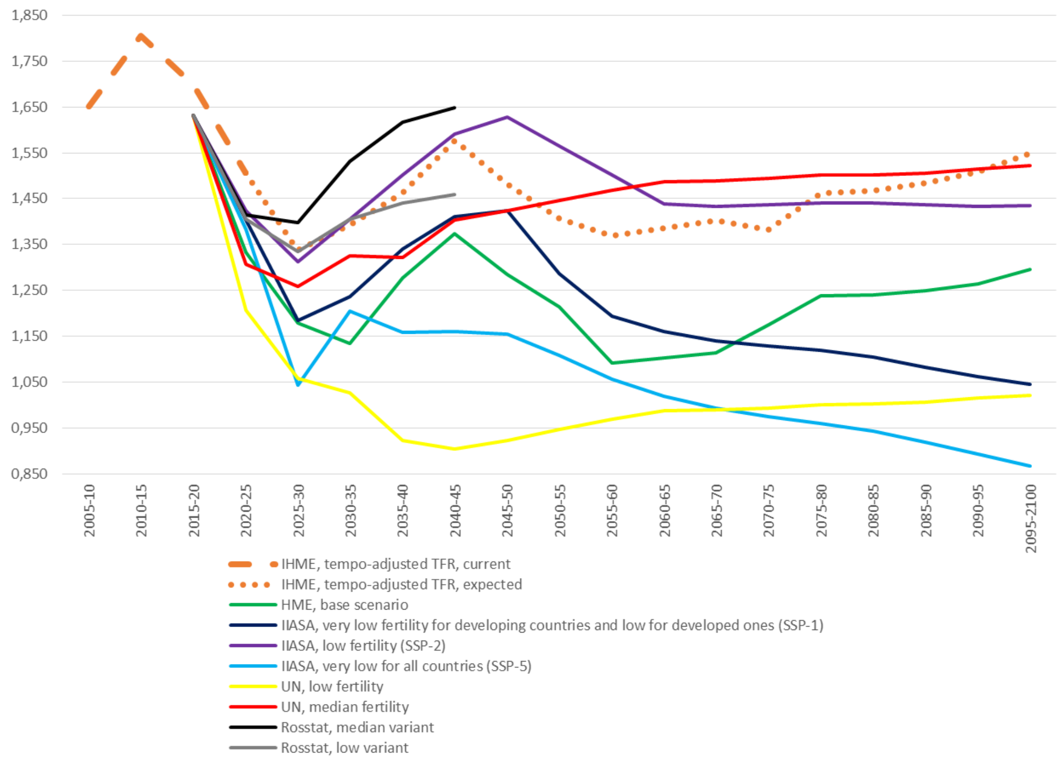
By the end of the 21st century, the PTFR for Europe, North America, Australia and Oceania is 0.5 children higher than in the low fertility scenario – between 1.50 and 1.65 children per woman, with similar values in Africa, Asia and Latin America at between 1.40 and 1.50 children per woman. But the difference in CCFR for cohorts of women born in the 2040s turns out to be less than 0.5 children per woman: at levels of 1.50-1.70 for Europe, 1.50-1.55 for North America, 1.25-1.55 for Australia and Oceania, 1.20-1.35 for Latin America, and 1.10-1.35 for Asian and African countries (except for Japan and Israel with rates in the region of 1.50 children per woman). For countries, see Table A9 in the Appendix.

**Figure 14. PTFR for the median fertility variant of the UN Population Division WPP-2024 for the main regions of the world, from 2020-2025 to 2095-2100, children per woman aged 15-49**




*Source: UN WPP-2024 data. Visualization in Excel.*

**Figure 15. PTFR and taTFR for different forecast scenarios for Russia, actual data for 2015-2020 and forecasts from 2020-2025 to 2095-2100, children per woman aged 15-49**




*Source: IHME, IIASA, WPP-2024, Rosstat data and authors' calculations. Visualization in Excel.*

Thus, the smaller difference in the fertility of birth cohorts indicates that the difference in PTFR for the median fertility variant is partially explained not only by the underlying hypothesis of a lower real intensity of childbearing, but also by a less intense aging of the fertility rate. This shows that the WPP-2024 median fertility scenario may become more realistic in a situation where the aging of the fertility rate as a result of the demographic transition is significantly less (KC et al. 2024).

A similar situation is observed, for example, in the demographic forecast of Rosstat until 2045 (Rosstat 2023), where both the low and medium forecast scenarios for fertility show the realization of either the model of general equilibrium of moderately low fertility, or the model of long-term equilibrium of moderately low fertility for female birth cohorts, but for PTFR they differ precisely in the scenarios for the rate of aging of the fertility: for the low scenario, stabilization at 1.25-1.40 children per woman, and for the medium scenario, slow growth with stabilization in the region of 1.60.

In fact, both of these forecast scenarios from the point of view of the WPP-2024 approach of the UN Population Division are more likely two different subtypes of the median fertility scenario (or SSP-2 in the understanding of IIASA-2023), and the low fertility scenario is missing, since it is precisely in it that the realization of the low fertility trap should appear - then the PTFR should fall to the levels indicated in the SSP-1 and SSP-5 variants of IIASA-2023 for the fictitious and actual low fertility traps, respectively (Figure 15), and in future forecasts of Rosstat, these scenarios must absolutely be added.

## Conclusion

In this paper, we considered the data on PTFR and taTFR for 2005-2025 and the projected PTFR estimates from 2020-2025 to 2095-2100 made by IHME, IIASA and the UN Population Division. Our results show that the low fertility trap is likely to be realized for all countries and territories of the world, i.e., fertility may fall below the levels of 1.25-1.30 children per woman in hypothetical and birth cohorts. This is evidenced by the increase in the rate of decline in the fertility rate that began in the mid-2010s and has not stopped to this day. Analysis of the calculated taTFR indicates that a fairly significant part of this decrease for countries with low and very low fertility is caused by another wave of aging fertility as part of the second demographic transition, but in these countries there is also a small or moderate reduction in the real intensity of childbearing (*quantum*), which will potentially lead to a decrease in the completed cohort fertility rate.

The probability of the realization of the actual low fertility trap has also increased significantly. Although it is still impossible to say that among the fertility convergence models there has been a definitive change in the most likely one, from a model of general and long-term equilibrium of moderately low fertility to a model of an actual low fertility trap, all three main international organizations (IHME, IIASA, UN Population Division) developing long-term demographic forecasts have already reflected this change in probabilities in the 2023-2024 forecast round.

It is important to understand that at present there is no reason to believe that humanity can significantly influence the dynamics of fertility, whether this means attempting to increase fertility or at least stop its decline. Direct pro-natalist policies have quite clearly demonstrated their failure (Coleman, Rowthorn 2011; Botev 2015) in terms of the possibilities of changing the completed cohort fertility rate and the degree of realization of reproductive intentions, although they do affect the dynamics of PTFR through direct timing translations in the birth calendar, then creating sharp waves of increased PTFR decline due to reverse timing translations in the birth calendar.

Available evidence confirms (Hellstrand et al. 2021; KC et al. 2024; United Nations 2024a) that further growth of human capital, primarily through expanding access to education in general (and especially education for women) and reducing gender inequality, may have some beneficial indirect effects on stabilizing fertility at slightly higher values (within 0.1-0.2 children per woman for PTFR and CCFR), but policies aimed at increasing human capital do not have a direct demographic focus and cannot be considered pro-natalist in this regard: they aim to improve the quality of life of individuals, social groups and classes, local societies, but not to increase fertility.

However, even this effect (0.1-0.2 children per woman) will not be enough to return long-term fertility to the level of population instant-replacement for female birth cohorts, which will inevitably lead to long-term depopulation and aging of the population. This signals that people's ability to change social processes is extremely limited, and perhaps researchers, by assuming a high hypothetical manageability of social processes (Reher 2019), underestimate the similarity of social patterns with the patterns studied by the natural sciences. In such a situation, regardless of how significantly the probability of the low fertility trap has increased, humanity and societies in individual countries will have to adapt to long-term low, very low, or even ultra-low fertility (Sobotka 2018).

The low fertility trap carries not only negative risks, but also moderately positive aspects associated with a decrease in the burden on the environment and in the severity of the resource crisis due to the depletion of non-renewable resources, as well as an increase in the standard of living and the value of individual human life. But the focus of social policy is designed in such a way that the management systems of public and state institutions try above all to minimize the negative consequences (Wilkins 2019), and the low fertility trap has many of them: a slowdown in economic growth and economic indicators in absolute values, an increase in the burden on public health, social and pension systems, a shortage of personnel and the emergence of distortions in the labor market, stagnation or even a decrease in investment in education due to a decrease in the share of children and young people in the population structure, and an increase in migration flows. All these problems are already relevant for demographically developed countries, but they will soon become commonplace for literally all countries, so it is advisable to use the experience of those societies where the process of demographic modernization has advanced further.

## References

Adhikari S., Lutz W., KC S. (2023). Rural/urban fertility differentials in the Global South: Is female education the key driver of declining birth rates? *IIASA Working Paper*. Laxenburg, Austria: WP-23-004. https://pure.iiasa.ac.at/id/eprint/18729/1/WP-23-004.pdf

Alders M., de Beer J. (2004). Assumptions on fertility in stochastic population forecasts. *International Statistical Review*, 72(1), 65–79. https://doi.org/10.1111/j.1751-5823.2004.tb00224.x

Anderson B. (2014). Forecasting low fertility: reflections on the plausibility and application of hypotheses. *Demographic Review*, 1(1), 57-105. https://doi.org/10.17323/demreview.v1i1.1827

Anderson T., Kohler H.P. (2015). Low fertility, socioeconomic development, and gender equity. *Population and development review*, 41(3), 381-407. https://doi.org/10.1111/j.1728-4457.2015.00065.x

Beaujouan E. (2020). Latest-Late Fertility? Decline and Resurgence of Late Parenthood Across the Low-Fertility Countries. *Population and Development Review*, 46, 219-247. https://doi.org/10.1111/padr.12334

Bergsvik J., Fauske A., Hart R.K. (2021). Can policies stall the fertility fall? A systematic review of the (quasi-) experimental literature. *Population and Development Review*. 47, 913–964. https://doi.org/10.1111/padr.12431

Bernstein A., Jones K.M. (2019). *The economic effects of contraceptive access: a review of the evidence.* Washington, DC: Report of Institute for Women's Policy Research. https://iwpr.org/wp-content/uploads/2020/07/Contraception-fact-sheet_final.pdf

Billari F.C., Graziani R., Melilli E. (2014). Stochastic Population Forecasting Based on Combinations of Expert Evaluations Within the Bayesian Paradigm. *Demography*, 51(5), 1933–1954.

Bloom D.E., Canning D. (2007). Mortality traps and the dynamics of health transitions. *Proceedings of the National Academy of Sciences*, 104, 16044–16069. https://doi.org/10.1073/pnas.070201210

Bloom D.E., Kuhn M., Prettner K. (2023). *Fertility in High-Income Countries: Trends, Patterns, Determinants, and Consequences.* Report of IZA (Institute of Labor Economics Germany), SSRN Electronic Journal. https://docs.iza.org/dp16500.pdf

Bongaarts J., Feeney G. (1998). On the Quantum and Tempo of Fertility. *Population and Development Review*, 24, 271–291. https://u.demog.berkeley.edu/~jrw/Biblio/Eprints/Tempo/bongaarts.feeney.1998.pdf

Bongaarts J., Sobotka T. (2012). A Demographic Explanation for the Recent Rise in European Fertility. *Population and Development Review*, 38, 83-120. https://doi.org/10.1111/j.1728-4457.2012.00473.x

Botev N. (2015). Could Pronatalist Policies Discourage Childbearing? *Population and Development Review*, 41(2), 301–314. https://doi.org/10.1111/j.1728-4457.2015.00048.x

Bourgeois-Pichat J. (1994). *La Dynamique des populations. Populations stables semi-stables et quasi stables.* (Travaux et Documents). Paris: INED. https://www.ined.fr/fr/publications/editions/cahiers/la-dynamique-des-populations/

Bricker D., Ibbitson J. (2019). *Empty planet: the shock of global population decline*. New York, NY: Crown.

Brinton M.C., Bueno X., Oláh L., Hellum M. (2018). Postindustrial Fertility Ideals, Intentions, and Gender Inequality: A Comparative Qualitative Analysis. *Population and Development Review*, 44, 281-309. https://doi.org/10.3197/jps.2019.3.2.87

Castiglioni M., Dalla-Zuanna G., Tanturri M.L. (2020). Post-transitional Demography and Convergence: What Can We Learn from Half a Century of World Population Prospects? In Mazzuco S., Keilman N. (Eds.), *Developments in Demographic Forecasting. Springer Cham. Volume 49, The Springer Series on Demographic Methods and Population Analysis book series* (pp. 63-87). https://doi.org/10.1215/00703370-9936991

Caswell H., Vindenes Y. (2018). Demographic variance in heterogeneous populations: matrix models and sensitivity analysis. *Oikos*, 127(5), 648-663. https://doi.org/10.1111/oik.04708

Cheng P.R., Lin E.S. (2010). Completing incomplete cohort fertility schedules. *Demographic Research*, 23, 223-256. https://doi.org/10.4054/DemRes.2010.23.9

Čipin I., Zeman C., Međimurec P. (2020). Cohort Fertility, Parity Progression, and Family Size in Former Yugoslav Countries. *Comparative Population Studies*, 45. https://doi.org/10.12765/CPoS-2020-18

Coleman D., Rowthorn R. (2011). Who's afraid of population decline? A critical examination of its consequences. *Population and Development Review*, 37, 217–248. https://doi.org/10.1111/j.1728-4457.2011.00385.x

Cook L.J., Iarskaia-Smirnova E.R., Kozlov V.A. (2023). Trying to reverse demographic decline: pro-natalist and family policies in Russia, Poland and Hungary. *Social Policy and Society*, 22(2), 355-375. https://doi.org/10.1017/S1474746422000628

Dalla Zuanna G., Micheli G. A. (Eds.). (2004). *Strong family and low fertility: a paradox?: new perspectives in interpreting contemporary family and reproductive behaviour* (Vol. 14). Springer Science & Business Media. https://doi.org/10.1007/1-4020-2837-7

De Silva T., Tenreyro S. (2017). Population control policies and fertility convergence. *Journal of Economic Perspectives*, 31(4), 205–228. https://doi.org/10.1257/jep.31.4.205

Demeny P. (2015). Sub-replacement fertility in national populations: Can it be raised? *Population Studies*, 69(Suppl. 1), 77–85. https://doi.org/10.1080/00324728.2014.962930

DHS DRC (2023-2024). INED (France), Institut National de la Statique et l'Ecole de Santé Publique de Kinshasa, Kinshasa, République Démocratique du Congo, and The DHS Program, ICF, Rockville, Maryland, USA. https://dhsprogram.com/pubs/pdf/PR156/PR156.pdf

DHS Senegal (2023). Agence Nationale de la Statistique et de la Démographie (ANSD), Dakar, Sénégal, and The DHS Program, ICF, Rockville, Maryland, USA. https://dhsprogram.com/pubs/pdf/FR390/FR390.pdf

DHS Tanzania (2022). Ministry of Health (MoH) [Tanzania Mainland], Ministry of Health (MoH) [Zanzibar], National Bureau of Statistics (NBS), Office of the Chief Government Statistician (OCGS), and The DHS Program, ICF, Rockville, Maryland, USA. https://dhsprogram.com/pubs/pdf/FR382/FR382.pdf

Dorius S.F. (2008). Global demographic convergence? A reconsideration of changing intercountry inequality in fertility. *Population and Development Review*, 34(3), 519–537. https://doi.org/10.1111/j.1728-4457.2008.00235.x

Durowaa-Boateng A., Yildiz D., Goujon A. (2023). A Bayesian model for the reconstruction of education- and age-specific fertility rates: An application to African and Latin American countries. *Demographic Research,* 49 (31), 809-848. https://doi.org/10.4054/DemRes.2023.49.31

Ediev D.M. (2013). Comparative importance of the fertility model, the total fertility, the mean age and the standard deviation of age at childbearing in population projections. In Meeting of the International Union for the Scientific Study of Population, Busan. Presented at the Meeting of the International Union for the Scientific Study of Population, Busan. https://iussp.org/sites/default/files/event_call_for_papers/TF%20MS%20SD_what%20matters_StWr.pdf

Frejka T. (2017). The Fertility Transition Revisited: A Cohort Perspective. *Comparative Population Studies*, 42. https://doi.org/10.12765/CPoS-2017-09

Gietel-Basten S., Scherbov S. (2020). Exploring the « true value» of replacement rate fertility. *Population Research and Policy Review*, 39, 763-772. https://doi.org/10.1007/s11113-019-09561-y

Gietel-Basten S., Sobotka T., Zeman K. (2014). Future fertility in low fertility countries. In W. Lutz, W.P. Butz, KC. Samir (Eds.), *World population and human capital in the twenty-first century* (pp. 136-244). Oxford: Oxford University Press. https://doi.org/10.1093/oso/9780198813422.001.0001

Guzzo K.B., Hayford S.R. (2023). Evolving Fertility Goals and Behaviors in Current U.S. Childbearing Cohorts. *Population and Development Review*, 4, 7-42. https://doi.org/10.1111/padr.12535

Hakim C. (1998). Developing a sociology for the twenty-first century: Preference Theory. *The British journal of sociology*, 49(1), 137-143. https://doi.org/10.2307/591267

Hellstrand J., Nisén J., Miranda V., Fallesen P., Dommermuth L., Myrskylä M. (2021). Not Just Later, but Fewer: Novel Trends in Cohort Fertility in the Nordic Countries. *Demography*, 58(4), 1373–1399. https://doi.org/10.1215/00703370-9373618

Hellstrand J., Nisén J., Myrskylä M. (2020). All-Time Low Period Fertility in Finland: Demographic Drivers, Tempo Effects, and Cohort Implications. *Population Studies,* 74(3), 315–329. https://doi.org/10.1080/00324728.2020.1750677

Hou Y., Ma X., Huang K. (2008). Research on the fertility desire and behavior of Beijing urban women from only-child families (in Chinese). *Population and Development (China)*, 14, 47-54.

Hwang J. (2023). Later, Fewer, None? Recent Trends in Cohort Fertility in South Korea. *Demography*, 60(2), 563–582. https://doi.org/10.1215/00703370-10585316

IHME GBD 2019 Demographics Collaborators (2020). Global age-sex-specific fertility, mortality, healthy life expectancy (HALE), and population estimates in 204 countries and territories, 1950–2019: a comprehensive demographic analysis for the Global Burden of Disease Study 2019. *The Lancet*, 396(10258), 1160-1203. https://doi.org/10.1016/S0140-6736(20)30977-6

IHME GBD 2019 Demographics Collaborators (2021). *Global Fertility, Mortality, Migration, and Population Forecasts 2017-2100.* Retrieved from https://ghdx.healthdata.org/record/ihme-data/global-population-forecasts-2017-2100

IHME GBD 2021 Fertility and Forecasting Collaborators (2024a). Global fertility in 204 countries and territories, 1950–2021, with forecasts to 2100: a comprehensive demographic analysis for the Global Burden of Disease Study 2021. *The Lancet*, 403(10440), 2057-2099. https://doi.org/10.1016/S0140-6736(24)00550-6

IHME Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2021 (2024b). *Fertility Estimates 1950-2021 and Forecasts 2022-2100*. Seattle, United States of America: Institute for Health Metrics and Evaluation (IHME). Retrieved from https://ghdx.healthdata.org/record/ihme-data/global-burden-disease-study-2021-gbd-2021-fertility-1950-2100

IIASA (2018). *Global population projections to 2100 year*. Retrieved from http://dataexplorer.wittgensteincentre.org/wcde-v2/

IIASA (2024). Global population projections to 2100 year. Retrieved from https://dataexplorer.wittgensteincentre.org/wcde-v3/

Jalovaara M., Neyer G., Andersson G., Dahlberg J., Dommermuth L., Fallesen P., Lappegård T. (2019). Education, Gender, and Cohort Fertility in the Nordic Countries. *European Journal of Population*, 35(1), 563-586. https://doi.org/10.1007/s10680-018-9492-2

Jones G.W. (2019). Ultra-low fertility in East Asia: policy responses and challenges*. *Asian Population Studies*, 15(2), 131–149. https://doi.org/10.1080/17441730.2019.1594656

Kan M. (2023). Sustained and universal fertility recuperation in Kazakhstan. *European Journal of Population*, 39(1), 23, 1-39.
https://doi.org/10.1007/s10680-023-09671-6

Kan M.Y., Hertog E. (2017). Domestic division of labour and fertility preference in China, Japan, South Korea, and Taiwan. *Demographic Research*, 36(18), 557-588.
https://doi.org/10.4054/DemRes.2017.36.18

KC S., Dhakad M., Potančoková M., Adhikari S., Yildiz D., Mamolo M., Sobotka T., Zeman K., et al. (2024). *Updating the Shared Socioeconomic Pathways (SSPs) Global Population and Human Capital Projections*. IIASA Working Paper. Laxenburg, Austria: WP-24-003.
https://pure.iiasa.ac.at/id/eprint/19487/1/WP-24-003.pdf

KC S., Moradhvaj M., Potančoková M., Adhikari S., Yildiz D., Mamolo M., Sobotka T., Zeman K., Abel G., Goujon, A. et al. (2023). *IIASA and Wittgenstein Center (WIC) Population and Human Capital Projections - 2023.*
https://zenodo.org/records/10618931

Keiding N., Ali M.M., Eriksson F., Matsaseng T., Toskin I., Kiarie J. (2021). The Use of Time to Pregnancy for Estimating and Monitoring Human Fecundity From Demographic and Health Surveys. *Epidemiology*, 32(1), 27-35.
https://doi.org/10.1097/EDE.0000000000001296

Keilman N. (2019). *Erroneous population forecast.* In Bengtsson T., Keilman N. (Eds.), Old and new perspectives on mortality forecasting. Demographic research monographs (A series of the Max Planck Institute for Demographic Research). Cham: Springer.
https://doi.org/10.1007/978-3-030-05075-7

Kishenin P.A. (2023). Total fertility of real generations in demographic projections: a comparative analysis of the prospects for changes in the countries of the former USSR. *Demographic Review*, 10(1), 79-107.
https://doi.org/10.17323/demreview.v10i1.17261

Kohler H.P., Billari F., Ortega J. A. (2002). The emergence of Lowest-Low fertility in Europe during the 1990s. *Population and Development Review*, 28(4), 641–680.
https://doi.org/10.1111/j.1728-4457.2002.00641.x

Lazzari E., Potančoková M., Sobotka T., Gray E., Chambers G.M. (2023). Projecting the Contribution of Assisted Reproductive Technology to Completed Cohort Fertility. *Population Research and Policy Review*, 42(1).
https://doi.org/10.1007/s11113-023-09765-3

Livi-Bacci M. (2017). *A concise history of world population.* Chichester: Wiley-Blackwell.
https://doi.org/10.1002/9781119406822

Lutz W. (1996). *The future population of the World. What can we assume today?* IIASA, Laxenburg, Austria.
https://pure.iiasa.ac.at/id/eprint/4762/1/XB-96-003.pdf

Lutz W. (2009). *Toward a systematic, argument-based approach to defining assumptions for population projections* (Interim report IR-09-037). Laxenburg: International Institute for Applied Systems Analysis.
https://pure.iiasa.ac.at/id/eprint/9115/1/IR-09-037.pdf

Lutz W., Butz W.P., KC S. (Eds.) (2014). *World Population and Human Capital in the Twenty-First Century*. Oxford University Press. https://doi.org/10.1093/oso/9780198813422.001.0001

Lutz W., Goujon A., KC S., Stonawski M., Stilianakis N. (2018). *Demographic and Human Capital Scenarios for the 21st Century: 2018 assessment for 201 countries*. Luxembourg (EUR 29113 EN, Publications Office of the European Union). https://op.europa.eu/en/publication-detail/-/publication/e1853ba8-4444-11e8-a9f4-01aa75ed71a1/language-en

Lutz W., Pachauri S. (2023). Systems Analysis for Sustainable Wellbeing. 50 Years of IIASA Research, 40 Years After the Brundtland Commission, Contributing to the Post-2030 Global Agenda. Laxenburg: International Institute for Applied Systems Analysis. https://doi.org/10.5281/zenodo.8214208

Lutz W., Scherbov S., Gietel-Basten S. (2013). Very long range global population scenarios to 2300 and the implications of sustained low fertility. *Demographic Research*, 28(39), 1145-1166. https://doi.org/10.4054/DemRes.2013.28.39

Lutz W., Skirbekk V. (2005). Policies Addressing the Tempo Effect in Low-Fertility Countries. *Population and Development Review*, 31(4), 699–720. https://doi.org/10.1111/j.1728-4457.2005.00094.x

Lutz W., Skirbekk V., Testa M.R. (2006). The Low-Fertility Trap Hypothesis: Forces that May Lead to Further Postponement and Fewer Births in Europe. *Vienna Yearbook of Population Research*, 4, 167–192. https://pure.iiasa.ac.at/id/eprint/8465/1/RP-07-001.pdf

Mazzuco S., Keilman N. (2020). *Developments in Demographic Forecasting.* Springer Cham. Volume 49, The Springer Series on Demographic Methods and Population Analysis book series. https://doi.org/10.1215/00703370-9936991

McDonald P. (2000). Gender Equity in Theories of Fertility Transition. *Population and Development Review*, 26: 427-439. https://doi.org/10.1111/j.1728-4457.2000.00427.x

MICS Nigeria (2021-2022). UNICEF. https://mics-surveys-prod.s3.amazonaws.com/MICS6/West%20and%20Central%20Africa/Nigeria/2021/Survey%20findings/Nigeria%202021_MICS_SFR_English.pdf

Myrskylä M., Goldstein J.R., Cheng Y.A. (2013). New Cohort Fertility Forecasts for the Developed World: Rises, Falls, and Reversals. *Population and Development Review*, 39(1), 31–56. https://www.demogr.mpg.de/papers/working/wp-2012-014.pdf

Neyer G., Caporali A., Gassen N. S. (2017). *EU-Policies and Fertility: The Emergence of Fertility-Related Family Policies at the Supra-National Level.* Stockholm Research Reports in Demography 10, Stockholm University, Demography Unit. http://www.familiesandsocieties.eu/wp-content/uploads/2017/06/WP79NeyerCaporaliGasse2017.pdf

Neyer G., Lappegård T., Vignoli D. (2013). Gender Equality and Fertility: Which Equality Matters? Egalité de genre et fécondité: de quelle égalité s' agit-il? *European Journal of Population/Revue européenne de Démographie*, 29, 245-272. https://doi.org/10.1007/s10680-013-9292-7

Okun B. (2013). Fertility and marriage behavior in Israel: Diversity, change, and stability. *Demographic Research*, 28(17), 457-504. https://doi.org/10.4054/DemRes.2013.28.17

Okun B., Shifris G. (2024). Cohort fertility of immigrants to Israel from the former Soviet Union. *Demographic Research*, 50(13), 377-392. https://doi.org/ 10.4054/DemRes.2024.50.13

Pelletier F. (2021). A sensitivity analysis of the projected median fertility trajectories in the WPP: towards a better understanding and reassessment of the Bayesian model. The United Nations, Department of Economic and Social Affairs, Population Division. Working Paper (May 2021). (UN DESA/POP/2021/TP/NO.1). https://desapublications.un.org/working-papers/sensitivity-analysis-projected-median-fertility-trajectories-world-population

Poston J.D.L. (2018). *Low Fertility Regimes and Demographic and Societal Change.* Springer Heidelberg. https://doi.org/10.1007/978-3-319-64061-7

Reher D.R. (2019). The Aftermath of the demographic transition in the developed world: Interpreting enduring disparities in reproductive behavior. *Population and Development Review*, 47(2), 475-503. https://doi.org/10.1111/padr.12266

Reiter, C., Goujon, A., KC, S. (2022). The Demography of Human Capital Formation in Sub-Saharan Africa, 1950-2100. In Odimegwu C., Adewoyin Y. (Eds.), *The Routledge Handbook of African Demography.* (pp. 591-615). Cham: Routledge. https://doi.org/10.4324/9780429287213-39

Rindfuss R.R., Choe M.K. (2015). *Low and Lower Fertility: Variations across Developed Countries.* Cham, Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-21482-5

Rindfuss R.R., Choe M.K. (2016). *Low Fertility, Institutions, and their Policies: Variations Across Industrialized Countries.* Cham, Switzerland: Springer International Publishing. https://doi.org/ 10.1007/978-3-319-32997-0

Rindfuss R.R., Choe M.K., Brauner-Otto S.R. (2016). The Emergence of Two Distinct Fertility Regimes in Economically Advanced Countries. *Population Research and Policy Review*, 35(3), 287-304. https://doi.org/10.1007/s11113-016-9387-z

Rosstat (2023). *Estimated population of the Russian Federation until 2045*. Retrieved from https://rosstat.gov.ru/compendium/document/13285

Sanderson W.C., Lutz W., Scherbov S. (1996). *Probabilistic world population projections based on expert opinion.* Laxenburg: International Institute for Applied Systems Analysis. https://pure.iiasa.ac.at/id/eprint/5008/1/WP-96-017.pdf

Schleutker E. (2013). Fertility, Family Policy and Welfare Regimes. *Comparative Population Studies*. 39, 1. https://doi.org/10.12765/CPoS-2013-18

Schmertmann C., Zagheni E., Goldstein J.R., Myrskylä M. (2014). Bayesian Forecasting of Cohort Fertility. *Journal of the American Statistical Association*, 109(506), 500-513. https://doi.org/10.1080/01621459.2014.881738

Schoen R. (2022). Relating period and cohort fertility. *Demography*, 59, 877-894. https://doi.org/10.1215/00703370-9936991

Ševcíková H., Li N., Kantorová V., Gerland P., Raftery A.E. (2016). Age-specific mortality and fertility rates for probabilistic population projections. In Schoen R. (Eds.), *Dynamic demographic analysis* (pp. 285–310). Cham: Springer. https://doi.org/10.1007/978-3-319-26603-9_15

Sobotka T, Matyziak A, Brzozowska Z. (2019). *Policy responses to low fertility: how effective are they?* Working Paper for UNFPA. Paris, France. https://www.unfpa.org/publications/policy-responses-low-fertility-how-effective-are-they

Sobotka T. (2017). Post-transitional fertility: the role of childbearing postponement in fueling the shift to low and unstable fertility levels. *Journal of Biosocial Science*, 49(1), 20-45. https://doi.org/10.1017/S0021932017000323

Sobotka T. (2018). *Global low fertility: Key trends.* Report of International Seminar on Indicators and. Policies on Low Fertility, KOSIS-UNFPA: Seoul. https://www.researchgate.net/publication/330602019_Global_low_fertility_Key_trends

Sobotka T., Lutz W (2011). Misleading Policy Messages Derived from the Period TFR: Should We Stop Using It?. *Comparative Population Studies*, 35(3) (Sep. 2011). https://doi.org/10.12765/CPoS-2010-15

Sobotka T., Matysiak A., Brzozowska Z. (2017). *Gender revolution, family reversal and fertility*. Paper presented at IUSSP Population Conference, Cape Town. https://www.eurrep.org/wp-content/uploads/RC28_Gender-revolution-family.pdf

United Nations, Department of Economic and Social Affairs, Population Division (2004). *World Population to 2300 year.* (United Nations publication 2004, Sales No. E.04.XIII.11). Retrieved from https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/files/documents/2020/Jan/un_2002_world_population_to_2300.pdf

United Nations, Department of Economic and Social Affairs, Population Division (2020). *World Population Prospects. The 2019 Revision, vol. I: Comprehensive Tables.* (United Nations publication, Sales No. E.20.XIII.7). Retrieved from https://population.un.org/wpp2019/

United Nations, Department of Economic and Social Affairs, Population Division (2022). *World Population Prospects. The 2022 Revision, vol. I: Comprehensive Tables.* (United Nations publication, Sales No. E.22.XIII.7). Retrieved from https://population.un.org/wpp2022/

United Nations, Department of Economic and Social Affairs, Population Division (2024a). *World Population Prospects 2024: Summary of Results*. UN DESA/POP/2024. https://population.un.org/wpp/Publications/

United Nations, Department of Economic and Social Affairs, Population Division (2024b). *World Population Prospects 2024*. UN DESA/POP/2024. https://population.un.org/wpp/Download/

van Dalen H. P., Henkens K. (2020). When is fertility too low or too high? Population policy preferences of demographers around the world. *Population Studies*, 75(2), 289–303. https://doi.org/10.1080/00324728.2020.1784986

Vollmer S., Strulik H. (2015). The fertility transition around the world. *Journal of Population Economics*, 28(1),31-144. https://doi.org/10.1007/s00148-013-0496-2

Vollset S.E., Goren E., Yuan C.W., Cao J., Smith A.E., Hsiao T., Murray C.J. (2020). Fertility, mortality, migration, and population scenarios for 195 countries and territories from 2017 to 2100: a forecasting analysis for the Global Burden of Disease Study. *The Lancet*, 396(10258), 1285-1306. https://doi.org/10.1016/S0140-6736(20)30677-2

Whittaker A. (2022). Demodystopias: Narratives of ultra-low fertility in Asia. *Economy and Society*, 51, 116-137. https://doi.org/10.1080/03085147.2021.1968672

Wilkins E. (2019). Policy responses to low fertility: How effective are they? *Working Paper №2 for UNFPA.* Paris, France. https://www.unfpa.org/sites/default/files/pub-pdf/FINAL_Determinants_of_low_fertility.pdf

Wilson C. (2011). Understanding global demographic convergence since 1950. *Population and Development Review*, 37(2), 375–388. https://doi.org/10.2307/23043287

Wilson C. (2013). Thinking about post-transitional demographic regimes: A reflection. *Demographic Research*, 28, 1373-1388. https://doi.org/10.4054/DemRes.2013.28.46

Winkler-Dworak M., Pohl M., Beaujouan E. (2024). Scenarios of Delayed First Births and Associated Cohort Fertility Levels. *Demography*, 61(3), 687-710. https://doi.org/10.1215/00703370-11315685

World Bank, Eurostat (2010). *Long-Range World Population Projections to 2150 year.* Retrieved from https://www.vsemirnyjbank.org/ru/access-to-information/request-submission

Zakharov S.V. (2024). Three Decades on Russia’s Path of the Second Demographic Transition: How Patterns of Fertility are Changing Under an Unstable Demographic Policy. *Comparative Population Studies*, 49 (Jan. 2024). https://doi.org/10.12765/CPoS-2024-02