DEMOGRAPHIC RESEARCH
A peer-reviewed, open-access journal of population sciences

DEMOGRAPHIC RESEARCH

VOLUME 54, ARTICLE 30, PAGES 973–986
PUBLISHED 27 MAY 2026
https://www.demographic-research.org/Volumes/Vol54/30/
DOI: 10.4054/DemRes.2026.54.30

Descriptive Finding

The ratio of births observed to births needed: An indicator to assess demographic sustainability

Thomas Spoorenberg

Vegard Skirbekk

Contents

Demographic Research: Volume 54, Article 30
Descriptive Finding

The ratio of births observed to births needed: An indicator to assess demographic sustainability

Thomas Spoorenberg[*1]

Vegard Skirbekk[2]

Abstract

BACKGROUND
A stationary population may offer advantages for societal, economic, and ecological sustainability. It requires that the number of births aligns with expected deaths under given mortality patterns. However, reproductive rates such as the TFR are not designed to assess whether the number of births observed is sufficient to replace expected deaths, necessitating direct assessment of birth–death balance for population sustainability.

OBJECTIVE
We aim to assess whether current fertility levels are sufficient to replace expected deaths using a new demographic indicator, the ratio of births observed to births needed (B_o/B_n).

METHODS
We analyze global and regional demographic sustainability from 1950 to 2100 using data from the World Population Prospects 2024. The B_o/B_n ratio is derived from stationary population theory, comparing actual births to those required under given mortality conditions.

RESULTS
Globally, births observed exceeded those needed by 18% in 2025, but this surplus is declining. According to the United Nations medium variant projection, by 2060, global births will be insufficient to replace expected deaths for the first time in modern history. By 2100, births are projected to fall 12% short of the level needed. Regional variation is substantial: Middle and Eastern Africa maintain B_o/B_n ratios above 2.0, while Eastern Asia exhibits a critically low ratio of 0.49. Currently, 43% of the global population live in countries with insufficient births, and this proportion will reach 75% by 2100.

[*] The views expressed in this paper are those of the author and do not necessarily reflect the views of the United Nations.

[1] Demographic Analysis Section, United Nations Population Division, New York, USA.
[2] University of Oslo and Norwegian Institute of Public Health, Oslo, Norway.

CONTRIBUTION

The B_o/B_n ratio provides a direct measure of demographic sustainability that complements traditional fertility indicators, offering crucial insights for policy planning in an era of global demographic transition.

1. Introduction

A stationary population with a constant growth rate and fixed age structure is a policy goal for many countries and offers advantages for societal, economic, and institutional sustainability. Zero population growth policies aim to align births with mortality patterns, preventing significant population fluctuations that strain resources, create economic volatility, and overwhelm infrastructure. Predictable demographic profiles enable better planning for housing, healthcare, education, and social services while fostering resilience against ecological and economic pressures.

Economically, a stable population size reduces labor market imbalances and fiscal strain. Rapid growth creates youth bulges that overwhelm education systems and job markets, while population decline increases old-age dependency ratios and burdens pension systems (Lee and Mason 2011). Balanced age structures support long-term economic planning through steady labor supply and predictable consumption patterns.

Ecologically, population stabilization alleviates pressure on natural resources, reducing deforestation, carbon emissions, and biodiversity loss. Stabilizing global population growth could reduce greenhouse gas emissions by 15%–20% by 2050 compared to high-growth scenarios (O'Neill et al. 2010), aligning with ecological carrying capacity to meet present needs without compromising future generations.

Contemporary demographic analyses predominantly center on the Total Fertility Rate (TFR), which has important limitations when assessing demographic sustainability. The TFR represents a synthetic cohort measure rather than the number of births actually occurring in a given period. Even cohort-based or tempo-adjusted variants are designed to summarize fertility behavior, not to measure the absolute balance between the births and deaths in a population. While the net reproduction rate (NRR) incorporates mortality, it focuses on reproductive rates rather than the actual number of births. The intrinsic growth rate (r) provides insights into long-term dynamics but lacks intuitive interpretation for policy communication. This study examines whether current births sufficiently replace expected deaths by comparing actual births with those needed under prevailing mortality conditions, providing a direct, interpretable measure that complements the existing indicators.

2. Methods and data

2.1 The B_o/B_n ratio

One way of estimating if the observed number of births is sufficient to replace the number of expected deaths is to use the stationary population model. A stationary population is a theoretical model in demography where population size remains constant over time because births equal deaths, resulting in zero population growth. The stationary population model provides a benchmark for estimating the births required to maintain long-run stationarity under current mortality and a stable age distribution.

In a stationary population, the crude birth rate (*CBR*), defined as the number of births (*B*) divided by the total size of the population (P_{tot}), is equal to the inverse of the life expectancy at birth (e_0) (Preston, Heuveline, and Guillot 2001: 55):

$$CBR = \frac{B}{P_{tot}} = \frac{1}{e_0} \tag{1}$$

Therefore, estimating the number of births needed (B_n) to replace the number of expected deaths in a stationary population at one point in time can be derived from formula (1) as follows:

$$B_n = \frac{P_{tot}}{e_0} \tag{2}$$

B_n represents the births required to maintain a stable population size under specific mortality patterns – the births needed to replace the expected deaths. Note that $\frac{P_{tot}}{e_0}$ derives from stationary population theory and represents the implications of maintaining current mortality patterns over time, rather than a direct count of deaths in a given year. The B_o/B_n ratio indicates whether the observed births replace the expected deaths. When B_o/B_n exceeds 1, the observed births are sufficient for replacement, leading to population growth. When below 1, the observed births are insufficient, resulting in population decline. This ratio provides a direct measure of demographic balance between births and mortality conditions.

The B_o/B_n ratio is mathematically equivalent to the observed crude birth rate multiplied by life expectancy ($CBR_o \cdot e_0$), comparing the observed CBR to that needed for zero growth ($\frac{1}{e_0}$). Unlike NRR or *r*, which involve complex cohort or stable population calculations, the B_o/B_n ratio directly shows whether births are sufficient to replace expected deaths under current age-specific mortality, making it accessible for policymakers while maintaining demographic rigor.

The B_o/B_n ratio is not intended to replace conventional fertility indicators but to address a distinct demographic question that they are not designed to capture. Measures such as the TFR, cohort fertility, or the net reproduction rate summarize reproductive intensity or cohort replacement under standardized age structures. By contrast, B_o/B_n is a system-level flow balance indicator that relates the number of births actually occurring in a population to the number of births required to offset expected deaths under prevailing mortality conditions and population size. As a result, populations with similar TFR or NRR values may display markedly different B_o/B_n ratios if they differ in age structure or mortality levels. In this sense, B_o/B_n complements existing fertility measures by quantifying the immediate numerical balance between births and deaths in absolute terms, which is directly relevant for assessing near- and medium-term demographic sustainability. The following two stylized examples illustrate how the B_o/B_n ratio complements conventional fertility indicators under different demographic configurations.

The examples are illustrative and not intended as empirical case studies.

2.1.1 Example 1: Similar fertility levels, different age structures

Consider two hypothetical populations (Country A and Country B) with identical total population size and the same total fertility rate (TFR = 1.6), but with markedly different age structures. Country A has a relatively young age structure, with a large share of women in reproductive ages, whereas Country B has an older age structure and a smaller reproductive-age population. Despite identical fertility intensity as measured by the TFR, the number of births observed is substantially higher in Country A than in Country B. As a result, Country A exhibits a B_o/B_n ratio above 1, while Country B exhibits a ratio below 1. This example illustrates that fertility measures alone do not capture how age structure shapes the immediate balance between births and expected deaths, which is directly reflected in the B_o/B_n ratio.

2.1.2 Example 2: Constant fertility, improving mortality

This example illustrates how changes in mortality affect the B_o/B_n ratio when fertility remains constant. Holding total population size and the number of births observed fixed, an increase in life expectancy reduces the number of births needed (B_n) to offset expected deaths. As a result, the B_o/B_n ratio increases mechanically, even in the absence of fertility change. This example highlights that B_o/B_n responds jointly to fertility and mortality conditions and underscores the importance of interpreting the indicator in light of the broader demographic context, particularly in populations experiencing rapid mortality improvement.

2.2 Framework limitations

The stationary model assumes constant mortality and a stable age structure, which likely will not hold for populations undergoing demographic transitions. The same B_o/B_n value can imply different outcomes depending on age structure: young populations with $B_o/B_n < 1$ may still grow due to demographic momentum, while aging populations with $B_o/B_n > 1$ may decline if the reproductive-age population is small. Additionally, improvements in life expectancy reduce the number of births needed (B_n), mechanically increasing the B_o/B_n ratio even when fertility remains constant (see Example 2 above). This mathematical effect may mask underlying fertility decline in populations experiencing rapid mortality improvement. The ratio should be interpreted as a long-term indicator of a demographic trajectory under current vital rates rather than a predictor of immediate population change.

2.3 Data sources

We use births estimated (1950–2023) and projected (2024–2100) from the World Population Prospects 2024 (WPP2024) (United Nations 2024a) as births observed (B_o), and compute births needed (B_n) using formula (2) with total population and life expectancy from WPP2024. For the projections period, we use as reference the medium variant projections. These data include 237 countries and areas, as well as subregional, regional, and global aggregates (United Nations 2024a). Estimates and projections from the WPP are consistent and comparable across countries (United Nations 2024b).

Using WPP2024 has several advantages. Birth estimates account for incomplete registration, which is common in many countries (Mikkelsen et al. 2023). The number of births needed, computed using WPP2024 population and life expectancy data, are internally consistent for all countries and areas.

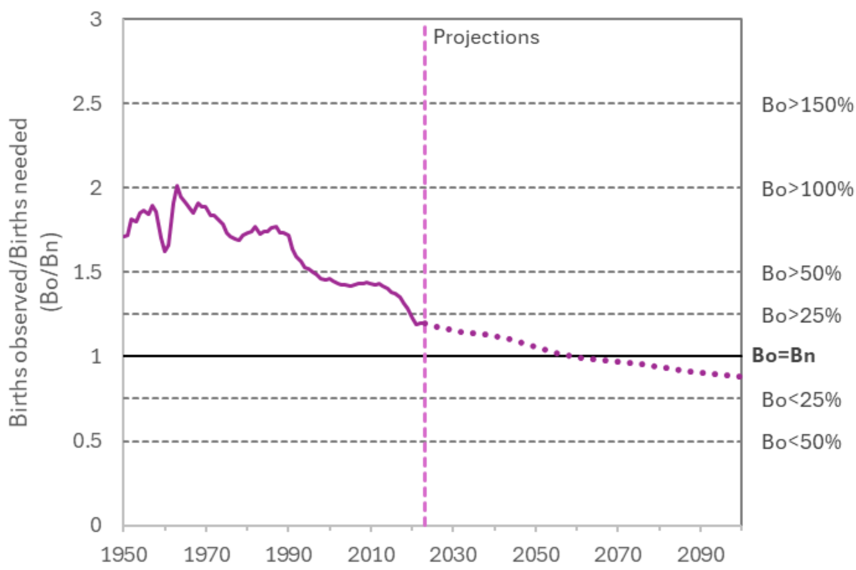
Confidence intervals for the B_o/B_n ratio are derived from WPP2024's upper and lower 95% prediction intervals. The confidence intervals compound, particularly for long-range projections where small differences in assumed trajectories produce substantially different outcomes, as evidenced by widening prediction intervals for 2100 versus 2050 in Figure 3.

3. Results

Globally, 132.4 million babies were born in 2025 (United Nations 2024a). Based on the level of life expectancy at birth and the total size of the global population for the same year, the number of births needed to replace the number of expected deaths is 112.2 million. The number of births observed (B_o) exceeds the number needed (B_n) by 20.2 million, or 18% (Figure 1).

Since 1950, the global number of births observed has declined, while remaining higher than the number needed to replace the number of expected deaths. Between 2000 and 2025 the ratio declined from 1.46 to 1.18, indicating that while declining, the total number of births observed remains well above the levels needed to replace the number of expected deaths. The ratio is projected to continue to decline over the coming decades. By 2060, the number of births observed is projected to be insufficient to replace the global number of expected deaths for the first time. By the end of the century, the global number of births observed is projected to be 12% below the number of births needed.

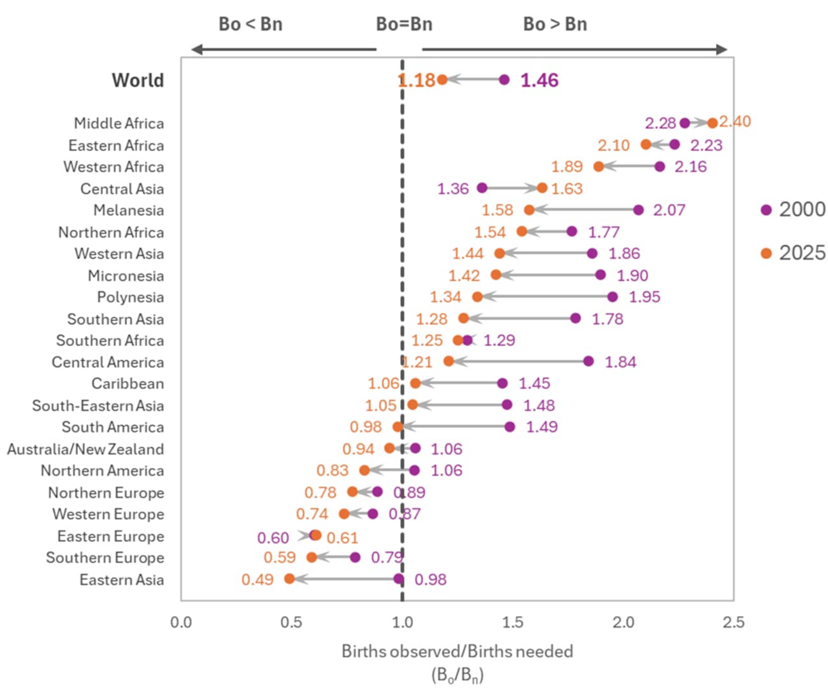
Figure 1: Ratio of births observed to births needed (B_o/B_n), World, 1950–2100



Note: Projections are based on the medium variant.
Source: Authors computations based on WPP2024.

Large differences exist across regions (Figure 2). For example, in 2025, Middle Africa (2.40), Eastern Africa (2.23), and Western Africa (1.89) continue to exhibit the highest B_o/B_n ratios, highlighting both sustained high fertility levels and rapid population growth. Middle Africa and Central Asia are the only regions where the ratio has increased between 2000 and 2025; European regions and Eastern Asia show much lower ratios. Eastern Asia's ratio dropped from 0.98 in 2000 to just 0.49 in 2025, indicating that the number of births is less than half of that needed to replace the number of expected deaths. This is due to fertility reaching ultra-low levels in the region. Other high-income regions such as the European regions show slightly less severe deficits. For example, Western Europe shifts from 0.87 in 2000 to 0.74 in 2025. Many regions in Latin America and Asia, such as Central America and South-Eastern Asia, experience declines but maintain ratios above or close to 1. South America shows a ratio of 0.96 in 2025, having declined from 1.27 in 2000, positioning it just below replacement level.

Figure 2: Ratio of the births observed to births needed (B_o/B_n), World and regions, 2000 and 2025

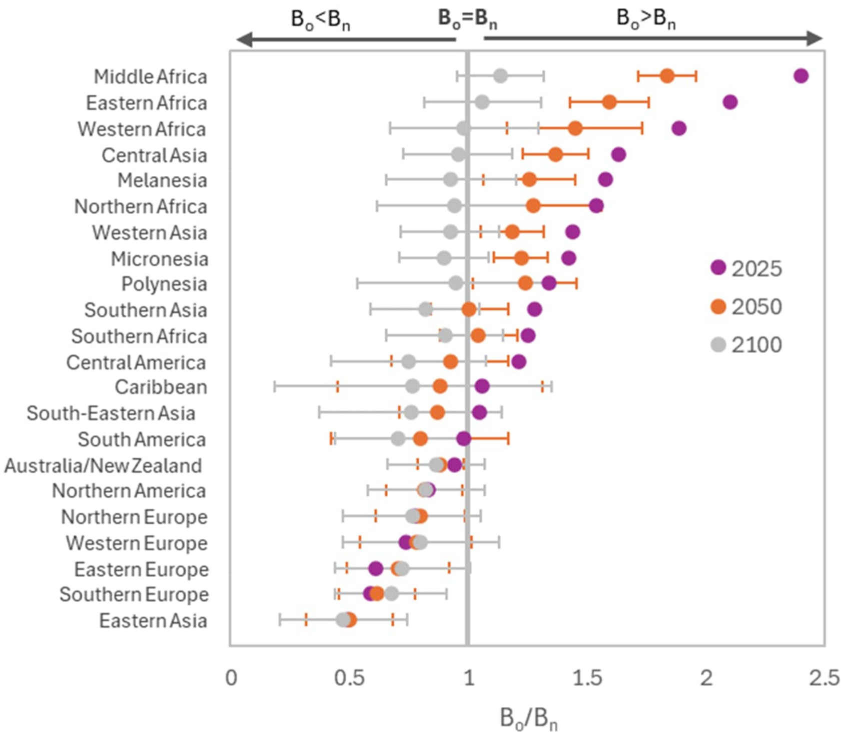


Note: Regions are ordered by their ratios in 2025.
Source: Authors computations based on WPP2024.

Until the end of the 21st century, most regions will experience a clear and progressive shift (Figure 3). In 2025, in many regions in Africa and parts of Asia the number of births observed is high enough to assure the replacement of the expected deaths, but in most of Europe, Northern America, Australia/New Zealand, and South America the ratio is already below 1, indicating that the number of births observed is insufficient to meet the level of the births needed to replace the expected deaths. By 2050 and especially by 2100, a substantial number of regions converge closer to or below a ratio of 1, though the wide 95% prediction intervals shown by the horizontal bars highlight considerable uncertainty in these projections, particularly for regions undergoing rapid demographic transitions. The uncertainty ranges are notably larger for 2100 than 2050, reflecting the compounding effects of demographic assumptions over longer projection periods. Despite this uncertainty, the medium variant projections suggest that in 2100, in all but two regions (Middle Africa and Eastern Africa) the number of births observed will not be sufficient to replace the number of expected deaths, though the prediction intervals indicate that some regions – particularly those in sub-Saharan Africa and parts of Asia – could experience outcomes ranging from continued growth to decline, depending on how fertility patterns evolve.

Regional differences reflect distinct demographic realities with different policy implications. High-ratio regions (Middle Africa: 2.40; Eastern Africa: 2.23) face the challenges of rapid growth, including pressure on education, employment, and infrastructure. Low-ratio regions (Eastern Asia: 0.49; Southern Europe: 0.62) confront severe aging, labor shortages, and fiscal pressure on pensions and healthcare. Intermediate regions (South-Eastern Asia: 1.02; Central America: 1.08) require proactive planning for the transition from growth to potential decline. These timing differences create global demographic asymmetry, with implications for migration patterns, economic development, and global age structure.

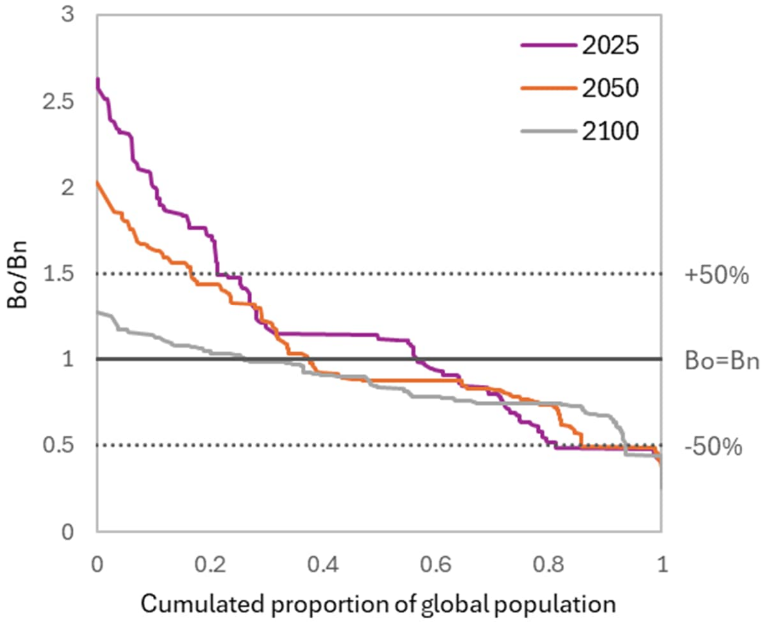
Figure 3: Ratio of the births observed (B_o) to births needed (B_o/B_n), regions, 2025, 2050, and 2100



Note: Regions are ordered by their ratios in 2025. Projections are based on the medium variant with horizontal bars in 2050 and 2100 indicating the 95% predictions intervals for the B_o/B_n ratio.
Source: Authors computations based on WPP2024.

In 120 countries, representing 43% of the global population in 2025, the number of births needed is above the number of births observed, meaning that not enough births are occurring in the population to replace the number of expected deaths (Figure 4). According to the WPP medium variant projection, by 2050 an additional 23 countries will fall into this category, bringing the total to 143 countries, representing almost two-thirds of the global population. By the end of the century, it is projected that 200 countries, representing almost three-quarters of the global population, will have an insufficient number of births to replace the number of expected deaths.

Figure 4: Cumulative distribution of global population by level of B_o/B_n, 2025, 2050, 2100



Note: Projections in 2050 and 2100 are based on the medium variant.
Source: Authors computations based on WPP2024.

4. International migration

International migration increasingly shapes population size and structure in low-fertility countries. We use the UN zero-migration scenario as a crucial counterfactual for assessing how future demographic trends depend on cross-border movements. In countries with consistently below-replacement fertility, positive net migration has frequently mitigated natural population decline, supported labor-force-age replenishment, and moderated population aging. Migration helps offset natural decline by increasing the population of reproductive age, thereby sustaining birth numbers. Without migration, both population size and observed births would decline, widening the gap between the births needed for demographic stability and those occurring, further decreasing the B_o/B_n ratio and accentuating challenges from sustained low fertility.

While international migrants represent a modest proportion of the global population, their demographic impact varies dramatically. By 2100, the largest differences in the Bo/Bn ratio between the medium scenario and the zero-migration variant reach 19 percentage points in Australia and New Zealand, 14 percentage points in Northern America and Western Europe, and 13 percentage points in Northern Europe. These regions, characterized by sustained immigration and aging populations with below-replacement fertility, increasingly rely on migration for demographic balance.

At the country level, the impact of migration becomes more pronounced, with international movements fundamentally determining population growth. The United Arab Emirates exemplifies extreme migration dependency: comparing the medium scenario with zero-migration, its 2050 B_o/B_n ratio would reach only 0.53 without migration, indicating births would replace just over half of expected deaths. With migration this ratio rises to 1.0, achieving replacement level – a remarkable 42 percentage point difference. This gap illustrates how migration takes countries from demographic decline to near stability. Without migration, the B_o/B_n ratios of many nations are approximately 20 percentage points lower, representing a substantial demographic impact that often determines whether countries experience growth, stability, or decline.

Migration operates through multiple channels: immigrants are typically concentrated at reproductive ages, directly increasing births, and often have higher initial fertility than native-born populations. For destination countries, migration provides temporary relief from natural decrease, but does not eliminate underlying below-replacement fertility challenges. For origin countries, emigration of reproductive-age individuals can accelerate population aging, potentially lowering B_o/B_n ratios even if fertility rates remain stable. Global demographic asymmetry suggests South–North and South–South migration flows will remain important throughout the 21st century.

5. Discussion and conclusion

This study proposes an additional indicator, the ratio of births observed to births needed, to assess whether current fertility levels are sufficient to replace expected deaths. The B_o/B_n ratio provides a direct measure of demographic sustainability that complements traditional fertility indicators, offering crucial insights for policy planning in an era of global demographic transition.

Our findings confirm the ongoing demographic transitions documented extensively in the literature (Lee and Mason 2011; United Nations 2024b). The B_o/B_n ratio contributes by providing an intuitive metric that directly compares births to replacement needs under prevailing mortality conditions. While the global number of births remained above replacement levels in 2025, this surplus is eroding and will reverse later in the century, leading to gradual population decline unless offset by substantial fertility rebounds or unforeseen survival improvements.

Regionally, the picture is uneven. High-fertility areas, especially in sub-Saharan Africa, continue to experience robust population growth, while Eastern Asia, Europe, and other high-income regions face rapid natural decrease and population aging. By the end of the 21st century it is projected that only Middle Africa and Eastern Africa will maintain sufficient birth surpluses to offset expected deaths.

These findings have important policy implications. In low-fertility, aging societies, sustaining social and economic systems will increasingly depend on managing the demographic consequences of natural decline. This includes adapting labor markets, pension systems, and healthcare services to shrinking and older populations, while also considering the potential role of international migration in moderating demographic imbalances. In high-fertility regions, managing rapid growth and its socioeconomic impacts remains a priority, alongside preparing for the consequences of demographic transitions that will unfold later in the century.

Several limitations warrant emphasis. First, the stationary population framework means the ratio should be interpreted as a long-term indicator rather than a predictor of immediate change; the same ratio value can imply different outcomes depending on age structure and momentum. Second, mortality improvements reduce B_n, potentially increasing the B_o/B_n ratio and potentially creating the counterintuitive result that countries with improving health appear less demographically sustainable. Third, compound uncertainty from both birth projections and life expectancy estimates means long-range projections should be interpreted with caution. Despite these limitations, the B_o/B_n ratio can be valuable in demographic communication because it provides an accessible measure that directly compares births to replacement needs. It also supports forward-looking planning in the increasingly common context of populations stabilizing or declining.

In sum, demographic sustainability requires context-specific approaches that no single metric can fully capture. By focusing on the relationship between births and expected deaths, this study proposes a straightforward, interpretable measure, the B_o/B_n ratio, which complements existing indicators and captures one dimension of the demographic pressure facing societies. As population dynamics evolve in complex and regionally diverse ways, such measures will be crucial for informing responsive, evidence-based policy strategies in the decades ahead.

6. Contributor roles statement

Vegard Skirbekk: Conceptualization, Visualization, Writing (original draft), Writing (review & editing).
Thomas Spoorenberg: Conceptualization, Methodology, Formal Analysis, Data Curation, Visualization, Writing (original draft), Writing (review & editing).

7. Funding

Funding from an ERC Advanced Grant Project – 101142786 – HOMME (PI Vegard Skirbekk) is acknowledged.

References

Lee, R.D. and Mason, A. (2011). *Population aging and the generational economy: A global perspective*. Cheltenham/Northampton: Edward Elgar Publishing. doi:10.4337/9780857930583.

Mikkelsen, L., Hooper, J., Adair, T., Badr, A., and Lopez, A.D. (2023). Comparative performance of national civil registration and vital statistics systems: A global assessment. *Bulletin of the World Health Organization* 101(12): 758–767. doi:10.2471/BLT.22.289033.

O'Neill, B.C., Dalton, M., Fuchs, R., Jiang, L., Pachauri, S., and Zigova, K. (2010). Global demographic trends and future carbon emissions. *Proceedings of the National Academy of Sciences* 107(41): 17521–17526. doi:10.1073/pnas.1004581107.

Preston, S.H., Heuveline, P., and Guillot, M. (2001). *Demography: Measuring and modeling population processes*. Malden, MA: Blackwell Publishing.

Sobotka, T. and Lutz, W. (2010). Misleading policy messages derived from the period TFR: Should we stop using it? *Comparative Population Studies* 35(3): 637–664. doi:10.12765/CPoS-2010-15.

United Nations (2024a). *World population prospects 2024*. New York: UN DESA, Population Division. https://population.un.org/wpp/.

United Nations (2024b). *World population prospects 2024: Methodology of the United Nations population estimates and projections*. New York: UN DESA, Population Division, UN DESA/POP/2024/DC/NO. 10. https://population.un.org/wpp/assets/Files/WPP2024_Methodology-Report_Final.pdf.