Terra Incognita:
The Economics of a Shrinking World

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The claim

- As of 2026, humanity is likely below replacement fertility.
  - As far as we can tell, this has never happened before in our history as a species, not during wars, not during pandemics.
- Population keeps growing for another 30 years or so through momentum, and then it falls: our reading puts the peak at roughly 9 billion around 2056.
  - The UN WPP 2024 "Medium Variant" says 10.29 billion in 2084. I will explain why I disagree.
- China already records 3.3 million more deaths than births a year.
- But the real surprise is where the fall is happening.

The surprise

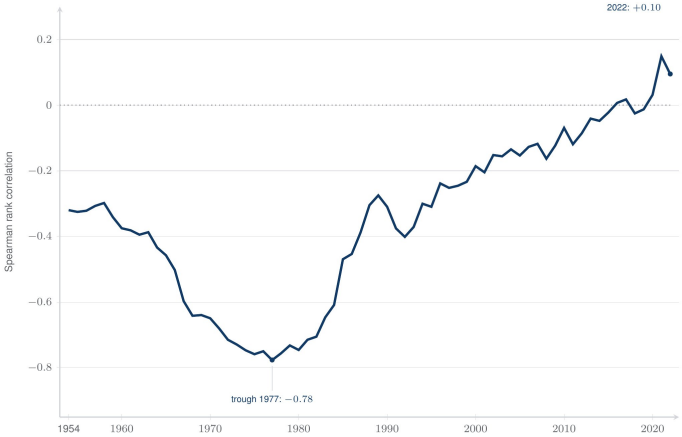
- The fall has concentrated in low- and middle-income countries, and within them among the poorer and less educated women.
- Mexico's TFR in 2024 was 1.2. Given observed births, in 2026, Mexico's TFR might be below Japan's. Mexico's GDP per capita at PPP of 28% of the U.S.
- Tunisia in 2024: TFR of 1.45, GDP per capita at PPP of 18% of the U.S. level.
- Never before have middle-income countries fallen below rich countries in fertility.
- Within the OECD, the cross-country correlation between TFR and GDP per capita, historically negative, switched sign in the 1980s.
- Within countries, the negative income-fertility gradient flattened in the U.S. between 1980 and 2010, and the cross-country correlation between TFR and female labor force participation is now positive (Doepke et al., 2023).

OECD EXCLUDING THE FORMER SOCIALIST MEMBERS

Richer no longer means fewer children

Rank correlation across 30 OECD countries of the total fertility rate with GDP per capita

1954 to 2022 · balanced panel, same 30 countries every year

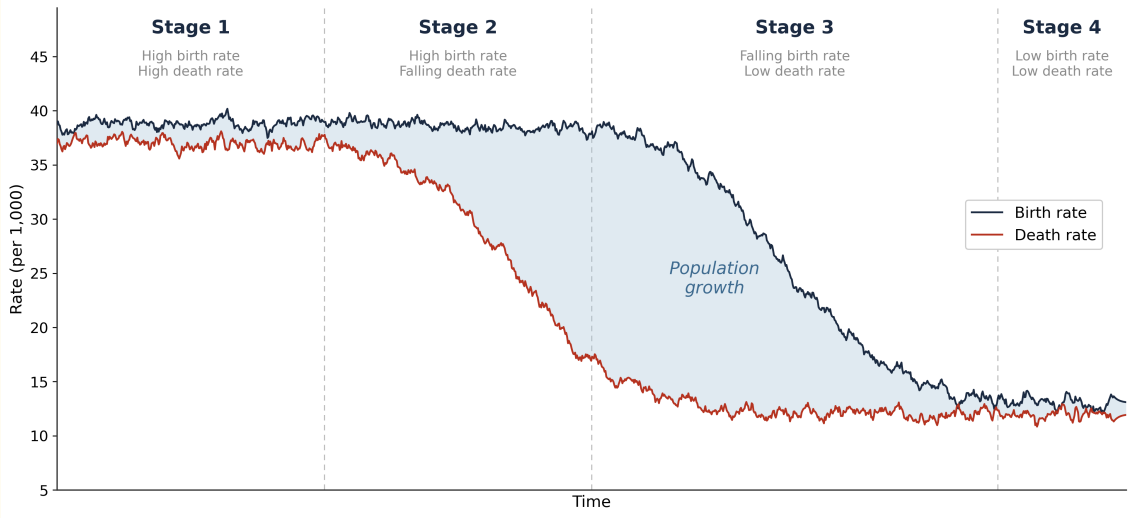


Rank correlation across countries within each year, not within-country over time. Sample: the 30 OECD members with continuous data from 1954, which excludes Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. Germany before 1991 is West Germany.

Sources: UN World Population Prospects 2024; Penn World Table 11.0 (rgdpe/pop). Author's calculations.

The canonical demographic transition

The canonical demographic transition

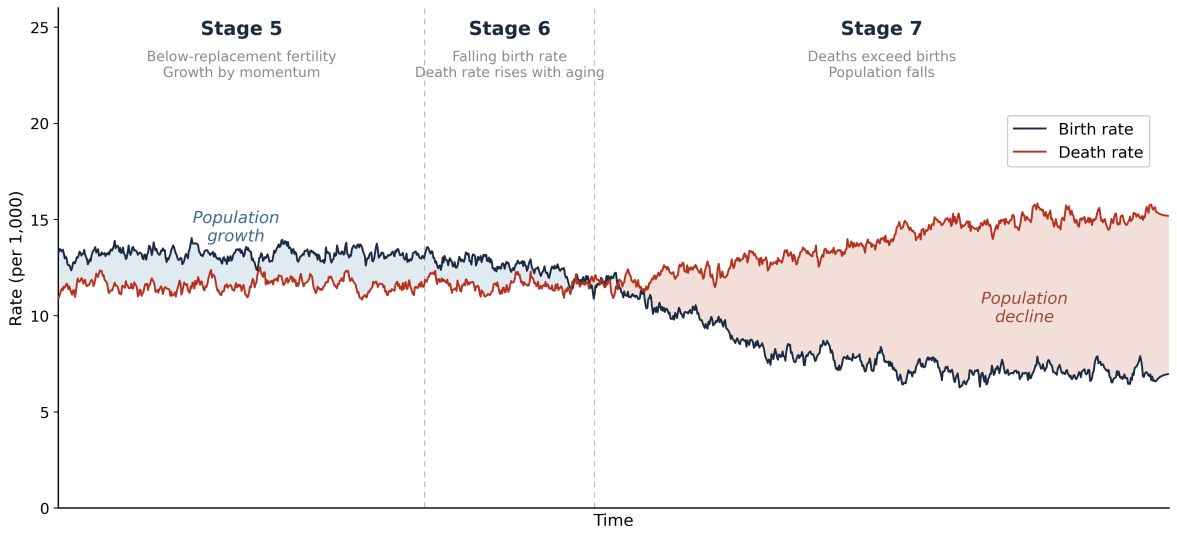


This part we understand

- The first great decline, from 5 or 6 children per woman to the levels of 1980, is well accounted for:
  1. A sharp fall in child mortality (the effective fertility rate was often close to 2).
  2. The shift from a low-skill rural agrarian economy to a high-skill urban industrial one.
- We have quantitative models that fit these facts: Galor-Weil, F-V (2001), Greenwood-Seshadri, Doepke (2004), Manuelli-Seshadri, Cervellati-Sunde, Galor (2011, 2025), Delventhal et al. (2021).
- These models leave room for country-specific factors, but as second-order mechanisms.
- This is also why most economists dismissed Ehrlich-style doom scenarios. We expected the poor world to follow the same path, faster.
- And we expected fertility to stop at replacement (Bongaarts, 2002). That is what did not quite work out as expected.

The second demographic transition

The second demographic transition



Why many missed it

1. The U.S. lagged behind.
   - Secularization came later, suburban housing stayed relatively cheap, and fertility among African American and Hispanic women was well above the national average.
   - U.S. demographic patterns are exceptional among advanced economies, and they skew how academics, most of whom sit in the U.S., see the world.
2. Standard datasets lag the data.
   - Given the suddenness of the drop, this matters more than usual.

- By the 1990s and early 2000s the denial was hard to sustain: Spain, Greece, South Korea, and China joined Japan and Italy at lowest-low fertility (TFR below 1.3).
- Over the last decade: Chile, Colombia, much of the Caribbean. And the U.S. and France are now well below the old 1.8 floor.

TFR around the world

- If you think below-replacement fertility is mainly a rich-country phenomenon, you would be mistaken. Middle-income economies are undershooting.

Country	TFR	Year
Thailand	0.87	2025
Colombia	1.01	2025
Mexico	1.20	2025
Iran	1.35	2025
Tunisia	1.45	2024
Brazil	1.52	2025
Cape Verde.	1.52	2025
U.S., non-Hispanic whites	1.57	2023
U.S., all	1.62	2023

- Mexico at 28% of U.S. GDP per capita (PPP); Tunisia at 18%. We stop at six only to spare you a long list.

An important point

- Emigration compounds the problem. Colombia and Spain share an ultra-low TFR of 1.0 to 1.2, but Colombians are moving to Spain. That cushions aging in Spain and accelerates it in Colombia.
- The country losing people gets the worst of both: fewer births *and* fewer young adults.

The exception and the one big unknown

- Israel is the only clear exception. TFR of 2.86 in 2024 against 2.91 in 1991: roughly constant for 35 years.
  - The composition is more striking than the level. Jewish fertility has held steady, *including among secular Jewish mothers*, while Muslim fertility has fallen fast.
  - Since 2020, and for the first time since 1948, the TFR of Muslims is below that of Jews.
- Sub-Saharan Africa is where we can see the least. The data are poor and many reported TFRs are closer to guesswork.
  - But the indications point to fast decline. The Republic of Congo: TFR from 5.1 in 2011-2012 to 3.5 in 2023-2025, a fall of 1.6 births per woman in under a decade and a half.
  - That is 0.3 births per woman *below* the WPP "Low Variant."

Do we believe the data?

Why we do not believe the WPP

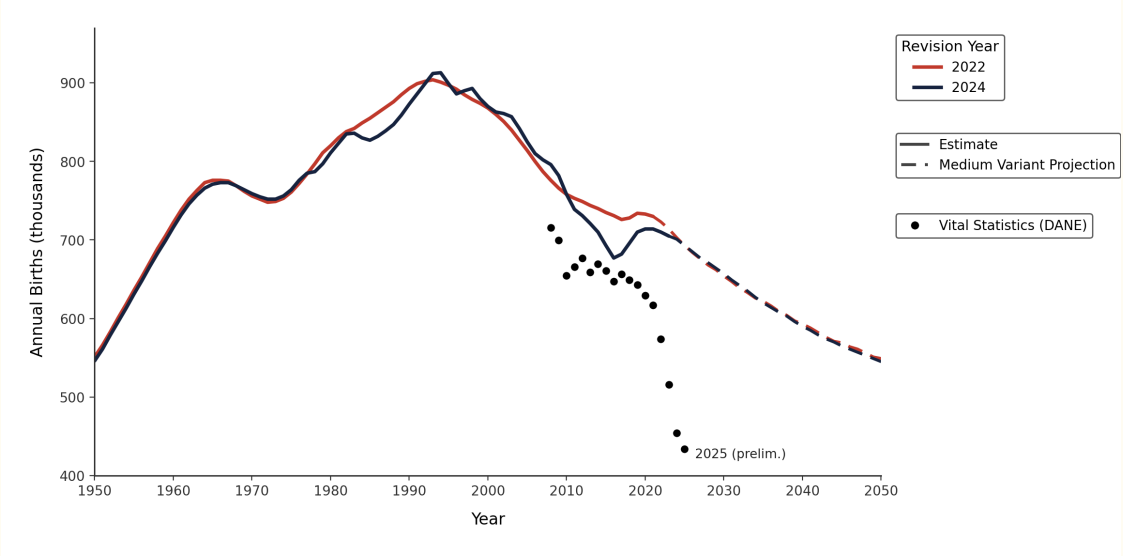
- The WPP is the most cited global demographic dataset, and there is no good alternative: nothing else combines global estimates and projections, multiple sources, and biennial updating. Most other projections are built on it.
- We think it is systematically biased upward. Three reasons:
  1. Its birth estimates exceed official vital registries, even for countries the UN itself rates as over 90% complete.
  2. Its projections rest on a mean-reverting assumption that produces immediate rebounds no matter how fast fertility is falling.
  3. Successive revisions keep moving down, and not fast enough.
- The birth numbers come from estimated and projected TFRs, 1950-2100, built in two stages by Bayesian hierarchical methods with a nontrivial amount of analyst discretion.

Reason 1: the registries say something else

Country	Year	Official births	UNPD estimate	Difference	% overestimate
Colombia	2022	573,625	710,000	136,375	23.8%
Colombia	2023	515,549	705,000	189,451	36.7%
Egypt	2022	2,192,947	2,375,000	182,053	8.3%
Egypt	2023	2,044,880	2,406,000	361,120	17.7%
Türkiye	2022	1,041,846	1,079,000	37,154	3.6%
Türkiye	2023	963,075	1,072,000	108,925	11.3%
Total		**7,331,922**	**8,347,000**	**1,015,078**	**13.8%**

- Three countries, two years, over one million excess births. These are *estimates* of the past, not projections.
- The UN's own report rates all three registries as at least 90% complete. The agencies themselves claim better.

Colombia: the UNPD and the registry



Reason 2: the projections mean-revert

- The UNPD splits countries into a "fertility transition regime" and a "low fertility regime."
- Transition regime: a random walk with drift,

$$f_{c,t+1} = f_{c,t} - d_{c,t}$$

  with $d_{c,t}$ a stochastic decrement from a sum of double-logistic functions, estimated hierarchically by MCMC.

- Low fertility regime (entered after two successive five-year increases once below 2.0): a mean-reverting AR(1),

$$f_{c,t+1} \sim N\big(\mu_c + \rho_c(f_{c,t} - \mu_c),\, \sigma^2\big)$$

  with $\mu_c \sim N(\bar{\mu}, \sigma_\mu^2)$, $\bar{\mu} \sim U[0, 2.1]$, $\sigma_\mu \sim U[0, 0.318]$.

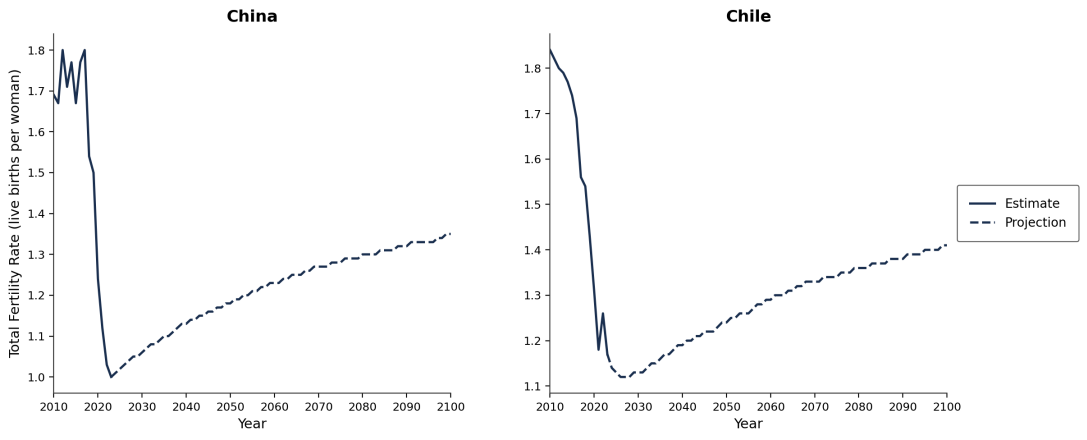
- That μ_c is what does the work. South Korea rises monotonically from 0.72 in 2023 to 1.30 in 2100; China from 1.00 to 1.35.

Mean reversion, immediately

Country	TFR, 2018	TFR, 2023	Δ 2018–2023	TFR, 2028	Projected Δ 2023–2028
China	1.54	1.00	−0.54	1.05	+0.05
South Korea	0.95	0.72	−0.23	0.79	+0.07
Chile	1.54	1.17	−0.37	1.12	−0.05
United States	1.72	1.62	−0.10	1.63	+0.01
India	2.18	1.98	−0.20	1.90	−0.08

- No matter how fast or how long the TFR has been falling, the projection turns around at the end of the estimation window.
- Demographers at the UNPD may think they are being clear about this. Very few economists know it.

China and Chile



- The projected recovery might happen. Nothing in the data as of today suggests it will.

The UN's justification

WPP 2024, Summary of Results, page 23, Box II.1

"The 'rebound' in future fertility for low-fertility countries is consistent with an expectation of continued progress toward gender equality and women's empowerment and improving social and economic opportunities for young people and families."

- The methodology report hedges it too: the rebound "is supported by the experience of many countries in Europe and East Asia... However, such an increase is not universal."
- We do not find this convincing, and the hedge does not do much work in practice.
- A more subtle point: conditional versus unconditional forecasts. A projection conditioned on continued progress toward gender equality is not the same object as a best guess about births.

The 2024 test: projections made in July 2024, for 2024

Country	Actual	WPP	Dev. (%)
Colombia	445,011	701,000	−36.5
South Africa	787,933	1,183,000	−33.4
Singapore	33,703	49,000	−31.2
Cyprus	9,766	14,000	−30.2
Rep. of Moldova	23,648	32,000	−26.1
Thailand	441,631	582,000	−24.1
Guatemala	299,256	380,000	−21.2
Poland	251,782	310,000	−18.8
Argentina	413,135	507,000	−18.5
Panama	59,729	72,000	−17.0
Albania	23,310	28,000	−16.8
Azerbaijan	102,310	121,000	−15.4
Türkiye	937,559	1,061,000	−11.6
Chile	154,441	172,000	−10.2
Uruguay	29,899	33,000	−9.4
Japan	686,173	751,000	−8.6
Hong Kong SAR	36,723	40,000	−8.2
Belarus	58,938	64,000	−7.9
Brazil	2,376,901	2,572,000	−7.6

Country	Actual	WPP	Dev. (%)
Slovenia	16,875	18,000	−6.2
Switzerland	78,256	83,000	−5.7
Spain	318,579	333,000	−4.3
Australia	292,318	305,000	−4.2
Greece	68,309	71,000	−3.8
Russian Federation	1,222,408	1,270,000	−3.7
United Kingdom	659,628	684,000	−3.6
Netherlands	166,143	172,000	−3.4
Denmark	57,079	59,000	−3.3
Republic of Korea	238,317	241,000	−1.1
France	629,000	636,000	−1.1
United Arab Emirates	106,915	108,000	−1.0
United States	3,628,934	3,654,000	−0.7
Uzbekistan	926,422	929,000	−0.3
Canada	365,737	361,000	+1.3
Kuwait	49,063	48,000	+2.2
Bosnia and Herz.	24,598	24,000	+2.5
Croatia	32,069	31,000	+3.4
Total	**16,052,498**	**17,699,000**	**−9.3**

All countries with registries the UN deems at least 90% complete and population above one million. Only 4 of 37 came in above projection. Absolute gap: 1.65 million births.

Reason 3: the revisions keep moving down

WPP revision	Projected population peak	Projected population in 2100 (billions)
2015	Still rising in 2100	11.213
2017	Still rising in 2100	11.184
2019	Still rising in 2100	10.875
2022	10.431 billion in 2086	10.349
2024	10.289 billion in 2084	10.180

- Worth pausing on the size of this: the revision is to a stock, not a flow. Shaving a billion people off the 2100 total in nine years requires an enormous revision of the entire path of births between now and then, all in the same direction.

The same exercise for the world TFR

WPP revision	Average TFR, 2025–2030	Average TFR, 2095–2100
2015	2.38	1.99
2017	2.39	1.97
2019	2.38	1.94
2022	2.29	1.84
2024	2.22	1.85

- The near-term world TFR has been revised from 2.38 as late as 2019 to 2.22 in 2024.
- The UNPD is revising downward. From our reading, not nearly fast enough to match the data, and each revision trims only a small amount from the last.

Our assessment

- World replacement rate: about 2.20 (we derive this in a moment).
- WPP "Medium Variant" world TFR in 2026: 2.23, from 132.5 million births. Slightly above replacement.
- Table above: at least 1.6 million excess births projected for 2024. Given the 2025 data for Egypt, Mexico, and the Philippines, the 2026 gap is probably around 2.5 million. And we suspect, but cannot prove, that Africa adds more.
- Correcting for this: world TFR in 2026 of at most 2.19. Below replacement.
- Notice how small the adjustment is: from 2.23 to 2.19. We are moving the second decimal.
- We do not make much of the exact year. What matters is that the two series are crossing, and every source of error we can identify points the same way.

And the population peak

- We put the peak of world population around 2056; the WPP "Medium Variant" says 2084.
- The WPP "Low Variant" puts it at 8.95 billion in 2053. So we are slightly *less* aggressive than the Low Variant.
- And given two years of observations since WPP 2024 was released, births are falling below even the Low Variant.
- Caveat worth stating: projecting the peak of a concave curve that becomes very flat near its top is notoriously hard. Very small differences move the peak a decade either way.

An empirical framework

A single-factor model

- We estimate a single-factor model in the tradition of Lee and Carter (1992), an application to demographics of Geweke (1977) and Sargent-Sims (1977):

$$TFR_{i,t} = \alpha_i + \delta_i t + \beta_{i,t}\lambda_t + \epsilon_{i,t}$$

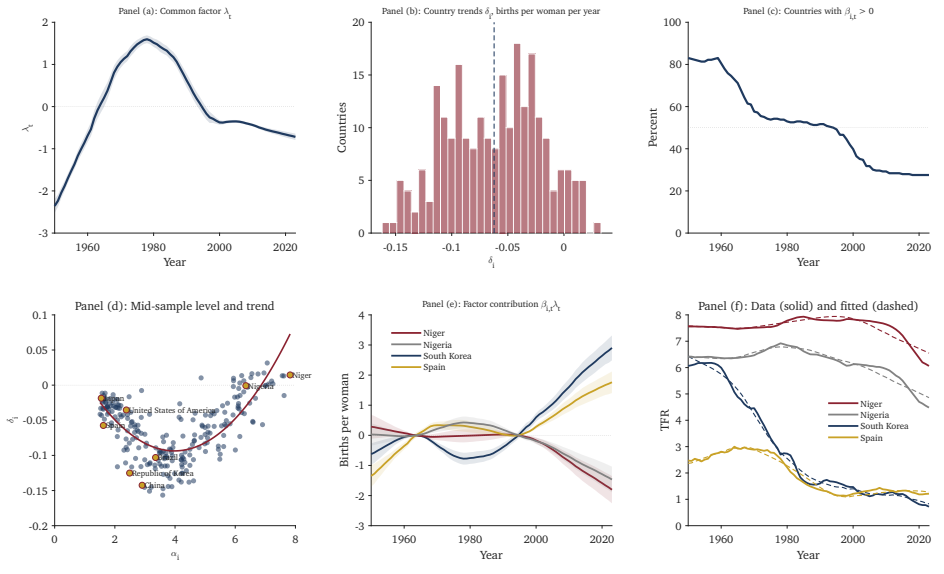
  - α_i: country fixed effect, the mid-sample level.
  - δ_i: country trend.
  - λ_t: common global factor.
  - $\beta_{i,t}$: loading, varying smoothly over time.

- Balanced panel: 236 countries and territories, 1950 to 2023, from the WPP.

- Why let β move? Because the data reject a constant one. Estimate the restricted model with $\beta_{i,t} = \beta_i$, split the sample in half, and the loadings correlate 0.18 across halves.

  - Countries enter their transitions decades apart, and a fixed loading cannot capture a shift along the time axis.

Common factor and heterogeneous trends



The bar any explanation must clear

Two criteria

1. A **nearly universal** drop in fertility: almost every country carries a negative trend with no sign of leveling off.
2. **Country-specific timing**: the dates of the fast declines differ by decades across countries.

- Increasing cross-country dispersion is driven less by a single global force than by countries moving through the transition at different times.
- Most of the candidate mechanisms in the literature deliver one criterion or the other. Very few deliver both.

Mechanisms

The unpleasant integer arithmetic of replacement

- Before asking what causes the fall, notice how low the bar is. Children come in integers.

Children per woman	Cohort A	Cohort B
0	15	26
1	10	23
2	60	46
3	10	5
4	5	0
Completed fertility	**1.80**	**1.30**

- Cohort A is roughly many advanced economies until the early 1990s, and the U.S. until around 2008. Cohort B is lowest-low fertility.

Candidate 1: economic fundamentals

- Quality-quantity à la Becker-Barro. Many of the country trends are likely this, kicking in at each country's own pace.
  - Delventhal et al. (2021): a Barro-Becker model matches the timing of transitions, including their acceleration, once augmented with the diffusion of skill-biased technology (Lucas, 2009), which does not arrive everywhere at once.
  - This gets us part of the way. It does not get us the suddenness.
- The price of parents' time. Bar et al. (2018): the income-fertility gradient flattened in the U.S. because rich parents buy childcare and domestic services, and rising inequality makes those services cheap relative to their own time.
  - Hazan et al. (2023): highly educated women, more likely childless than others in 1990, had converged by 2020. Children are becoming a luxury good.
- The general problem: it is hard to find movements in the skill premium large enough. No plausible calibration delivers Colombia's 35% fall in births in ten years through this channel alone.

Housing: more complicated than it looks

- Rising house prices make owners wealthier and make it harder for renters to buy or trade up. The two groups respond in opposite directions.
  - Dettling and Kearney (2014): a $10,000 rise in local house prices raises births among homeowners by about 5% and lowers births among non-homeowners by roughly 2.4%. Since most U.S. households own, the net effect is positive. Similar in Denmark.
  - Yi and Zhang (2010) find a negative effect in Hong Kong, where real estate is extraordinarily expensive.
- But who owns has changed: the young rent for longer.
  - Fazio et al. (2025), Brazilian housing credit lotteries: winning a home raises the probability of a child by about a third among 20 to 25-year-olds.
  - Couillard (2025): had real housing costs stayed at 1990 levels, 13 m. more children would have been born in the U.S. over 30 years.
- Our problem with it: housing prices cannot account for fast drops where real estate is cheap relative to income, as in many rural areas.

Candidate 2: government policy

- A common problem: we do not see large impacts, either repressing fertility or raising it.
- Take China's one-child policy, and use Taiwan as a quasi-control: close culture and norms, no one-child policy.
  - 1979 (policy introduced): Taiwan 2.67, China 2.80.
  - 2015 (policy lifted): Taiwan 1.18, China 1.57.
  - Taiwan's TFR collapsed, and fell *further* than China's.
- Not airtight: Taiwan developed earlier and had its own milder policies; the one-child policy had dozens of exemptions and lax rural enforcement.
- But the point goes beyond Taiwan. Plot the TFR of ethnic Chinese in Malaysia or Singapore and you will have trouble telling the lines apart from the mainland's. Chinese Americans are among the lowest-fertility groups in the U.S.
- Something more fundamental is at work in East Asia than any concrete policy.

Pro-natalist policy: positive, small, well identified

- Milligan (2005): Quebec's Allowance for Newborn Children, up to C$8,000 for a third child. A sharp rise in births, correlated with the size of the transfer.
- Cohen, Dehejia, and Romanov (2013): Israeli child subsidies, price elasticity of fertility near -0.5, concentrated among low-income households.
- González (2013): Spain's universal baby bonus raised conceptions and lowered abortions.
- Laroque and Salanié (2014): French family benefits raise completed fertility modestly.
- Raute (2019): a German reform tying maternity benefits to previous earnings raised births among highly educated women, the group pro-natalists most want to reach.
- Two reasons for skepticism: it might all be timing (same children, earlier), and the policies might not pass a cost-benefit test.
- Still: differences in completed fertility of 0.1 to 0.2, well within the range of credible estimates, accumulate into very large differences in population over a few decades.

Candidate 3: preferences and social norms

- A broad family of forces: individualism, secularization, women's liberation, less interest in marriage, lower desire for descendants, and a parenting standard that makes each child more expensive in time and worry.
- Delventhal et al. (2021) document demographic contagion: the timing of a country's transition depends not only on GDP per capita but on whether its *neighbors* have started theirs, where neighbors are defined by cultural as well as geographic distance.
- Kearney, Levine, and Pardue (2022) reach the same place by elimination. They examine and rule out unemployment, housing costs, childcare, contraception, and student debt for the recent U.S. decline.
  - What is left is a "Solow residual of fertility": a measure of our ignorance, which they interpret as shifting priorities across cohorts.
- We arrive here more by elimination than by conviction too.

Candidate 4: smartphones

- Myers and Hooper (2026) exploit the fact that from June 2007 through February 2011 the iPhone was sold only by AT&T, identifying the effect from variation in that carrier's mobile broadband coverage.
  - They estimate the iPhone accounts for 33 to 52% of the decline in the general fertility rate among women aged 15 to 44.
  - Hudson and Moscoso Boedo (2026) find the same for teen conceptions in England and Wales.
- Our reading: smartphones accelerated the fall more than they caused it.
  - Italy's TFR was 1.19 in 1995. In 2025 it was 1.14. That gives you a sense of how much scope smartphones have as an explanation.
- Where they do matter is in the diffusion of norms. What took 25 years now takes 10.
  - Guatemala went from 3.8 children per woman in 2005 to 1.9 in 2025.
  - Without smartphones, Guatemala would also have reached 1.9, just 20 years later.

A conjecture: modernity

- By modernity we mean a society organized around formal institutions, specialized expertise, and large-scale coordination.
  - Weber: modern societies organize economic life, law, and government through calculation, impersonal rules, and bureaucracy staffed by trained specialists.
  - Gellner, Giddens, Scott: complex societies become manageable only because knowledge is standardized and detached from local custom.
  - Mokyr: sustained growth became possible once useful knowledge was codified, accumulated, and widely shared.
- Modernity is not another name for capitalism. If anything the record points the other way.
  - Hungary fell below replacement in 1960, Czechoslovakia in 1966. Both had modest, short-lived baby booms in the mid-1970s; neither reversed the trend.
- We are aware this is more speculative than what economists usually entertain. We think it deserves the space.

Expensive third child, cheap childlessness

- A modern society makes the third child expensive and childlessness cheap, even at a fraction of frontier GDP per capita.
- Why children are expensive:
  - A child must be equipped to function in a world of formal knowledge and credentials: years of costly investment.
  - Children are no longer productive in the household, not even for small chores, having been replaced by "engines of liberation" now available to poor households too.
  - Modernity imposes tight career schedules, set by large organizations, that collide with the biological clock and with the kin networks that used to share the work.
- Why childlessness is cheap:
  - An impersonal society imposes next to no penalty on those who have no children. Pensions and health care do the work that sons and daughters once did, and lineage counts for little.

The gender mismatch

- Goldin (2026) pushes the line further: modernity changes gender roles unevenly.
  - Women's opportunities expand fast through education, work, and independence.
  - Expectations about housework and childcare change more slowly.
  - Particularly sharp as economies shift toward services, where women's comparative advantages are better rewarded.
- The mismatch operates on both margins: more women remain childless, and mothers have fewer children.
- This is attractive because it explains East Asia and now Latin America: the societies where the mismatch is largest.
- It suggests a paradoxical reversal: societies with highly unbalanced gender norms start with very high TFRs, as men impose their preferences, and end with very low ones, as women resist.
- It also explains why cash transfers accomplish little while parental leave makes a difference. The binding constraint is not the price of a child, but who does the work of raising them.

Where modernity leaves each country

- Expensive children plus cheap childlessness gets us well below replacement, perhaps to 1.4. Recall the integer arithmetic: it does not take much.
- When each country arrives at 1.4 depends on how fast modernization runs, which is not the same thing as the level of GDP per capita.
  - That gives a nearly universal negative trend with growing heterogeneity: exactly the two criteria from the factor model.
- From 1.4, countries move in either direction:
  - Up to 1.6 or 1.7: higher income, better work-family balance, more gender equality, cheaper housing, less acute educational arms races, or a significant religious subpopulation. The U.S. has many, not all, of these.
  - Down to 0.7 or 0.8: lower income, no work-family balance, less gender equality, expensive housing, brutal educational competition, rapid secularization. China, Taiwan, and South Korea have all of these at once.
- In short: modernity in its current form seems largely incompatible with replacement-level fertility.

There is no feedback mechanism

- Economists trust markets because they self-regulate. Shortages raise prices, quantity demanded falls, new suppliers enter.
  - Not just theory: Smith (1962) showed double auctions converge with a handful of traders who know nothing about aggregate demand and supply. Gode and Sunder (1993) replaced the humans with machines bidding at random subject to a budget constraint, and allocative efficiency still reached almost 100%.
- Nothing analogous pushes fertility back to replacement.
  - No reason the positive consequences of a falling population (cheaper housing) should overcome the negative ones (slower growth, higher taxes) and restore a steady state.
  - And the welfare theorems break down in overlapping generations: generations far apart cannot trade, so the economy behaves as if markets were incomplete. The double infinity of agents and dated commodities kills the standard proof.
- Weil (2024) puts it best: the replacement rate has no special status as an attractor or a target. Nothing pushes a society to settle there.

Three mechanisms that fail

1. Policy. The best-identified effects are real but small.
2. Selection, as higher-fertility subpopulations become a larger share of the total.
3. Relative prices induced by a falling population (Jones, 2022).

- None works fast, and none ensures efficiency.
- And the planet does not self-regulate either, at least not in the short run. The Malthusian mechanism is real, but it works over centuries.
  - Nearly none of the fertility decisions of women in Seoul or Bogotá are determined by the availability of food or by mortality risk.
  - The consequences for labor forces, pensions, and public debt arrive within decades.

Economic consequences

First, the good news

- Teenage pregnancies. Sharp declines in the U.S. over the last two decades, and around three-quarters of pregnancies among American teenagers are unintended. Much of this decline is welcome.
- Resources and infrastructure. Slower growth or falling population eases pressure on infrastructure, housing, and emissions, and makes sustainable resource policy easier to design.
  - Latin America could redesign the cities that grew wildly, and often without decent services, during the boom of the 1950s to 1980s.
- A window for emerging economies. They can educate smaller cohorts better, rebuild infrastructure, and, before aging fully takes hold, enjoy some fiscal space for structural reform.
- Climate. Lower fertility might ease the transition to net zero. Integrated assessment models take population as an exogenous input, and their emission paths are sensitive to it in ways the literature has rarely explored.
  - Against this: the fiscal pressures of aging may make it harder to fund that transition.

The accounting of demographics

- Start from an identity:

$$\underbrace{y}_{\text{output}} = \underbrace{\frac{y}{l}}_{\text{labor productivity}} * \underbrace{l}_{\text{labor}}$$

- In growth rates:

$$\underbrace{g_y}_{\text{output growth}} = \underbrace{g_{\frac{y}{l}}}_{\text{labor productivity growth}} + \underbrace{g_l}_{\text{labor growth}}$$

- These definitions discipline what we can expect. Everything that follows is arithmetic, not a model.

The way we were

- The U.S. around 2000, in round numbers close to the actual ones:

$$\underbrace{3.0\%}_{\text{output growth}} = \underbrace{2\%}_{\text{labor productivity growth}} + \underbrace{1\%}_{\text{labor growth}}$$

- This is why most economists around 2000 took 3% as the standard for measuring economic performance:

  1. Booming, unemployment falling and labor growing faster than average: you see 4%.
  2. Depressed, unemployment rising and labor growing slower than average: you see 2%.

The way we will be

- The U.S. around 2050, holding labor productivity growth fixed and assuming no net immigration:

$$\underbrace{1.5\%}_{\text{output growth}} = \underbrace{2\%}_{\text{labor productivity growth}} + \underbrace{-0.5\%}_{\text{labor growth}}$$

- 1.5% is the new normal. A boom delivers 2.5%, a slump 0.5%.
- The Fed can do nothing about this with monetary stimulus, and neither can the federal government with fiscal packages.
- A shrinking labor force is not a shortfall in aggregate demand. It is a drop in the long-run trend of potential output.
- And, as we will see, the 2% assumption is itself generous.

Japan: the poster child of bad economic performance

Pesek (2014), Japanization

...few lessons are more timely or critical than those offered by Japan, a once-vibrant model for developing economies that joined the world's richest nations, lost its way and has been struggling to relocate it ever since.

In this book I explore what the world can learn from a Japanese economic funk that began more than 20 years ago and has never really ended. That means exploring where Japan went wrong, how it sank under the weight of hubris and political atrophy, and missed opportunity after opportunity to scrap an insular model based on overinvestment, export-led growth, and excessive debt.

- Between 1991 and 2023, Japanese GDP grew at 0.79% a year, far below the 2.60% of the U.S.

Japan is doing about as well as it can

1991-2023	Canada	France	Germany	Italy	Japan	Spain	UK	U.S.
GDP	2.40	1.56	1.27	0.79	0.79	1.92	2.13	2.60
GDP per capita	1.26	1.07	1.14	0.67	0.78	1.24	1.56	1.69
GDP per work.-age adult	1.38	1.28	1.41	0.92	1.33	1.28	1.63	1.73
GDP per hour worked	1.09	1.07	1.37	0.67	1.22	0.58	1.45	1.62
GDP per worker	0.91	0.82	0.90	0.48	0.62	0.39	1.34	1.55
Population	1.12	0.49	0.13	0.12	0.01	0.68	0.55	0.90
Working-age adults	1.00	0.28	−0.14	−0.13	−0.53	0.63	0.48	0.85
Total hours worked	1.34	0.50	−0.10	0.14	−0.43	1.35	0.66	0.98

- Average annual growth rates in percent. Working-age adults are 15 to 64.

Swap the demographics

- Using data per hour worked:

$$\underbrace{0.79\%}_{\text{Japan's output growth}} = \underbrace{1.22\%}_{\text{Japan's productivity growth}} + \underbrace{-0.43\%}_{\text{Japan's labor growth}}$$

$$\underbrace{2.60\%}_{\text{U.S. output growth}} = \underbrace{1.62\%}_{\text{U.S. productivity growth}} + \underbrace{0.98\%}_{\text{U.S. labor growth}}$$

- Now hold productivity fixed and switch labor growth between the two:

$$\underbrace{2.20\%}_{\text{Japan, counterfactual}} = \underbrace{1.22\%}_{\text{Japan's productivity growth}} + \underbrace{0.98\%}_{\text{U.S. labor growth}}$$

$$\underbrace{1.19\%}_{\text{U.S., counterfactual}} = \underbrace{1.62\%}_{\text{U.S. productivity growth}} + \underbrace{-0.43\%}_{\text{Japan's labor growth}}$$

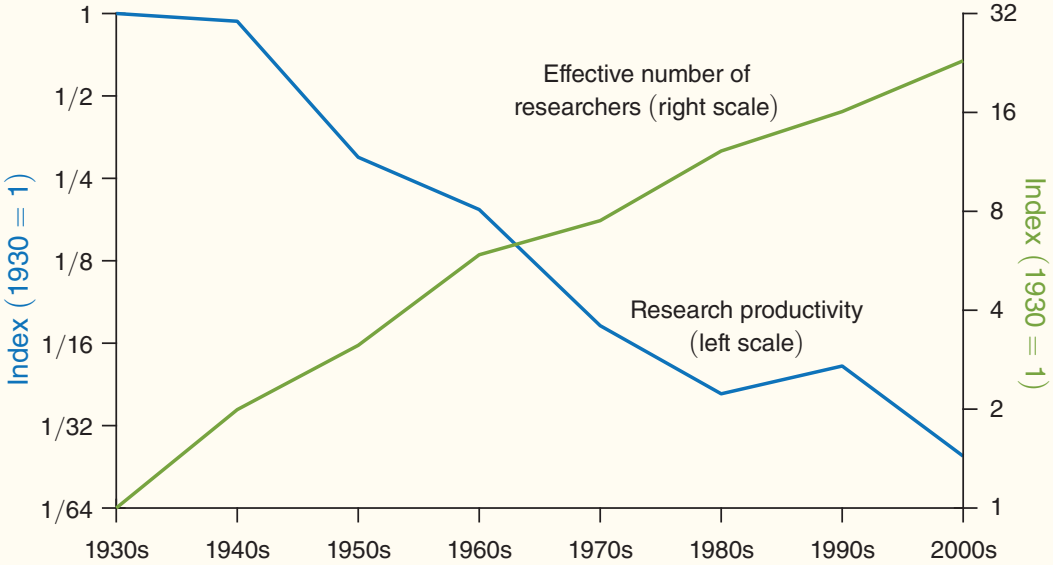
- The verdict reverses. Instead of the U.S. leading Japan by 1.8% a year, the U.S. lags by 1.0%.

Before you object

- The U.S. still does better in productivity. That part of the story survives.
- But this is no longer a story of a stagnant Japan driven by poor policy choices. It is a story of a U.S. that outperforms all seven other countries.
- "Hours worked is not purely demographic." True: workers move on the intensive and the extensive margin. That is why the table reports working-age adults *and* total hours.
  - The results are the same, because Japan and the U.S. raised hours worked relative to working-age population by roughly the same amount.
- "But many elderly Japanese work." Many elderly Japanese were already working in 1991. Do not confuse a statement about levels with a statement about rates.
- You can slow the effects for a while by pulling more adults into the workforce or having them work longer hours. Eventually a country runs out of demographic space.

Will productivity growth hold at 2%? Ideas

- Semi-endogenous growth: the long-run growth rate of income per capita is proportional to the growth rate of the number of researchers (Jones, 1995). Researchers cannot grow faster than population in the long run.
- The logic runs deeper than accounting. Ideas are nonrival: smaller populations produce fewer ideas *and* spread their cost among fewer users.
  - Jones (2022): an economy with permanently negative population growth converges to a path where knowledge and living standards stop growing altogether. The *empty planet*.
- And ideas are getting harder to find. Bloom et al. (2020): U.S. research productivity falls by roughly 5% a year. We need an ever larger number of researchers just to hold growth constant.
- A country with a TFR of 1.2 will not have many pathbreaking scientists and engineers.

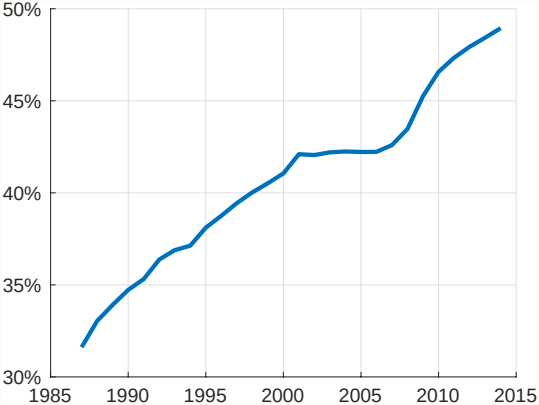

1
1/2
1/4
1/8
1/16
1/32
1/64
Index (1930 = 1)
32
16
8
4
2
1
Index (1930 = 1)
Effective number of researchers (right scale)
Research productivity (left scale)
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s

Not just the number of researchers: the top of the distribution

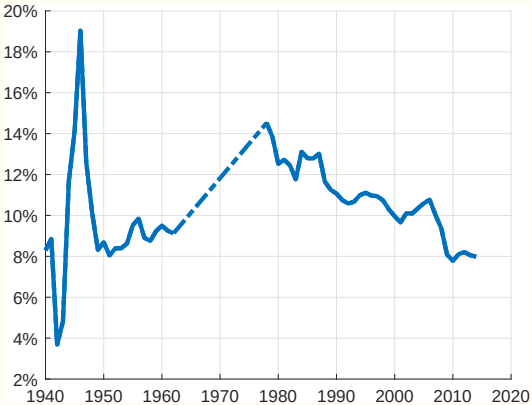
- South Korea: 1,080,535 births in 1960 against 230,028 in 2023. A 4.7-fold decline in cohort size.
- What does that do to the *most talented individual* in each generation?
- Gaussian tail: not much. The top child born in 1960 is expected to be 4.84σ above the mean; the top child born in 2023, 4.53σ.
  - Nearly a million additional births buy less than a third of a standard deviation at the very top.
- Pareto tail with $\alpha = 2$: very different. The frontier scales with the square root of cohort size. The median of the cohort maxima is 883 times the median person in 1960, against 407 in 2023.
- Which case applies? The evidence on returns to innovation points to fat tails, and specific individuals matter beyond their number (Azoulay et al., 2010).
  - If growth depends on a handful of exceptional innovators, shrinking cohorts hurt most.

Firm dynamism and technology adoption

- Liang, Wang, and Lazear (2018): a one standard deviation fall in median age buys 2.5 percentage points of new firms, some 40% of the mean rate.
- Hopenhayn, Neira, and Singhania (2022): the recent evolution of firm concentration, entrepreneurship, and the labor share in the U.S. traces back to slower population growth.
- Karahan, Pugsley, and Şahin (2024): demographics account for two-thirds of the decline in the U.S. start-up rate since the late 1970s, identified off state variation in labor supply growth from fertility two decades earlier.
- Jones (2009, 2010): the education required to reach the frontier keeps rising, which compresses the innovative life cycle and reduces aggregate creative output.
- And older workforces and older firms adopt new technologies more slowly.



(a) Share of Firms Age 11+



(b) Entry Rate

The optimistic counterargument

- Acemoglu, Autor, Beirne, and Scott (2026) argue that the labor scarcity created by low fertility might induce labor-saving technologies.
- The argument is intriguing. The variation they exploit is not informative about the fertility we face today.
  - The lowest birth rate in their 1950 cross-section is Austria, TFR of 2.09: essentially replacement.
  - Even in their 1980 panel the floor is Germany at 1.56.
- Consider what those numbers mean over a century:
  - A TFR of 1.56 leaves 40% of the initial population after a century.
  - A TFR of 0.75 leaves 3.5%. A factor of eleven.
- Both count as "low fertility" in a regression, yet they are different regimes. The authors say as much in their conclusion: changes this rapid lie outside the support of the historical evidence.

But don't we care about output per capita?

- Yes and no.
- Yes: output per capita is the right measure of individual welfare. Slower labor force growth costs us less than the headline numbers suggest. Japan has kept improving its living standards, and simulations for the U.S. suggest the same (Weil, 2026).
- No: our capacity to service public debt and meet social security obligations depends on total output. Bondholders and retirees are paid in levels, not in ratios.
- And in a world of great-power competition, defense spending requires total output, not output per capita.
- Second-round effects we cannot explore here: inflationary pressure as governments try to monetize debt, real interest rates, housing prices, and the internal redistribution of population, with a few large "sponge cities" absorbing a dwindling population.

The political economy of aging

- Many economists forget that the first-order problem of an aging society is how to redistribute income from workers to retirees. How fast output grows is, surprisingly, the lesser question.
- With roughly as many retirees as workers, and approximate parity of income, what each worker produces must be split in two.
  - It does not matter whether we do it through taxes, as in a pay-as-you-go system, or through capital income, as in a fully funded one.
  - Workers will not be happy to see so much of GDP channeled to retirees.
- This is likely to poison the political system and lead to dysfunctional policies. We already see it in Western Europe's fights over retirement benefits, which make structural reform harder.
  - Much of the American unhappiness about the profits of large corporations, largely owned by the old, is the same conflict in the fetishized form of equity ownership.
- "AI will fix this" misses the point. The redistribution problem is about politics, not productivity growth.

And Japan was the easy case

- The Japanese slowdown we documented is arguably the best-case scenario.
  - A homogeneous society with high levels of consensus.
  - Strong institutions.
  - High income per capita.
- Now imagine Mexico or Tunisia facing the same pressures in 30 or 40 years, with low-capability states, less consensus, a tradition of political conflict, and a fraction of the income per capita.
- Middle-income countries will not have the margins of maneuver Japan has.

Concluding remarks

Terra incognita

- When I open my undergraduate course on world economic history, I argue that history teaches lessons about today's economy.
- That is not true of population. We have never seen TFRs as low as today's.
- Will they recover? We do not know. Our best guess is a small rebound from tempo effects and, short of a large change in society, not much more:
  - East Asia: likely stuck near 1, given unbalanced gender norms and toxic education systems.
  - Latin America: the same gender problem plus weak growth prospects. Around 1.2.
  - Northern Europe: more egalitarian family structures. Might hold near 1.5.
  - Very religious societies: probably the only ones that sustain 1.8.
- Within countries, the higher-income and more educated will have more children than the lower-income and less educated. A reversal of the oldest regularity in demography.

Where that leaves us

- We may end up in a shrinking world where the very rich nations have the highest TFRs, and even those below replacement.
- Not knowing the causes, we cannot forecast fertility over the coming decades. And forecasting is the easy part compared with designing policy.
- Economists are used to markets that correct themselves. Nothing in an economy pushes fertility back to replacement.
- All of this could change with AI or with shifts in population composition. We will see.
- But on current evidence, deep sub-replacement fertility is the "new new normal," and unless we find a way to reorganize our societies, we had better learn to handle it.
- We do not have a map. What we have is birth numbers, and those are sobering. In these waters, the pretense of knowledge is the most dangerous temptation.

Extra material

Definitions: CBR, CDR, TFR, CFR

- CBR and CDR: births and deaths per thousand inhabitants per year. Easy to compute wherever vital registers exist, and they have existed for centuries (English parish registers from 1538, Sweden's Tabellverket from 1749).

The total fertility rate (TFR)

The average number of children a woman would bear if (i) she faced current age-specific fertility rates throughout her life, and (ii) she survived through ages 15-49.

- The CFR (completed fertility rate) is the number actually born to a cohort of women. It tells us more, but it arrives with a long lag.
- So we use the TFR, and pay for it with tempo effects: if women born in 2000 have the same number of children but bear them later, the measured TFR runs below the CFR for years.

The replacement rate

- Definition:

$$\text{Replacement rate} \approx \frac{1 + \text{sex ratio at birth}}{\text{Probability of a woman surviving to 30}}$$

- An advanced economy:

$$\text{Replacement rate, rich country} \approx \frac{1 + 1.05}{0.98} \approx 2.1$$

105 boys per 100 girls; of 210 children, about 108 boys and 102 girls; about 98% of the girls survive to 30, leaving 100 women to replace the original 100.

- India c. 2005, with sex-selective practices and high child mortality:

$$\text{Replacement rate, India c. 2005} \approx \frac{1 + 1.10}{0.90} \approx 2.33$$

The replacement rate for the planet

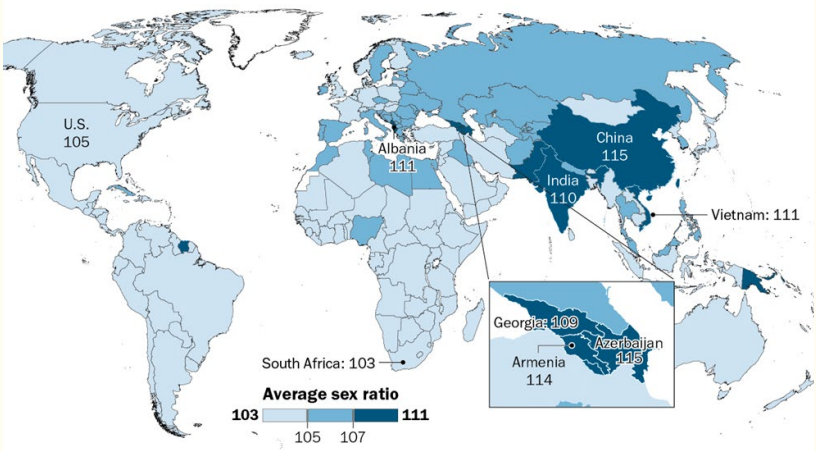
- Global sex ratio at birth: about 1.07, still above the biological 1.05 because China and India account for such a large share of world births, although the gap is closing.
- Global under-five mortality: about 37 per thousand, so roughly 94% of girls born today survive to 30. Those who die early are concentrated in high-TFR populations, which this approximation does not fully capture.
- Hence:

$$\text{Replacement rate, world} \approx \frac{1 + 1.07}{0.94} \approx 2.20$$

- The world needs a TFR near 2.2 to hold its population constant, not the 2.1 of the rich countries. The gap looks small. It is not.

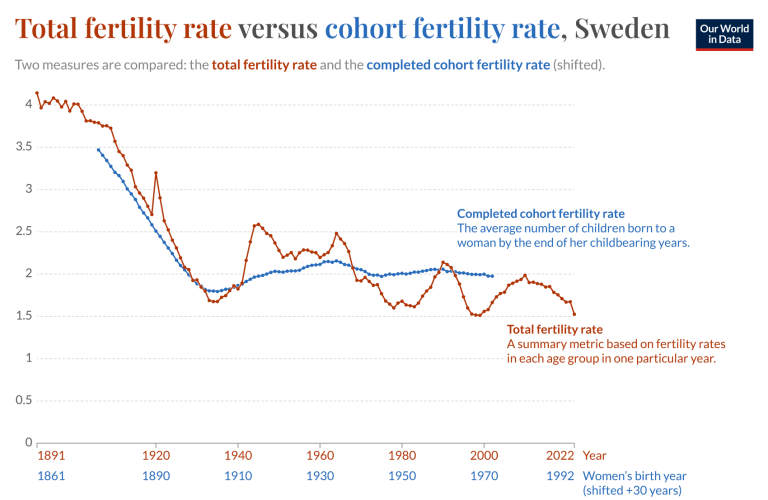
The sex ratio at birth

Average sex ratio at birth, or the number of male births per 100 female births, from 2000-20



Note: Globally, the natural sex ratio at birth ranges from 103 to 107 boys per 100 girls.
Source: United Nations World Population Division, 2019.
"India's Sex Ratio at Birth Begins To Normalize"

Sweden


Total fertility rate versus cohort fertility rate, Sweden
Our World in Data
Two measures are compared: the total fertility rate and the completed cohort fertility rate (shifted).
4
3.5
3
2.5
2
1.5
1
0.5
0
Completed cohort fertility rate
The average number of children born to a woman by the end of her childbearing years.
Total fertility rate
A summary metric based on fertility rates in each age group in one particular year.
1891
1920
1940
1960
1980
2000
2022
Year
1861
1890
1910
1930
1950
1970
1992
Women's birth year (shifted +30 years)
Data source: Human Fertility Database (2024)
Note: The completed cohort fertility rate is typically given by the woman's birth year. In this chart, it has been shifted +30 years to see how the two measures compare at roughly the average age of mothers at childbirth.
OurWorldinData.org — Research and data to make progress against the world's largest problems.
Licensed under CC-BY by the author Saloni Dattani

What about immigration?

- Not as easy as it seems.
- First, the TFR is falling everywhere. Net immigration into the Earth is zero.
- Second, the numbers advanced countries would need to bring in are phenomenal, and would strain any society.
- Third, we live in a welfare state, and that is unlikely to change soon.
  - Roughly, the bottom 70% of the population receives net payments and services from the government over their lifetime; the 70th to 90th percentile receives about zero; the top 10% pays it all.
  - Most people arriving from abroad worsen the fiscal position of the government.
- Fourth, each person who leaves a poor country for a rich one makes the poor country's position harder. Colombia's population is already falling partly because of departures for the U.S. and Spain.

If one wanted to do something

- Remember: most of the current drop below 2.1 is on the extensive margin, not the intensive one. The target is the woman going from one child to zero, or two to one.
- Housing, and not only its price:
  1. Cheaper, yes.
  2. But also more *convenient*: size, transportation, proximity to family.
  3. Modern city planning is deeply anti-family and anti-child.
  4. And recall Couillard (2025): building fewer large units generates 2.3 times more births than more small ones.
- Education: the arms race is a cost imposed on parents by other parents. South Korea is the extreme case.
- Who does the work: on the evidence, parental leave and childcare do more than cash transfers, because the binding constraint is time, not price.