Economic Growth and Childbearing in the Short- and Long-Run

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Abstract: The relationship between aggregate income and fertility plays an important role in many theories of economic development and demographic change, but the literature on this topic sheds limited light on how childbearing behavior evolves with the macroeconomy at various time horizons in a broad set of developing countries. To analyze the short- and long-run relationships between economic growth and fertility change, we draw on the birth histories of 2.1 million women in 65 low- and middle-income countries over the period 1950-2010. We differentiate among (1) the long-run relationship between trends in GDP per adult and trends in conception rates at various ages; (2) the short-run relationship between deviations from these trends; and (3) the net impact of these forces on the lifetime fertility of women experiencing different macroeconomic conditions over their reproductive lifecycles. In the short run, conception rates are procyclical, declining sharply during recessions, with over half of this response offset in the subsequent year. In the long run, prime-age and total conception rates fall more rapidly in faster-growing economies, although older-age conception rates fall more slowly, due to the postponement of childbearing. These forces interact in a nuanced way over the reproductive lifecycle. Comparing birth cohorts within a country, the level of economic activity at prime reproductive age is associated with slightly lower lifetime fertility, but economic growth at mid- to late-reproductive age is associated with higher lifetime fertility.

Introduction

Despite its importance to theories of demographic change and economic development, the relationship between macroeconomic conditions and fertility in developing countries remains incompletely understood. In historic pre-industrial populations, birth rates rose during eras of relative prosperity, much in line with Malthus's characterization of fertility control as a "preventive check" on population size [1, 2, 3]. Birth rates are similarly procyclical in present-day industrialized countries, falling during recessions [4]. But fertility is currently highest in the poorest and least-developed countries, suggesting that the economies that grew most in recent history contain the populations in which reproduction slowed most [5, 6].

Does fertility respond to income differently in contemporary developing countries, or does its response to short-run economic fluctuations differ from its association with long-run economic growth? A small literature has documented drops in fertility during economic crises in select developing countries, consistent with the procyclicality observed in other settings, but this research does not speak to the distinction between the short and long run, and its generalizability to a broader set of countries is not clear [7, 8, 9, 10]. Leading theories of demography and economic growth emphasize how long-run economic progress may reduce childbearing incentives, for example by increasing the return to child investment or women's work, so the time horizon distinction is theoretically as well as practically important [11]. Also unknown in developing countries is whether any fertility responses to short-run fluctuations extend beyond adjustments in a woman's childbearing timing to affect her lifetime number of children, as they do in the United States [12]. These questions are difficult to answer for a broad set of countries because standard cross-national databases track fertility change at a low frequency in many developing countries.[1] Aggregate data also obscure heterogeneity in these relationships, for instance by age, education, or sector of residence.

In this paper, we combine macroeconomic data with birth history data on 2.1 million women from 184 household surveys to shed light on these issues in 65 low- and middle-income countries (SI Appendix, Table S1) over the period 1950-2010. Our fertility data come from the World Fertility Surveys (WFS) and Demographic and Health Surveys (DHS), in which nationally-representative samples of women of childbearing age list each of their children ever born, with information on birth

[1] Birth registration is incomplete in many developing countries [13]; censuses and household surveys are infrequent. As a result, the United Nations and World Bank rely heavily on interpolation and smoothing [14, 15].

date, survival status, and several maternal characteristics. From these microdata, we retrospectively generate two types of fertility rates: conception rates for each age from 15 to 44, by country and year, and the completed fertility rate, by country and birth cohort. The age-specific conception rates are period measures of fertility, each relating to outcomes occurring in a specific year, while the completed fertility rate is a cohort measure of fertility, relating to the lifetime outcomes of a group of women born in the same year. We link these rates with macroeconomic variables computed from the Penn World Table (PWT), using annual changes in the logarithm of real GDP per working-age adult to measure short-run fluctuations, and using the 15+ year time trend in the same variable to measure long-run growth.

These data serve as inputs to three analyses. First, we examine how conception rates respond to economic growth fluctuations in the short run, paying close attention to whether any immediate effects are offset in subsequent years and to whether conceptions respond differently to booms and busts. Second, we estimate how long-run trends in conception rates relate to long-run economic growth. Third, we look across birth cohorts within a country to ask how completed fertility varies with macroeconomic conditions experienced at different phases of the reproductive lifecycle.

For the analysis of period fertility, we study the timing of conception rather than birth because economic growth may be more likely to affect the former [12]. Because we do not have information on miscarriages or abortions, we focus on conceptions that resulted in a live birth; because we do not have information on gestational age at delivery, we assume that conception took place 9 months before the date of birth. We count multiple births as coming from a single conception and allow for the possibility that a woman may conceive twice in one year. For the analysis of cohort fertility, we treat fertility as complete by age 45, so the completed fertility rate is available for cohorts aged at least 45 when surveyed.

Data and Methods

Fertility Data. We assemble birth history data from all WFS [16] and DHS [17] surveys that are nationally representative for all women and can be merged with our macroeconomic dataset. All sample countries were classified as low- or middle-income at the time of the survey (World Bank 2015). Some surveys only interviewed women who had ever been married or had completed schooling; for

these surveys, we only use data on women who at the time of the survey belonged to an age group in which the rate of ever marriage or school completion exceeded 95%. To estimate fertility aggregates for country-year-age or country-cohort cells, we pool data from all surveys in the same country and rescale the survey weights to reflect each survey's sample size contribution to the cell. To increase precision, we exclude cells with fewer than 30 observations (<5% of cells). We estimate the age-specific conception rate, CR_{cta}, as the number of conceptions per 1000 women aged a in year t from country c, and the completed fertility rate, CFR_{cj}, as the number of children per 1000 women from country c and birth cohort j. For CFR_{cj}, we only include women over 45 at the time of the survey, treating their fertility as complete. We count both children ever born and surviving children. In the *SI Appendix*, we also use the surveys' data on marriage, education, and sector of residence.

Macroeconomic Data. The central independent variable is the logarithm of GDP per adult age 15-64 for country c in year t, $GDPpa_{ct}$, where the age range for the denominator is chosen to minimize concern about the endogeneity of population size due to fertility and mortality. To ease interpretation, this variable is multiplied by 100, so that the results are quantified in log points, which approximately reflect percentage points. When analyzing levels, we adjust for purchasing power parity (PPP); when analyzing growth rates, we adjust for inflation but still use national prices, following the recommendation in [18]. In both cases, we obtain GDP data from PWT v. 8.1 [19]. We obtain population and age structure statistics from the United Nations [14]. In the SI Appendix, we also use data from the Human Fertility Database, World Development Indicators, the UN's *World Contraceptive Use* database, and the UCDP/PRIO Armed Conflict Dataset.

Methods. We carry out three analyses**:** of short-run changes in age-specific conception rates, of long-run trends in age-specific conception rates, and of cohort completed fertility rates. Throughout, we weight observations equally to ease interpretation of the results, and we cluster standard errors by country, allowing for arbitrary error covariance within country while imposing independence across countries. We always label the association of interest β, although its interpretation differs across analyses. In the SI Appendix, we conduct additional analyses involving covariates, interactions, other outcome variables, alternative regression specifications, and alternative weighting schemes.

The conceptual foundation for our analysis of period fertility rates is an equation relating the levels of the conception rate and GDP per adult for each 5-year age group A from $[15, 19)$ to $[40, 44)$:

$$CR_{cta} = \beta^A Y_{ct} + \mu_c^A + \tilde{\tau}_t^A + \omega_a^A + \lambda_c^A t + \alpha_a^A t + \tilde{\varepsilon}_{cta}^A \tag{1}$$

where $Y_{ct} = 100 \times \ln(GDPpa_{ct})$; μ_c^A, $\tilde{\tau}_t^A$, and ω_a^A are country, year, and age fixed effects; and λ_c^A and α_a^A are country- and age-specific trends. The coefficient β^A measures how deviations from country- and age-specific trends in the conception rate respond to deviations from country- and age-specific trends in log GDP per adult, net of shared year-specific factors.

In the short-run period analysis, we run a first-differenced version of equation (1) because the residual ε_{cta}^A is likely to be serially correlated, and growth rates do not require PPP adjustment:

$$\Delta CR_{cta} = \beta^A g_{ct} + \lambda_c^A + \tau_t^A + \alpha_a^A + \varepsilon_{cta}^A \tag{2}$$

where ΔCR_{cta} is the change in the conception rate from the previous year, and g_{ct} is the annual change in $100 \times \ln(GDPpa_{ct})$, which approximates the growth rate. τ_t^A and ε_{cta}^A are first differences of the year fixed effect and the error term from equation (1); after differencing, λ_c^A, τ_t^A, and α_a^A are country, year, and age indicators. To assess non-linearities, we discretize the distribution of $100 \times \Delta \ln(GDPpa_{ct})$ into six bins k, including < -10, $[-10, -5)$, $[-5, 0)$, $[0, 5)$, $[5, 10)$, and ≥ 10. We then run a semi-parametric version of (2):

$$\Delta CR_{cta} = \sum_k \beta_k^A \mathbb{1}[g_{ct} \in k] + \lambda_c^A + \tau_t^A + \alpha_a^A + \varepsilon_{cta}^A \tag{3}$$

where $\mathbb{1}[\cdot]$ is an indicator variable, and $\beta_{[0,5)}^A$ is normalized to 0. Each coefficient β_k^A measures how the age-specific conception rate responds to a fluctuation in GDP per adult of size k, relative to the base category, moderate economic growth of 0-5 log points. To assess lag structure, we run a distributed-lag version of (2) with the first 3 lags of the independent variable:

$$\Delta CR_{cta} = \sum_{0 \leq L \leq 3} \beta_L^A g_{c,t-L} + \lambda_c^A + \tau_t^A + \alpha_a^A + \varepsilon_{cta}^A \tag{4}$$

Each coefficient β_L^A measures the partial effect of a log-point change in GDP per adult on the

change in the conception rate L years later. We also compute running sums of these coefficients, $\gamma_L^A = \sum_{0 \leq M \leq L} \beta_M^A$, each of which corresponds to the cumulative effect of a one-time log-point change in GDP per adult on the level of the conception rate L years later. Alternative discretizations and lag lengths produce similar results.

The long-run period analysis seeks to understand the relation between trends in conception rates and living standards: variation in ΔCR_{cta} and g_{ct} that was absorbed by the country effect λ_c^A. A natural way to estimate this relation is to regress the average of ΔCR_{cta} for a country-age cell on the average of g_{ct} in the same cell. However, gaps in the data imply that the average of annual changes does not use all information available for estimating trends. For example, if data are observed in 1970, 1971, 1990, and 1991, the average of annual changes ignores developments during 1971-1990. To leverage all available information, we implement a two-step procedure. In the first step, we estimate trends in CR_{cta} and $100 \times \Delta \ln(GDPpa_{ct})$ for each country-age cell by regressing each variable on year within each cell. In the second step, we regress the estimated fertility trend on the estimated economic trend for each 5-year age group A:

$$trend_{ca}^{CR} = \beta^A trend_{ca}^{GDPpa} + \alpha_a^A + \varepsilon_{ca}^A \tag{5}$$

where $trend_{ca}^{CR}$ is the trend in CR_{cta} and $trend_{ca}^{GDPpa}$ is the trend in $100 \times \ln(GDPpa_{ct})$.[2] The single-year age indicator α_a^A absorbs any age-related factors common across countries. The coefficient β^A measures the association of long-run economic growth with long-run fertility change.

For all analyses of age-specific conception rates, we summarize the age group results by reporting the implied result for the total conception rate (TCR) per 1000 women, defined as the expected number of conceptions in a hypothetical cohort of 1000 women who experience current age-specific conception rates at every age from 15 to 44. The implied result for the TCR is the sum of the age group coefficients, multiplied by 5 to account for the length of each age group:

$$\beta^{TCR} = 5 \left(\sum_A \beta^A \right) \tag{6}$$

An analogous estimator is also applied to the binned coefficients β_k^A, the lagged coefficients β_L^A, and

[2] In SI Appendix, Fig. S3, estimates using average annual changes rather than trends are similar but less stable across alternative sample definitions.

the cumulative effects γ_L^A.

In the cohort analysis, we regress the cohort's completed fertility rate on average economic conditions experienced in each age interval A from $[15, 19)$ to $[40, 44)$, adjusting for the cohort's average age when surveyed $\overline{a}_{cj}$, a country indicator λ_c, and a cohort indicator δ_j:

$$CFR_{cj} = \sum_A \beta^A \overline{econ}_{cj}^A + \theta \overline{a}_{cj} + \lambda_c + \delta_j + \varepsilon_{cj} \tag{7}$$

where $\overline{econ}_{cj}^A$ is the average over age interval A of economic conditions, which we measure as 100 times the logarithm of GDP per adult or its annual rate of change. Each coefficient β^A captures how completed fertility responds to within-country, within-cohort differences in economic conditions over the lifecycle. When we use the level of GDP per adult, β^A reflects the net influence of short- and long-run associations. When we use its rate of change, the country indicator absorbs cross-country variation in long-run economic growth, so β^A reflects the influence of only short-run associations.

Results

To help distinguish between short-run changes and long-run trends in the analysis of period fertility, we focus on country-age combinations with conception rates and macroeconomic data spanning at least 15 years. As reported in the first two columns of Table 1, this sample restriction gives rise to 56,273 distinct cells defined by country, year, and age, with conception rates based on the fertility histories on 2.1 million women from 65 countries. Pooling all ages 15-44, age-specific conception rates have a mean of 194 per 1000. The annual change in log GDP per adult, which approximates the annual growth rate, averages 0.9 log points, with a standard deviation of 6.1. Female education averages 4 years; the urbanization rate, 40 percent; and GDP per adult, 4,666 international dollars, adjusted for purchasing power parity.

Fig. 1*A* describes the conception rate and its rate of change over the reproductive lifecycle. The connected scatterplots depict averages, while the spikes depict 90% (minor caps) and 95% (major caps) confidence intervals. Average conception rates (black) follow an inverted u-shape in age, peaking at 257 per 1000 among 20-24 year olds. To summarize this curve, we calculate the total conception rate (TCR) per 1000, or the number of conceptions expected of a hypothetical cohort of 1000 women

experiencing these age-specific conception rates over their reproductive lifecycles. This quantity stands at 5363, or 5 conceptions per woman. On average, conception rates in all age groups declined by 1 to 3 points per year, with greater declines at older ages (grey). The average annual change in the TCR was -69, corresponding to a decadal reduction of two-thirds of a conception per woman.

These rates of change in conception rates serve as dependent variables in the analyses of Fig. 1*B*. The black plot reports the short-run association between the annual change in log GDP per adult and the annual change in the conception rate, using only within-country, within-year, and within-age variation. By using within-country variation, we isolate the fertility effects of fluctuations of the growth rate from its long-run country average. All of the short-run associations are positive, indicating procyclical fertility, with statistical significance in the prime childbearing ages. The largest association of 0.49 ($P < 0.01$) implies that a one log point increase in GDP per adult raises the number of conceptions by $\frac{1}{2}$ per 1000 25-29 year olds. Combining all age groups, the TCR rises by 8.5 per 1000 ($P < 0.01$) in response to a log point growth fluctuation. These results are unchanged in extended models controlling for the lagged level of GDP per adult and changes in conflict, female education, urbanization, and infant mortality (*SI Appendix*, Fig. S1), and they are also robust to alternative modeling choices, such as weighting by cell size and including country-specific trends (*SI Appendix*, Fig. S2). If one disaggregates conception rates by the number of previous pregnancies instead of by age, the short-run association rises with parity, starting at 0.25 ($P < 0.01$) for first births, reaching 0.44 ($P < 0.01$) for third births, and then leveling off (*SI Appendix*, Table S2).

Nearly opposite results obtain in the analysis of long-run trends, reported in grey. Countries that grew faster on average saw larger long-run declines in prime-age conception rates. This pattern is strongest among 30-34 year olds, among whom a 1-point faster annual growth trend is associated with a 0.38-point ($P < 0.01$) more negative trend in conception rates. However, older-age conception rates fell more slowly in faster-growing economies, as reflected in the long-run association of 0.15 ($P < 0.01$) for 40-44 year olds. This result reflects the postponement of childbearing in faster-growing economies. On net, the offsetting associations for trends at different ages imply a long-run TCR association of -4.2 ($P < 0.01$); overall, faster long-run economic growth is associated with more rapid fertility decline. As with the short-run analysis, these long-run results are robust to the inclusion of the initial level of GDP per adult as well as trends in conflict, female education, urbanization, and infant mortality (SI Appendix, Fig. S1). Alternatives to the 15-year minimum

time horizon also lead to similar estimates (SI Appendix, Fig. S3).

Analyses of marriage and of heterogeneous fertility responses can further illuminate the short-run results. First, marriage appears to play little role. The marriage rate is unresponsive to economic fluctuations, and conceptions are procyclical among both married and unmarried women (SI Appendix, Table S3*A*). Second, within countries, women of lower socioeconomic status are more responsive to economic fluctuations; the average education of conceiving mothers is countercyclical (SI Appendix, Table S3*B*). Third, across countries, the procyclicality of conceptions does not vary significantly with the level of GDP per adult, contraceptive prevalence, the extent of women's work, the level of women's education, or the urbanization rate of women (SI Appendix, Table S4). At the same time, the data reveal marginally significant regional variation, with countries in Africa, Latin America, and the Caribbean exhibiting stronger procyclicality than those in Asia (SI Appendix, Table S5). In fact, conception rates are entirely unresponsive to economic fluctuations in South and Southeast Asia.

All of the preceding models assume linearity, but conception rates may respond differently to booms and busts, and these responses may be non-linear in the size of the economic fluctuation. Returning to the original period sample, Fig. 2 explores this possibility by converting the annual change in log GDP per adult, which is a continuous variable, into a categorical variable for economic fluctuations of different sizes. It then estimates the effect of each fluctuation size on the change in the conception rate, relative to moderate growth between 0 and 5 log points. For most age groups, conception rates decline sharply during recessions but do not rise during expansions (Fig. 2*A*). 25-29 year olds are hardest hit, with conceptions declining 14 per 1000 ($P < 0.01$) in recessions of more than 10 log points. Aggregating all age groups, a recession of that size reduces the TCR by 175 conceptions per 1000 women ($P = 0.02$), while a similarly sized expansion has no effect (Fig. 2*B*).

Another issue is whether these recession-related declines in conception rates have permanent effects on women's completed fertility. While the cohort analysis will shed fuller light on this issue, one can gain initial insight by adding lagged economic fluctuations to the short-run model. Fig. 3*A* extends the model in this way for each age group, with the results showing pronounced offset behavior in the years following an economic fluctuation. In response to a 1-point positive fluctuation, conceptions among 25-29 year olds rise 0.47 per 1000 ($P < 0.01$) in the same year but fall 0.41 per 1000 ($P < 0.01$) in the following year. As shown in Fig. 3*B* (grey), the TCR rises 9.4 ($P < 0.01$) at first but then falls 6.5 ($P < 0.01$) in the following year. These associations reflect the partial

effect of past economic fluctuations on the current change in the conception rate. By taking their running sum (from 0 to L lags), we obtain the cumulative effect of a one-time fluctuation on the level of the conception rate (L years later). Fig. $3B$ (black) reveals that the cumulative effect of a fluctuation on TCR is insignificantly different from zero one year after the fluctuation, but it settles at a statistically significant 4-6 children per 1000 women thereafter. These results suggest that some but not all of the short-run fertility response to economic fluctuations is offset through subsequent adjustments to childbearing.

To assess whether these effects persist to the end of childbearing, we assemble a separate sample of country-cohort cells with data on lifetime fertility (after age 45) and a complete macroeconomic history from ages 15 to 44. 4 countries have no cohorts with complete macroeconomic histories, so the sample reduces to 61 countries. As reported in the last two columns of Table 1, data are available on 838 country-cohort cells containing 212k women over 45. Across these cohorts, the completed fertility rate averages 5,948 if one counts all children ever born and 4,862 if one only counts those that survived to the survey date. An individual woman experiencing these rates would bear 6 children, with 1 dying before she reached middle age. Compared with the period sample, the cohort sample is characterized by a higher average age because it excludes women below age 45. Average educational attainment is also lower because earlier cohorts received less education. Other characteristics have similar means in the two samples.

Fig. 4 reports how a cohort's completed fertility rate relates to its experience of macroeconomic conditions over the reproductive lifecycle, with each point reflecting the influence of average economic conditions during a specified five-year age interval. We measure macroeconomic conditions with either the average level of log GDP per adult or the average annual change of log GDP per adult (which approximates the average growth rate). The level estimations ask whether, within a country, cohorts experiencing greater resources per capita over their reproductive lifecycles finish with more or fewer children. The answer depends on whether the net cumulative impact of the short-run and long-run associations is positive or negative. In contrast, the growth estimations ask whether cohorts experiencing greater growth in resources per capita finish with more or fewer children, net of average growth in the country. They reflect only the cumulative impact of fluctuations, with no offsetting influence of long-run trends.

The analysis distinguishes between all children ever born (black) and those that survived to the

survey date (grey), but the two measures of completed fertility lead to similar results. Meanwhile, the level (Fig. 4*A*) and growth (Fig. 4*B*) estimations in lead to starkly different conclusions. Across cohorts within a country, a higher level of resources per capita in the prime childbearing ages is associated with lower completed fertility; long-run trends dominate short-run effects in the level estimations. However, the growth estimations, which net out country-level differences in average growth rates, show positive effects of growth on completed fertility. Across cohorts within a country, economic growth experienced before age 30 has no relation to completed fertility, but growth experienced in the 30s is positively associated with completed fertility. A log point increase in average growth during ages 30-34 raises the number of children ever born by 40 per 1000 ($P = 0.02$); that same growth increase during ages 35-39 leads to 30 ($P = 0.10$) additional children. For surviving children, the analogous effects are 34 ($P = 0.06$) and 29 ($P = 0.09$) children. By focusing on within-country variation in growth rates, Fig. 4*B* removes the confounding influence of trends and isolates the lasting effects of economic fluctuations over the lifecycle. To assess any further confounding, one could include cohort average education and urbanization as covariates, but because school-leaving decisions may respond to economic growth, the inclusion of education is inappropriate in models that estimate the effects of growth at younger ages. In models linking growth after age 25 with completed fertility, the results are robust to controlling for these covariates (SI Appendix, Table S6).

Discussion

Conflicting evidence on the relationship between macroeconomic conditions and fertility has hampered the understanding of demographic change during the process of economic development. This paper contributes three main results that illuminate this relationship over different time horizons in contemporary developing countries. First, conception rates are procyclical in the short run, falling during recessions. Second, prime-age conception rates decline with long-run economic growth, while older-age conception rates rise with it. Third, across birth cohorts within a country, those experiencing higher economic growth late in the reproductive lifecycle attain higher completed fertility.

The short-run procyclicality is consistent with evidence on fertility responses to economic fluctuations both in historical, pre-industrial populations and in contemporary, industrialized populations [3, 4]. Since this result is robust to the inclusion of covariates and is estimated using only within-

country, within-year, and within-age variation, it may represent a causal effect of macroeconomic fluctuations on conception rates. The result is driven entirely by downturns and is stronger for less educated women, suggesting a potentially important role for credit constraints that prevent poor households from smoothing their budgets through recessions. Beyond this implication, however, the mechanism behind procyclicality in the short run is not clear. One possibility is that couples take intentional steps to reduce conception risk during recessions, by using modern contraception or traditional birth control strategies like withdrawal, the rhythm method, or abstinence. Alternatively, other mechanisms beyond conscious choice may be at work. The tightening of budget constraints may decrease coital frequency among cohabiting couples, and migration for labor market opportunities may temporarily split couples [20]. Crisis-related malnutrition may also reduce fecundity, for example through amenorrhea or intrauterine mortality [21]. How to distinguish these possibilities presents a fruitful direction for future research. Another promising direction concerns the reason for the apparent absence of procyclicality in South and Southeast Asia.

The suggestive evidence on regional variation raises the question of how the short-run fertility response to economic fluctuations in WFS/DHS countries compares with that in developed countries, which have been the focus of the literature on fertility and the business cycle [4]. Cross-national data on conception rates by year in developed countries are not readily available, so we relied on birth rates to explore this issue. Specifically, we analyzed annual age-specific birth rates from our WFS/DHS microdata and from the Human Fertility Database (HFD) [22], a compilation of natality data from populations with high-quality vital registration systems, mostly in developed countries. Using the same statistical model as Fig. 2*B*, we related changes in these birth rates to the weighted average of current and lagged changes in log GDP per adult, assigning weight $\frac{1}{4}$ to the current change and $\frac{3}{4}$ to the lagged change to roughly match the period in which the current year's births were conceived (SI Appendix, Table S7). In the WFS/DHS sample, the results closely tracked the conception rate results in Fig. 2*B*, with an implied total fertility rate association (which is analogous to the total conception rate association) of 7.24 ($P < 0.01$). In the HFD sample, where the average population is 20 times richer and $\frac{2}{3}$ less fertility than the WFS/DHS sample, this association was slightly smaller, at 5.23 ($P < 0.01$), although the difference between samples is not significant. Thus, fertility is similarly procyclical in developing and developed countries.

For an additional point of comparison, we reran this analysis using total fertility rates (instead

of age-specific birth rates) from the World Development Indicators (WDI), a popular dataset in cross-country research (SI Appendix, Table S7). In the developed country sample, estimates from the WDI were identical to those from the HFD. However, in the developing country sample, the WDI delivered estimates 20 times smaller than than the WFS/DHS, likely because the WDI's fertility data are heavily smoothed for countries with low-quality vital registration systems. Researchers using this popular cross-country dataset would have incorrectly concluded that fertility is far more procyclical in richer, lower-fertility countries.

The short-run patterns stand in stark contrast to the relationship between long-run trends in aggregate income and fertility, which is negative on average but heterogeneous across age groups. This result is also robust to adjustment for relevant covariates, although its reliance on cross-sectional variation puts it at greater risk of confounding. Its main takeaway point is that some factor that accompanies long-run economic growth leads to faster declines in childbearing, as reflected in the negative long-run association for the total conception rate, and also to delays in childbearing, as reflected in the positive long-run association for conceptions among 40-44 years olds. Leading economic theories posit that the technological progress associated with economic growth raises the returns to women's work and to human capital investment in both women and children, which raise the costs of childbearing and therefore push fertility downward [11]. Female investment in own human capital through schooling or on-the-job-training may also delay childbearing, although the results clarify that trends in formal schooling among adults do not explain the long-run associations. In principle, one could also test the women's work hypothesis by including female labor force participation as a covariate, but panel data coverage over the sample period in WFS/DHS countries is sparse. Theories centered on investment in children's human capital are more difficult to test because they require information on schooling 1-2 decades after the fertility outcome. It is also possible that long-run economic growth is associated with reversals in intergenerational wealth flows [23], individualization or secularization [24], or other forms of ideational change [25], which may influence fertility trends.

How these patterns in period fertility translate to cohort completed fertility depends delicately on how one accounts for cross-country differences in the level and trend of economic activity. When we compare the *levels* of economic activity and completed fertility across cohorts within countries, we find slightly lower fertility among cohorts that experienced higher economic activity at prime reproductive age. This finding reflects the net impact of the short- and long-run relationships between changes

in economic activity and changes in fertility: positive but dissipating in the short run, negative in the long run. When we instead look within a country at how the level of completed fertility varies with cohort experiences of economic *growth*, we find a starkly different result: economic growth experienced at mid- to late- reproductive age is associated with higher lifetime fertility. Because this comparison nets out cross-country variation in average economic growth, it speaks to the lifetime fertility consequences of economic fluctuations, rather than trends, over the lifecycle. The results suggest that economic fluctuations affect both the tempo (timing) and quantum (lifetime cumulation) of fertility [26].

The link between economic growth at mid- to late- reproductive age and cumulative fertility at the end of the reproductive lifecycle is consistent with women in their 30s lacking the time to make up for a lost childbearing opportunity due to a recession. Puzzlingly, the headline estimate—that a log point decline in average economic growth from ages 30 to 34 reduces the lifetime number of children ever born by 40 per 1000 women—is roughly twice as large as the short-run effects would imply if they were permanent. This accumulating effect appears inconsistent with the dissipation of the short-run effects in Fig. 3. Research on the US has found similar patterns of short-run effects accumulating over the lifecycle [12], although the key margin in that context is childlessness, which does not play an important role here.[3] Three points may help explain this puzzle. First, in the short-run model with lags, 30-34 is the only age group in which both the current and lagged economic fluctuations have positive coefficients. So the short-run model predicts some accumulation of fluctuations in this age range. Second, fertility may respond non-linearly to a sustained and deep recession, which may be better reflected in a five-year average than a single-year growth measure. Third, the estimated effect on completed fertility is imprecise. Its 95% CI contains the magnitude that would be implied by the short-run effects if they dissipated by half, as suggested by the short-run model with lags.

Because we estimate fertility retrospectively using birth histories, our results are subject to concerns about several sources of bias. Respondents may forget births or misreport their timing, and maternal mortality may bias the sample of women alive at the time of the survey. Our back-dating of conceptions without information on gestational age also introduces measurement error. And international migration may generate bias if it responds to macroeconomic fluctuations. This concern would apply to any dataset, however, and international migration is more limited than the intranational

[3]Childlessness rates are low in sample cohorts, averaging 4 percent, and are unrelated to within-country variation in cohort experiences of economic growth.

migration that bedevils analyses of fertility over the business cycle within individual countries.

While our results help clarify divergent results on the relationship between aggregate income and fertility, they raise interesting questions about mechanisms and about how fertility's relation to economic growth varies with the underlying source of that growth. They also highlight the importance of careful measurement, showing how one can use large amounts of retrospective survey data to improve on standard cross-national datasets.

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Table 1. Summary statistics

	Period sample		Cohort sample	
	Mean	SD	Mean	SD
Fertility rates (per 1000)				
Age-specific conception rate	194	93		
Completed fertility rate, ever born			5,948	1,243
Completed fertility rate, surviving			4,862	850
Macroeconomic conditions				
Country GDPpa, PPP	4,666	4,308	4,317	3,312
Change in log GDPpa, log pts	0.9	6.1	0.8	1.6
Cell characteristics				
Age	27	8.0	47	1.3
Average years of education	4.2	3.0	3.5	2.4
Percent urban at survey	40	21	39	22
Number of women	2,058,143		211,609	
Number of cells	56,273		838	
Number of countries	65		61	

Period sample consists of country-year-age cells; cohort sample consists of country-cohort cells. "GDPpa" is gross domestic product per adult age 15-64. For the cohort sample, macroeconomic conditions are first averaged over each cohort's reproductive lifecycle and then summarized across cohorts.

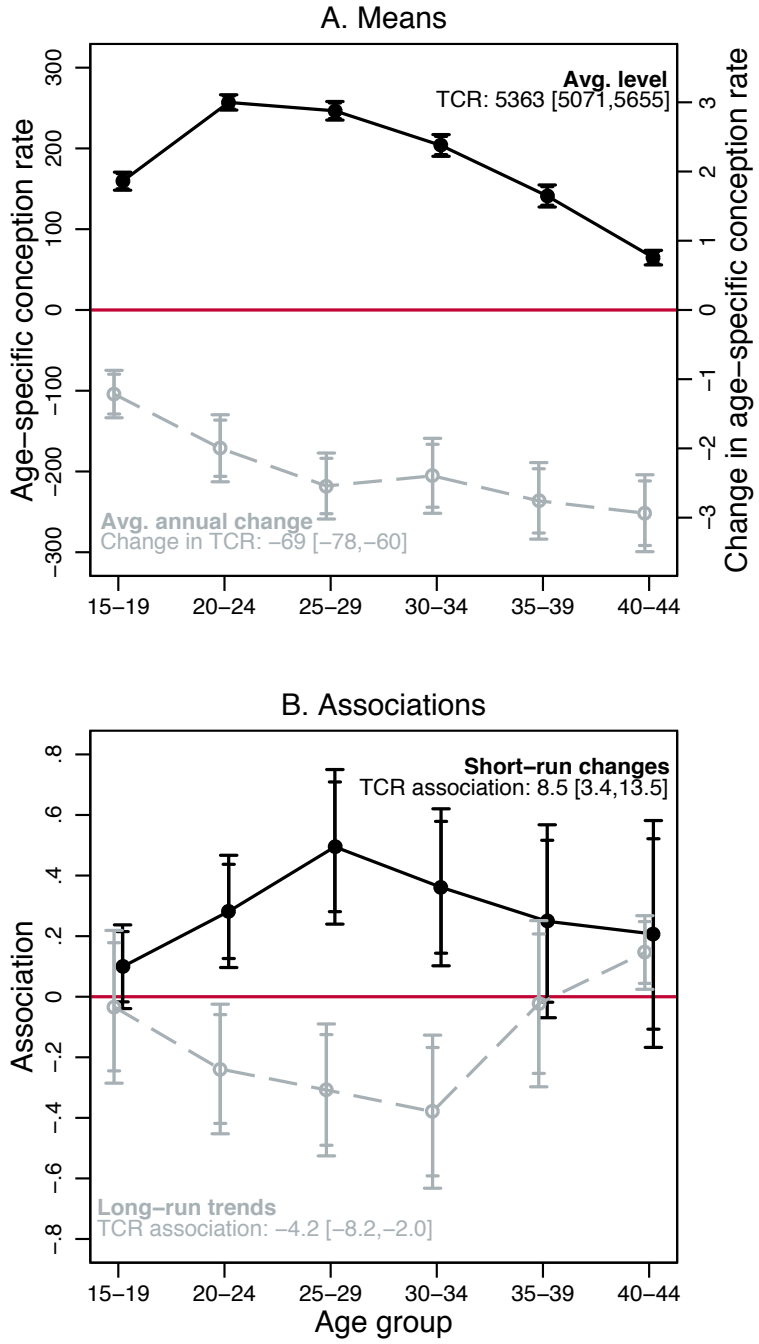


Fig. 1. Economic growth and conception rates in the short- and long-run. (*A*) means and CIs of age-specific conception rates and their annual rates of change. (*B*) coefficients and CIs from: (1) regressions of annual changes in the age-specific conception rate on annual changes in 100 × log GDP per adult, adjusting for country, year, and age indicators (black); (2) regressions of trends in the age-specific conception rate on trends in 100 × log GDP per adult, adjusting for age indicators (grey). Analyses are run by 5-year age group. Major caps are 95% CIs; minor caps are 90% CIs. TCR estimates equal 5 times the sum of age-group-specific estimates; brackets contain 95% CIs. CIs are clustered by country.

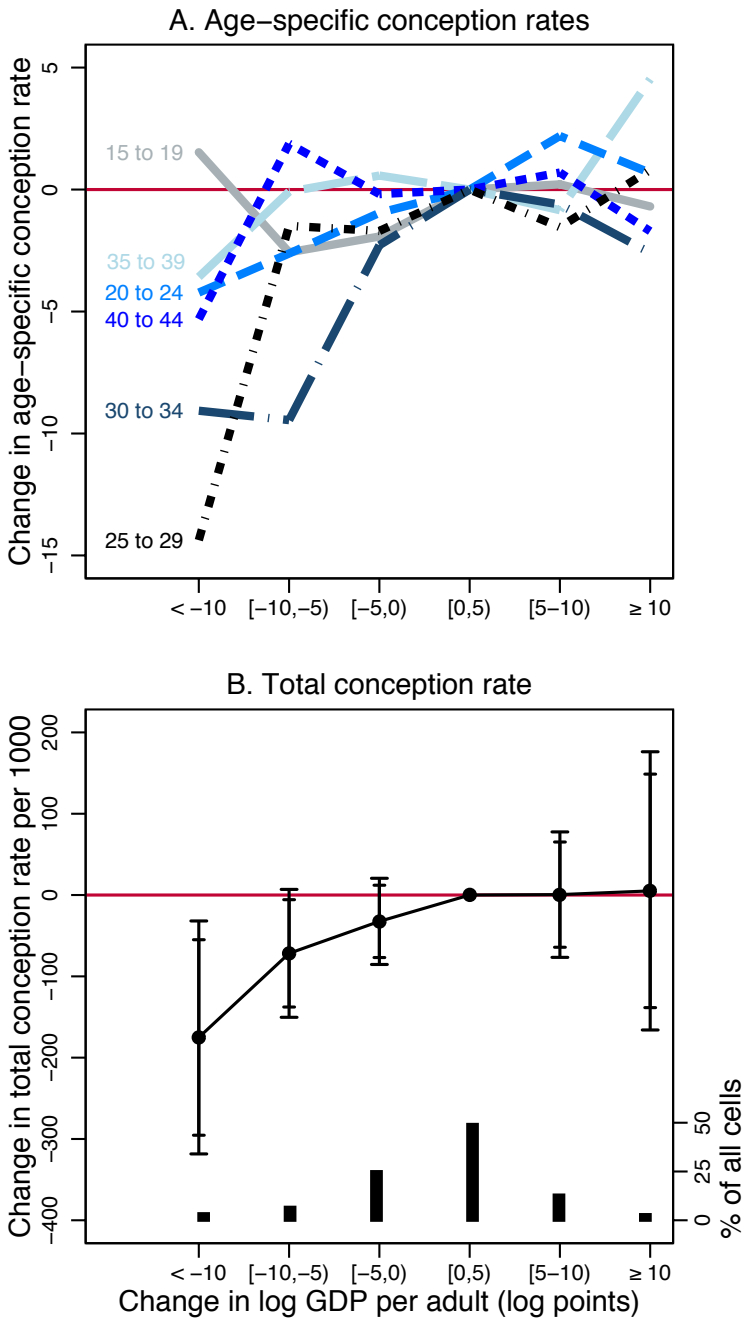


Fig. 2. Non-linear estimates of the short-run relationship between economic growth and changing conception rates. (*A*) Coefficients for each age group from regressions of annual changes in the age-specific conception rate on binned annual economic growth, adjusting for country, year, and age indicators. (*B*) Implied estimates and CIs for the total conception rate per 1000 women, obtained by summing the age-group-specific estimates and multiplying by 5. Omitted category is [0,5). Major caps are 95% CIs; minor caps are 90% CIs. CIs are clustered by country.

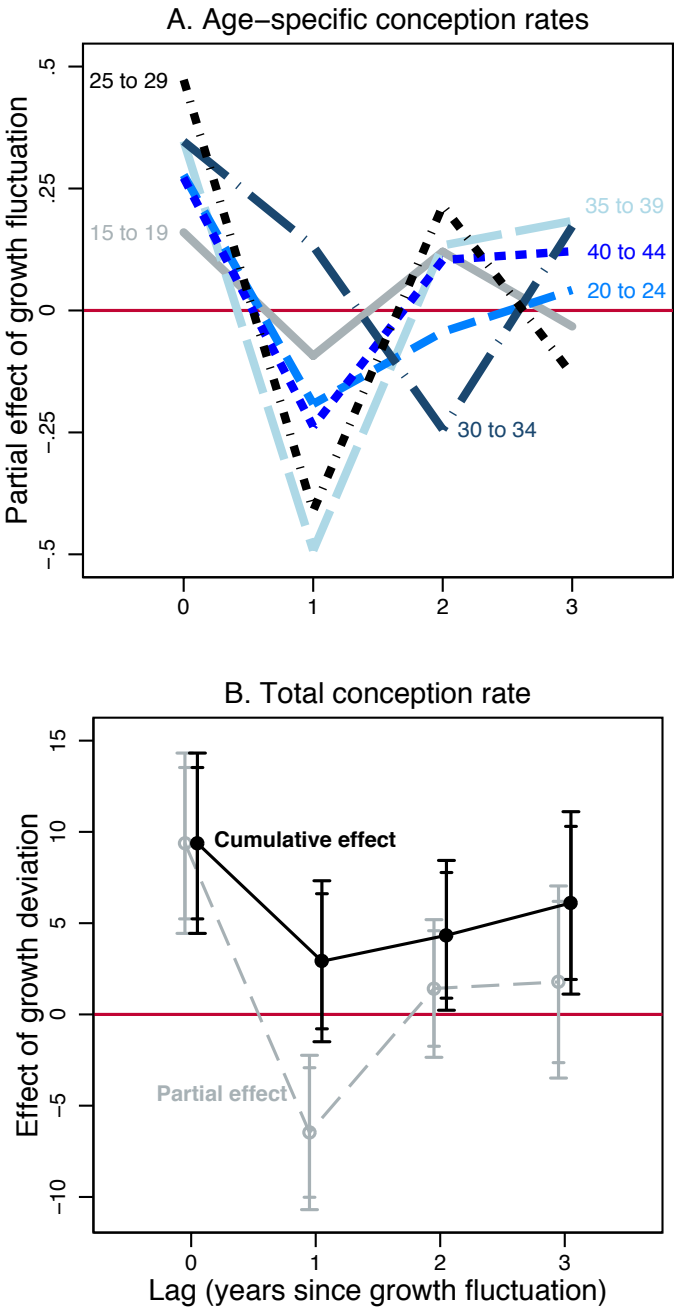


Fig. 3. Distributed lag estimates of the short-run relationship between economic growth and changing conception rates. (*A*) Coefficients for each age group from regressions of annual changes in the age-specific conception rate on current, lagged, twice lagged, and thrice lagged annual changes in 100 × log GDP per adult, adjusting for country, year, and age indicators. (*B*) Implied estimates and CIs for the total conception rate per 1000 women. Partial effects equal 5 times the sum of age-group-specific estimates; cumulative effects are the running sum of partial effects. Omitted category is [0,5). Major caps are 95% CIs; minor caps are 90% CIs. CIs are clustered by country.

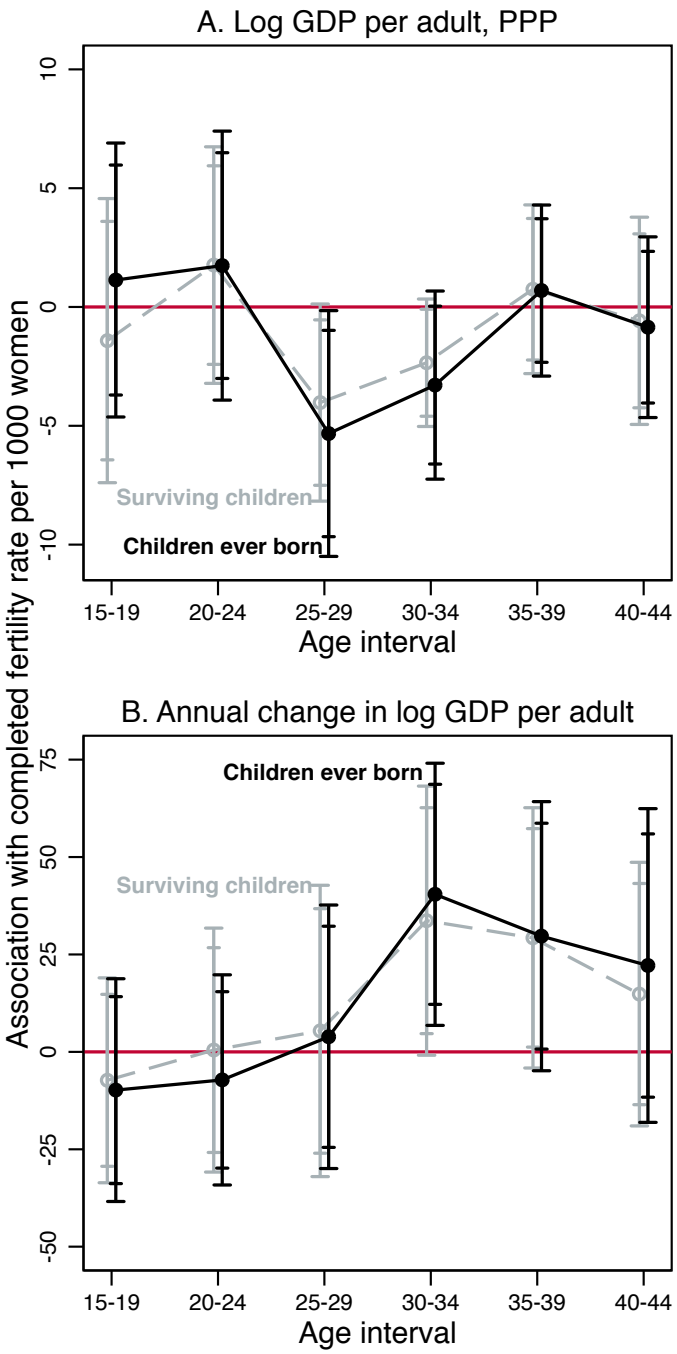


Fig. 4. Macroeconomic conditions over the reproductive lifecycle and lifetime fertility. Coefficients and CIs from regressions of the number of children ever born (black) or the number of surviving children (grey) per 1000 women in a cohort on average macroeconomic conditions during each age interval, adjusting for country indicators, cohort indicators, and the average age of the cohort when surveyed. Major caps are 95% CIs; minor caps are 90% CIs. CIs are clustered by country.

SUPPORTING INFORMATION

Table S1. Number of WFS/DHS Surveys per Country

Albania	1	Gabon	2	Pakistan	3
Armenia	2	Ghana	6	Panama	1
Bangladesh	5	Guatemala	2	Paraguay	2
Benin	4	Guinea	3	Peru	9
Bolivia	4	Honduras	2	Philippines	4
Brazil	2	India	3	Rwanda	4
Burkina Faso	2	Indonesia	7	São Tomé and Príncipe	1
Burundi	2	Kenya	6	Senegal	6
Cambodia	3	Kyrgyz Republic	2	Sierra Leone	1
Cameroon	4	Lesotho	2	South Africa	1
Central African Republic	1	Liberia	2	Swaziland	1
Chad	2	Madagascar	4	Tajikistan	1
Colombia	6	Malawi	4	Tanzania	5
Comoros	2	Mali	4	Togo	2
Congo, Dem. Rep.	1	Mexico	1	Trinidad and Tobago	1
Congo, Rep.	2	Morocco	2	Tunisia	2
Costa Rica	1	Mozambique	3	Turkey	3
Dominican Republic	6	Namibia	3	Ukraine	1
Ecuador	1	Nepal	5	Zambia	4
El Salvador	1	Niger	4	Zimbabwe	5
Ethiopia	3	Nigeria	5		

List includes all 184 World Fertility Surveys and Demographic and Health Surveys that could be matched with macroeconomic data from the Penn World Table.

Table S2. Short-Run Associations for Parity-Specific Conception Rates

	Parity 1	Parity 2	Parity 3	Parity 4	Parity 5
Association	0.247	0.234	0.435	0.405	0.387
	[0.070]***	[0.122]*	[0.146]***	[0.141]***	[0.190]**
Mean concep. rate	134	277	255	244	236
Mean change in concept. rate	-0.2	-3.3	-4.4	-4.6	-4.8
Number of cells	2,848	2,759	2,678	2,583	2,468

Coefficients from regressions of the annual change in the parity-specific conception rate on the annual change in 100 $\times$ log GDP per adult, adjusting for country indicators and year indicators. "Parity" equals one plus the number of previous pregnancies that resulted in a live birth. Rates are calculated for all ages pooled. Brackets contain standard errors clustered by country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table S3. Evidence on the Role of Marriage and Within-Country Heterogeneity in Short-Run Associations

Outcome	Association	SE	Mean	SD
A. Rates per 1000 women				
Conception rate	0.199	[0.074]***	197	(57)
Pre-marital conception rate	0.260	[0.148]*	86	(60)
Post-marital conception rate	0.351	[0.147]**	234	(75)
Marriage rate	-0.031	[0.039]	27	(23)
B. Average characteristics of mothers				
Age	0.0005	[0.0012]	23	(3)
Years of education	-0.0027	[0.0009]***	3.5	(2.7)
Percent urban	-0.011	[0.013]	36	(20)
Percent married	0.0095	[0.0065]	93	(14)

To minimize changes in sample composition from country-year-age cells with no births or no unmarried women, the analysis is run at the country-year year level, so outcomes are estimated for all ages pooled. Sample includes 2,545 country-year cells. Coefficients from regressions of the annual change in each outcome on the annual change in 100 $\times$ log GDP per adult, adjusting for country indicators, year indicators, and changes in the age composition of each cell. The regressions in *B* also adjust for changes in average years of education, percent urban, and percent married among all women in each cell. Brackets contain standard errors clustered by country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table S4. Heterogeneity in the Short-Run Total Conception Rate Association by Aggregate Characteristics

Aggregate Characteristic:	Lagged GDPpa, PPP	Lagged contraceptive prevalence	Female labor force share in 1990	Lagged average years of education	Lagged share urban at survey
Association below characteristic's median	7.84 [3.58]**	9.03 [3.69]**	10.47 [3.66]***	7.93 [3.74]**	8.65 [3.49]**
Association above characteristic's median	9.57 [2.24]***	9.01 [2.74]**	7.87 [3.16]**	8.86 [1.71]***	7.23 [1.86]***
p-value for difference	0.647	0.998	0.573	0.807	0.681
Number of cells	54,154	44,546	54,154	54,154	54,154

Total conception rate associations based on regressions of annual changes in the age-specific conception rate on annual changes in 100 $\times$ log GDP per adult, adjusting for country, year, and age indicators. Associations are estimated by 5-year age group and then summed and multiplied by 5 to obtain TCR association. In all samples, the association for the full sample is between 8.4 and 8.8. Brackets contain standard errors clustered by country. Sample sizes vary because data on some of the aggregate characteristics are not available for the full sample. "GDPpa" is GDP per adult, from the Penn World Table; contraceptive prevalence is the estimated share of women of childbearing age using modern contraceptives, from the UN; female labor force share is the percent of the labor force aged 15-64 that is female, from the WDI; average years of education and share urban are estimates in the from WFS/DHS survey data. We use the female labor force share in a single year because little meaningful panel variation exists in standard cross-national datasets; in the WDI, country effects account for over 95% of the variation. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table S5. Regional Heterogeneity in the Short-Run Total Conception Rate Association

	Short-run association	*p*-values from pairwise tests		
		Africa	C/W Asia	S/SE Asia
Africa	9.53			
	[3.23]***			
Central/Western Asia	5.16	0.01		
	[2.50]**			
South/Southeast Asia	-3.44	0.14	0.32	
	[8.16]			
Latin America/Caribbean	12.22	0.52	0.08	0.07
	[3.30]***			
p-value from joint test	0.15			
Number of cells	54,154			

Total conception rate associations based on full-sample regressions of annual changes in the age-specific conception rate on annual changes in 100 $\times$ log GDP per adult interacted with region indicators, adjusting for country, year, and age indicators. An additional (unreported) interaction term is included for the group of five countries (Albania, Fiji, Korea, Moldova, Ukraine) that did not fit into these regional classifications. Analyses are run by 5-year age group; age group associations are summed and multiplied by 5 to obtain TCR association. Brackets contain standard errors clustered by country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table S6. Alternative Cohort Regression Models

	Children Ever Born			Surviving Children		
Coef. on average economic growth during ages...						
15-19	-10			-7		
	[15]			[13]		
20-24	-7			0		
	[14]			[16]		
25-29	4	10	8	5	8	6
	[17]	[13]	[13]	[19]	[13]	[13]
30-34	40	45	36	34	35	26
	[17]**	[13]***	[13]***	[18]*	[13]***	[12]**
35-39	30	32	31	29	30	27
	[18]*	[17]*	[16]*	[17]*	[15]*	[14]*
40-44	22	24	34	15	16	27
	[21]	[21]	[19]*	[17]	[17]	[14]*
Cohort FE	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Covariates			✓			✓
Num. cells	738	738	738	738	738	738

Coefficients from regressions of the number of children per 1000 women in a cohort on average annual changes in 100 $\times$ log GDP per adult during each age interval, adjusting for the average age of the cohort when surveyed. Covariates include cohort average education and urbanization. Brackets contain SEs clustered by country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table S6. Comparison of Short-Run Birth Rate Results with Other Datasets

	Country-years in the WFS/DHS Mean 2005 GDPpa, PPP = 5,472 Mean GDPpa growth = 0.81			**Country-years in the HFD** Mean 2005 GDPpa, PPP = 42,690 Mean GDPpa growth = 2.36		
	WFS/DHS		WDI	HFD		WDI
	Mean rate	Association	Association	Mean rate	Association	Association
Ages 15-19	133	0.118		28	0.107	
		[0.069]*			[0.030]***	
Ages 20-24	253	0.121		101	0.366	
		[0.087]			[0.063]***	
Ages 25-29	254	0.397		119	0.222	
		[0.101]***			[0.036]***	
Ages 30-34	215	0.334		78	0.204	
		[0.116]***			[0.034]***	
Ages 35-39	156	0.312		32	0.105	
		[0.149]**			[0.019]***	
Ages 40-44	78	0.275		7	0.018	
		[0.225]			[0.005]***	
Total fertility rate per 1000	5439	7.78	0.45	1832	5.11	5.31
		[2.44]***	[0.24]*		[0.63]***	[0.76]***
Num. of cells	55,607	55,607	2,553	27,720	27,720	934

"WFS" = World Fertility Survey; "DHS" = Demographic and Health Survey; "HFD" = Human Fertility Database; "WDI" = World Development Indicators. Coefficients from regressions of annual changes in the age-specific fertility rate on the weighted average of current and lagged annual changes in 100 × log GDP per adult, with weight 0.25 on the current change and weight 0.75 on the lagged change. In the WFS/DHS and HDI, unit of observation is a country-year-age cell, and the dependent variable is the age-specific birth rate; analyses are run by 5-year age group and adjusted for country, year and age indicators. For these analyses, total fertility rate estimates equal 5 times the sum of age-group-specific estimates. In the WDI, unit of observation is a country-year cell, and the dependent variable is the total fertility rate; analyses are adjusted for country and year indicators. Brackets contain standard errors clustered by country. Sample includes all WFS/DHS and HFD cells that can be matched with macroeconomic data from the Penn World Table and total fertility rate data from the WDI, excluding cells with < 30 obs and from country-age combinations spanning < 15 yrs. WFS/DHS countries are listed in Table 1; HFD countries include Austria, Belarus, Bulgaria, Canada, Czech Republic, Estonia, Finland, France, Germany, Hungary, Iceland, Japan, Lithuania, Netherlands, Norway, Portugal, Russia, Slovakia, Slovenia, Sweden, Switzerland, Ukraine, United Kingdom, and the United States. We omit Japanese data for 1966, when birth rates dropped 25% due to superstition surrounding the year of the fire horse. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

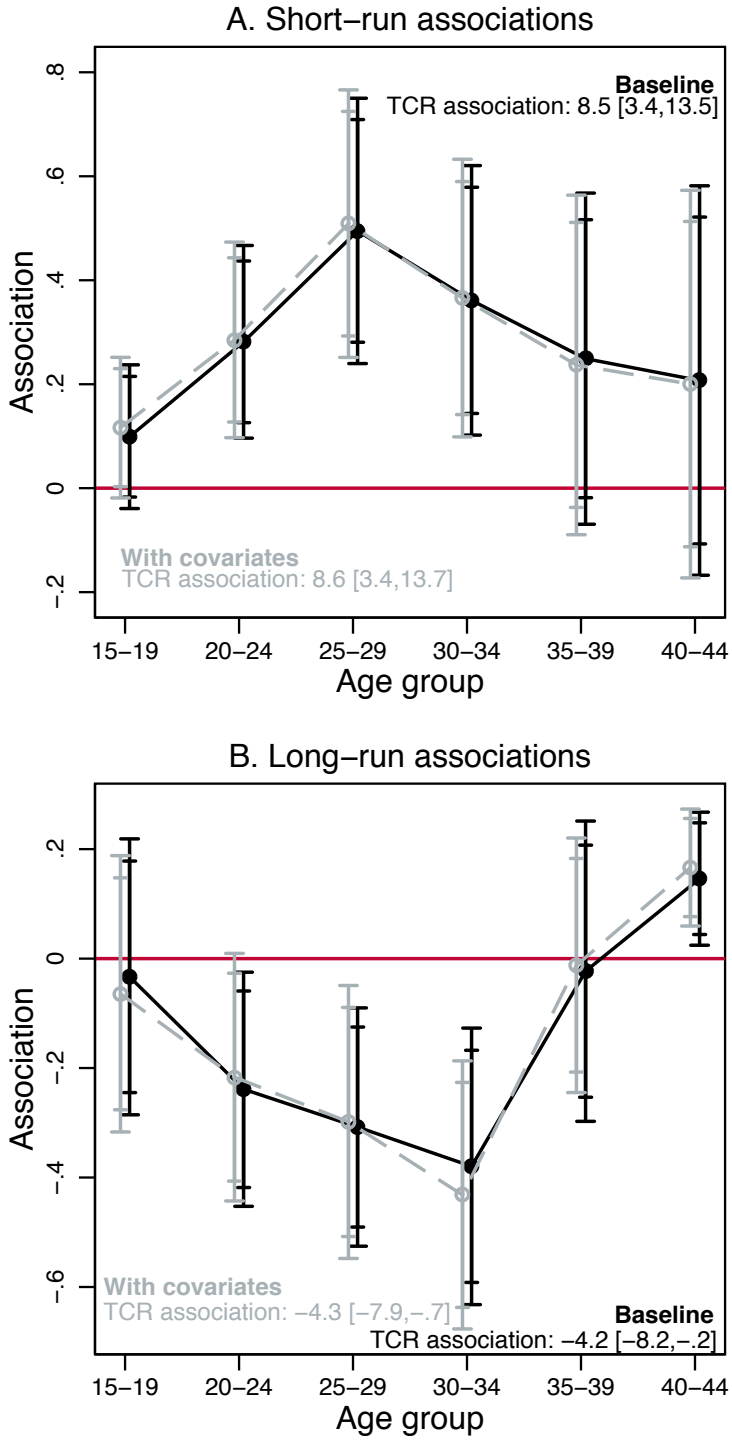


Fig. S1. Robustness to covariates. Short-run (*A*) and long-run (*B*) regressions from Fig. 1*B*, with and without covariates. Covariates include the initial level of GDP per adult, PPP, and the change or trend in female education, urbanization, infant mortality, and conflict. Conflict data are from the UCDP/PRIO Armed Conflict Dataset. Analyses are run by 5-year age group. Major caps are 95% CIs; minor caps are 90% CIs. TCR estimates equal 5 times the sum of age-group-specific estimates; brackets contain 95% CIs. CIs are clustered by country.

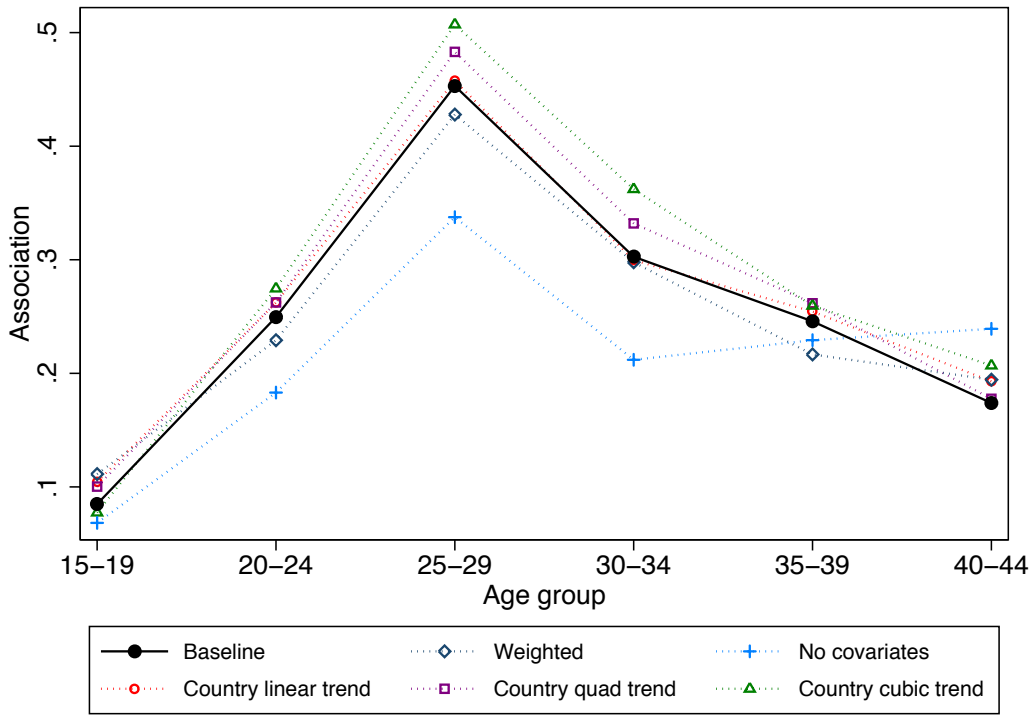


Fig. S2. Alternative Short-Run Regression Models. "Baseline" is the short-run model reported in Fig. 1*B*; "weighted" uses the same model but weights cells by their sample size; the trend models add country-specific polynomials in time to the baseline model. The model without covariates is biased by the association between long-run economic growth and long-run fertility trends, which is positive for age 40-44 and negative for all other age groups.

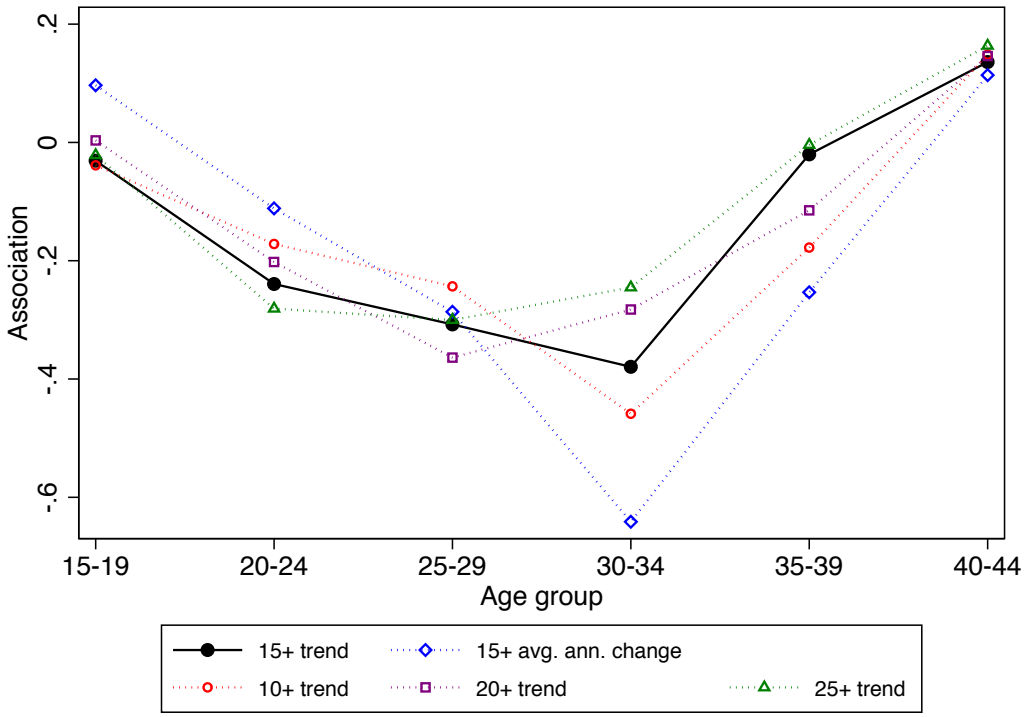


Fig. S3. Alternative Long-Run Regression Models. "15+ trend" is the long-run model reported in Fig. 1*B*. "15+ average annual change" uses the average of annual changes instead of the estimated trend, leading to the between-effects model complementing the within-effects model of the short-run analysis. As noted in *Materials and Methods*, the trend is preferable to the average of annual changes because it takes into account variation occurring during gaps in the data. The remaining results use alternative minimum time horizons (10, 20, and 25 years) for trend estimation, showing that the results are robust to different definitions of the long run.