Escaping Malthus:

Economic Growth and Fertility Change in the Developing World[*]

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Abstract

Following mid-20^{th} century predictions of Malthusian catastrophe, fertility in the developing world more than halved, while living standards more than doubled. We analyze how fertility change related to economic growth during this episode, using data on 2.3 million women from 255 household surveys. We find different responses to fluctuations and long-run growth, both heterogeneous over the lifecycle. Fertility was procyclical but declined and delayed with long-run growth; fluctuations late (but not early) in the reproductive period affected lifetime fertility. The results are consistent with models of the escape from the Malthusian trap, extended with a lifecycle and liquidity constraints.

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1 Introduction

The 1960s were a time of grave popular, political, and academic concern about global overpopulation (Connelly 2008). The world's population was growing faster than ever before, led by the developing world, where its growth rate exceeded that in the developed world threefold. Yet a Malthusian crisis was averted as fertility more than halved in the developing world, from six children per woman to fewer than three today, while both GDP per worker and GDP per capita more than doubled.[1] Despite a large body of economic theory positing a link between economic growth and fertility (see Galor 2011 for a review), existing empirical research provides few basic facts on how they related to each other during this puzzling episode in world population history. Did the simultaneous rise in income and drop in fertility across the developing world signify a break from long-standing Malthusian dynamics in which population rose with productivity, or have these dynamics persisted in the background due to the continued importance of land as a factor of production (Hansen and Prescott 2002)?

This paper seeks to empirically characterize the relationship between economic growth and fertility change in the developing world since 1950, with an eye toward matching the facts with leading economic theories of growth and demographic change. We argue that careful attention to time horizons and the lifecycle is crucial to developing a coherent account of the relationship. Fertility may respond differently to growth occurring over different time horizons, and these responses may vary over the lifecycle. For instance, long-run growth may alter returns (e.g., to child investment) or prices (e.g., women's wages) in ways that short-run fluctuations do not, while short-run fluctuations may have liquidity and intertemporal substitution effects that are absent or different in the long run. And in both cases, variation in growth can affect both the lifetime number of births—in demographic parlance, the *quantum* of fertility—and their timing—the *tempo*. Existing research pays limited attention to these issues, particularly as they relate to the process of economic development. We fill this gap by using rich microdata to disentangle fertility responses to fluctuations and long-run growth over the lifecycle.

Table 1 details how we extend the existing literature, separating (for both existing findings and our own) fluctuations from long-run growth and overall findings from decompositions of tempo and quantum effects. Existing evidence on fluctuations is most complete in currently rich countries,

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[1] Here we follow the UN in defining Europe, the Western Offshoots and Japan as More Developed Regions, and the rest of the world as Less Developed Regions. The fertility claim is based on the UN *World Population Prospects*, while the labor productivity claim is based on the Penn World Table. Section 2 introduces both data sources.

where a large literature finds that birth rates are procyclical both at present (Sobotka, Skirbekk, and Philipov 2011) and hundreds of years ago (Galloway 1988; Lee 1997). Most studies do not track subsequent fertility over the lifecycle, but Currie and Schwandt (2014) find in the US that downturns at particular ages decrease lifetime fertility, implying a mix of tempo and quantum effects. In the contemporary developing world, research on select countries finds fewer births after economic crises, but its generalizability across countries is unclear, as is its lifecycle interpretation.[2] Moving to the longer run, two stylized facts motivate the theoretical literature on growth and fertility (Galor 2011): (1) the coincidence of fertility decline with the emergence of modern growth in historical time series, and (2) the inverse association between per capita income and fertility across countries today. Although these patterns suggest a link between growth and fertility decline, panel analyses of the relationship are rare and inconclusive, so its magnitude and contributing factors are poorly understood.[3] Even more poorly understood is the relationship between long-run growth and the timing of fertility over the lifecycle.[4]

Table 1: Summary of Existing and New Evidence on Fertility Responses to Growth

	Overall	**Tempo (timing) vs. quantum (lifetime)**
Fluctuations	**Existing evidence:** fertility procyclical in MDCs and pre-industrial Europe; limited systematic evidence on LDCs.	**Existing evidence:** in US, downturns delay births, reduce lifetime fertility if experienced in the 20s; no evidence on LDCs.
	New evidence: fertility procyclical in LDCs; driven by downturns, stronger among less-educated women.	**New evidence:** downturns delay births in LDCs, reduce lifetime fertility if experienced after age 30.
Long-run growth	**Existing evidence:** in historical time series, growth takeoffs coincide with fertility decline; incomplete correlational evidence on LDCs.	**Existing evidence:** varied importance of starting, spacing, and stopping strategies; little direct evidence on relation to growth.
	New evidence: growth associated with fertility decline in LDCs; related to rising enrollment, not sectoral comp., death, female educ., FLFP.	**New evidence:** growth associated with fertility delay in LDCs; age-specific rates fall more quickly before 40, slower after.

Note: MDC/LDC = more/less developed country. FLFP = female labor force participation.

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[2] See National Research Council (1993); Tapinos, Mason, and Bravo (1997); Lindstrom and Berhanu (1999); and Adsera and Menendez (2011), which with 18 Latin American countries provides the broadest geographic coverage.

[3] Bongaarts and Watkins (1996) find that growth in the Human Development Index (HDI) predicts decline in the total fertility rate (TFR), 1960-90, but do not separate the components of the HDI. Schultz (1997) finds that, conditional on a range of covariates, economic growth was unrelated to TFR change, 1972-88, with no further exploration of the result. Over the 20^{th} century, Herzer, Strulik, and Vollmer (2012) find that growth predicts fertility decline, while Murtin (2013) finds a non-monotonic relationship, but neither distinguishes fluctuations from long-run growth. All draw on standard cross-country datasets and do not consider the lifecycle.

[4] In the West, fertility control depended on the marriage timing during the Malthusian era (Hajnal 1965) and on increased spacing and earlier stopping (Knodel 1987; Bean, Mineau, and Anderton 1990) during the fertility transition. In contemporary developing countries, early marriage is becoming rarer (Mensch, Singh, and Casterline 2005), and birth spacing has increased (Casterline and Odden 2016). None of this research touches on the role of economic growth.

To study growth-fertility linkages at different time and lifecycle horizons, we combine macroeconomic data with the reproductive histories of 2.3 million women from 255 World Fertility Surveys (WFS) and Demographic and Health Surveys (DHS), covering 81 low- and middle-income countries. The survey data allow us to avoid standard cross-country demographic databases, which rely heavily on interpolation, smoothing, and demographic modeling (United Nations 2015; World Bank 2015): problematic for studying fluctuations—which may be smoothed out—and age heterogeneity—which is typically restricted by demographic models. We also use the survey data to calculate cohort measures of fertility and investigate within-country heterogeneity—both difficult to do with cross-country databases—and to better match the timing of conception (rather than birth).

With these data in hand, we can provide a geographically and temporally broader account of growth-fertility links at various time and lifecycle horizons than previously possible. We carry out three analyses to add new evidence to each cell of Table 1: two on the flow of fertility at the population level (i.e., period fertility) and one on the stock of fertility at the cohort level (i.e., cohort fertility). First, we examine how the annual rate of starting a successful pregnancy (i.e., conceiving a future liveborn child) responds to growth fluctuations in the short run, assessing whether immediate effects are subsequently offset and whether fertility responds differently to booms and busts. Second, we estimate how the long-run rate of economic growth relates to the long-run rate of fertility decline across the lifecycle. Third, we look across cohorts within a country to ask how completed fertility varies with macroeconomic conditions experienced along the lifecycle.

Our findings support the view that time horizon and lifecycle heterogeneity is important. When we study annual fluctuations, we find that fertility is procyclical at all ages, with statistical significance at prime parenting ages (20-34, when fertility is highest). The procyclicality is driven by downturns and is stronger for less-educated women, suggesting a role for liquidity constraints that prevent poor households from smoothing through recessions. In contrast, when we study average rates of change over 20 or more years, we find that fertility declines and delays with economic growth, consistent with price effects unique to the long run. Faster-growing economies see faster declines in prime-age fertility and slower declines in older-age fertility, with the former dominating for total fertility. The asymmetry between short- and long-run growth is substantial: among 25-29 year olds, a 1-log point growth fluctuation is associated with a spike of 0.6 pregnancies per 1000 women, whereas the same magnitude increase in the long-run growth rate is associated with an annual decline of 0.4

pregnancies per 1000.[5] When we compare cohorts within a country, we find that growth experienced early in the reproductive period is unrelated to lifetime fertility, while growth in the 30s leads to higher lifetime fertility. We also show that many of our findings would be obscured in standard cross-country fertility data, while others are altogether impossible to study, underscoring the benefits of combining hundreds of surveys. In a simple theoretical framework, we demonstrate that these findings are consistent with the parental choice problem from the literature on long-run growth and the demographic transition, extended to include a lifecycle with liquidity constraints.

While all of the analyses are correlational, they differ substantially in their statistical interpretation. The short-run and cohort analyses use demanding regression specifications that isolate within-country variation, while the long-run analysis must rely on cross-country variation in rates of change. But notably, the long-run results are not explained by the initial levels of GDP per adult and population density; nor by changes in adult female education, adult female labor force participation, the sectoral composition of value added, urbanization, infant mortality, conflict, and democracy. We find only one trend that explains part of the long-run association: rising school enrollment (among teens, not mothers). Insofar as this trend suggests rising returns to human capital investment, our results are consistent with human capital-based theories of unified growth (Galor and Weil 2000).

Our use of hundreds of survey datasets places us in an exciting literature at the intersection of growth economics and development economics, which combines large quantities of microdata from across the developing world to shed light on macroeconomic aspects of the development process (Young 2013; Kleven and Landais 2016; Aaronson et al. 2017; Lagakos et al. 2017). Advances in data availability make it possible to characterize population moments with more precision and (geographic and temporal) generalizability than ever before. Besides the direct contribution to knowledge on growth and the demographic transition, our results also relate to the recent literature that estimates wealth or income effects on fertility using variation from natural resource (Black et al. 2013; Brueckner and Schwandt 2015) or housing (Lovenheim and Mumford 2013; Dettling and Kearney 2014) booms. While the question of whether children are 'normal' is related to ours, substitution and liquidity effects are key to understanding our setting, making it a separate contribution. Conceptually and methodologically, our analysis is more similar to research on the link between economic growth and mortality change—which is typically negative at all time horizons in developing countries (Deaton

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[5] We analyze growth in GDP per adult to avoid reverse causality; results are similar when we use overall GDP.

2007; Baird, Friedman, and Schady 2011)[6]—and on the cumulative mortality effects of economic shocks over the lifecycle (Cutler, Huang, and Lleras-Muney 2016).

The paper clarifies how to place the developing world's postwar experience in the timeline of long-run growth and demographic change. In the Malthusian era, productivity growth increased living standards in the short run and population in the long run (through higher fertility and lower mortality), with the latter effect limiting the duration of the former effect (Lee 1997; Ashraf and Galor 2011). The patterns here represent a marked departure from those long-standing dynamics; instead of rising to offset productivity growth, fertility falls with growth in the long run, augmenting its per capita effects. This departure has implications for cost-benefit analyses of development policies, which are more effective without Malthusian population offset. In a complementary analysis of data from developed countries, we find similar short- but not long-run results, suggesting that our results pertain to the phase after an economy begins the escape from the Malthusian trap but before it attains high living standards and low fertility.

2 Data

We use survey microdata to generate fertility aggregates but draw on standard databases to measure economic growth. This section describes both data sources and explains how we use them to construct our analysis datasets. It then introduces several other databases we use in extensions.

Macroeconomic Data To measure growth, we obtain data on GDP from the Penn World Table (PWT) v. 8.1, matching it with data on population and age structure from the United Nations. 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 use national prices, following the recommendation in Johnson et al. (2013).

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[6] An exception is Colombia, where infant health is countercyclical (Miller and Urdinola 2010), as in the United States (Dehejia and Lleras-Muney 2004).

Fertility Microdata To measure fertility, we assemble data from all publicly available, standard format WFS and DHS surveys that are nationally representative for all women and can be merged with our macroeconomic dataset, leading to a sample of 81 countries. Online Appendix Table A1 lists the number of surveys for each of these countries, which were all classified as low- or middle-income at the time of the surveys (World Bank 2015). Respondents provided full birth histories, listing all of their children ever born, with information on birth date and survival status.[7] These data allow us to track fertility behavior over time and the lifecycle, although they are sometimes subject to reporting errors (Schoumaker 2014), a matter we discuss further below. Reporting errors take the form of both omitted births (which are likely to have been in the distant past or to have involved deceased children) and displaced births (either forward or backward in time). Some surveys only interviewed women who had ever been married or had completed schooling; in those cases, 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%.

For all analyses, we collapse the individual-level data into country-year-age or country-cohort cells, allowing us to weight countries in a consistent way across a range econometric models. We categorize age and birth cohort in single years. To estimate the fertility rate for each cell, 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, excluding cells with fewer than 30 observations (<5% of cells).[8] We generate two types of fertility rates: period, summarizing fertility outcomes by age in a given year, and cohort, summarizing the lifetime fertility outcomes of women born in the same year.

Period Dataset For the analysis of period fertility, we study the age-specific conception rate, CR_{cta}: the number of conceptions per 1000 women aged a in year t from country c. Because we do not have information on miscarriages or abortions, we focus only 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.[9] As such, we do not directly analyze childbearing behavior but instead use approximate dates of conception for fetuses that survived

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[7] The DHS from El Salvador 1985 and Nigeria 1999 have well-known deficiencies in their birth histories (Casterline and Odden 2016). For these surveys, we do not use the birth histories but do use data on lifetime fertility.

[8] Because reporting errors may be more likely for longer recall periods, we apply a Bartlett kernel to the rescaled survey weights in a robustness exercise, down-weighting births that occurred long before the survey.

[9] We count multiple births as coming from a single conception and allow for the possibility that a woman may conceive twice in one year.

gestation: a limitation, given that economic conditions may affect the risk of fetal death.[10] To help distinguish the short and long run, we focus on country-age combinations with conception rates and macroeconomic data spanning at least 20 years. As reported in the first two columns of Table 2, this sample definition gives rise to 58,992 distinct cells defined by country, year, and age, with conception rates based on the fertility histories on 2.3 million women from 65 countries.[11] Pooling all ages 15-44, age-specific conception rates have a mean of 199 per 1000. The annual change in log GDP per adult averages 1.0, with a standard deviation of 5.8. Female education averages 4 years; the urbanization rate, 38%; and GDP per adult, 4,476 international dollars, adjusted for purchasing power parity.

Cohort Dataset For the analysis of cohort fertility, we study the completed fertility rate, CFR_{cj}: the number of children per 1000 women from country c and birth cohort j. We only include women over 45 at the time of the survey, treating their fertility as complete. Our main cohort analyses are based on all children ever born, although we show that we obtain similar results when we only count children who survived to the date of the survey. As reported in the last column of Table 2, data are available on 935 country-cohort cells from 62 countries, containing 212k women over 45. The completed fertility rate per 1000 women averages 5951 children ever born and 4862 surviving children; an individual woman experiencing these rates would bear 6 children, of whom 1 would die before she reached her late 40s. 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.

Additional Data Sources For covariates, analyses of heterogeneity, alternative measures of fertility, and comparisons with developed countries, we draw on additional aggregate data sources. We obtain alternative fertility data from the World Development Indicators (WDI) and United Nations (UN); information on contraceptive use, population density, and the sectoral composition of value added from the UN; school enrollment and labor force statistics from the WDI and International Labor Organization (ILO); democratization scores from the Polity IV project; and conflict indicators from the UCDP/PRIO Armed Conflict Dataset. Average female education, the infant mortality rate,

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[10] The term ‘conception rate’ is thus a slight abuse of terminology, but one that follows Currie and Schwandt (2014) in their work on unemployment and fertility. The focus on conception (rather than birth) timing also follows them.

[11] Every sample in Table 2 has fewer than 81 countries because the period analysis omits surveys with unrepresentative or low quality birth histories, while the cohort analysis omits cohorts that lack complete macroeconomic histories. Online Appendix Table 2 lists the countries included in each sample.

and the urbanization rate are estimated from WFS/DHS microdata. For comparison with developed countries, we use the Human Fertility Database, which assembles high-quality vital registration data.

3 Analysis of Period Fertility

Our analysis of period fertility focuses on how changes in fertility across the age distribution vary with short- and long-run economic growth. We begin by laying out how we distinguish between short- and long-run patterns empirically, followed by the main results for both horizons. We then delve further into the results—assessing non-linearity, lag structure, heterogeneity, and alternative covariates—first for the short run and then for the long run.

3.1 Defining Time Horizons

A key issue is how to define "short run" and "long run." To allow the data to speak to this issue, we run a series of first-difference regressions in which we vary the length of the difference. Because we are holding age fixed as time changes, we are effectively studying cross-cohort changes in age-specific fertility. For each 5-year age group A from $[15, 19)$ to $[40, 44)$, we run:

$$CR_{cta} - CR_{c,t-\Delta,a} = \beta^A \left(Y_{ct} - Y_{c,t-\Delta}\right) + \alpha_a^A + \varepsilon_{cta}^A \tag{1}$$

where $Y_{ct} = 100 \times \ln\left(GDPpa_{ct}\right)$. Because the distribution of single-year ages within each 5-year age group varies across countries and over time, we include a single-year age effect α_a^A, thus allowing fertility levels to trend differently for each single-year age within the 5-year age group. We estimate equation (1) using a range of values for the length of the difference Δ, from 1 to 30 years. Figure 1 displays the results, for each age group plotting estimates of the coefficients against the length of the difference.[12]

Figure 1 makes clear that economic growth and fertility change have different relationships over different time horizons. In the annual first difference ($\Delta = 1$), all age groups have positive coefficients, indicating procyclical fertility. But all but one age group immediately begin trending downward with rising Δ, becoming negative by $\Delta = 14$ and leveling off at about $\Delta = 20$. In other words, for all age

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[12] Online Appendix Figure A1 shows similar patterns if we leave out the single-year age effects or only use data from country-age cells with conception rates spanning at least 20 or at least 30 years.

groups less than 40, economic growth is negatively associated with fertility change in the long run. Above 40, economic growth is positively related with fertility change at all time horizons.

These patterns have two further implications. First, the annual first-difference coefficients estimated with equation (1) actually reflect a mix of short- and long-run associations, depending on the relative contributions of transitory fluctuations and long-run growth to the variance of the annual growth rate. Second, the sharp drop of the coefficients for the first five age groups beyond $\Delta = 1$, as well as their leveling at about $\Delta = 20$, suggest 1 and 20 years as reasonable definitions of the short and long run.

3.2 Methods

Based on the patterns in Figure 1, we divide our study of period fertility into a short-run analysis of annual fluctuations and a long-run analysis of average annual changes over periods of at least 20 years. To distinguish time horizons as clearly as possible, we restrict both analyses to country-age cells that span at least 20 years. For the short-run analysis, we modify equation (1) to fully disentangle the short- and long-run relationships by including a country effect, which absorbs the country's average changes in log GDP per adult and the conception rate. For completeness, we also include a year effect, addressing any spurious global trends. The first-difference specification then becomes:

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

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. λ_c^A, τ_t^A, and α_a^A are the country, year, and single-year age effects, which in first differences serve to control for correlated level trends.[13] The coefficient β^A isolates how fluctuations of the growth rate from its long-run country average affect changes in the conception rate, net of year- and age- specific factors. A 1-log point growth fluctuation raises the change in the conception rate by β^A.

For the long-run analysis, we seek to estimate a long-difference version of equation (1). The

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[13] Equation (2) can be obtained from differencing a level specification with country (μ_c^A), year ($\tilde{\tau}_t^A$), and age (ω_a^A) fixed effects, as well as country (λ_c^A) and age (α_a^A) linear trends:

$$CR_{cta} = \beta^A \left(100 \times \ln\left(GDPpa_{ct}\right)\right) + \mu_c^A + \tilde{\tau}_t^A + \omega_a^A + \lambda_c^A t + \alpha_a^A t + \tilde{\varepsilon}_{cta}^A$$

On differencing, μ_c^A and ω_a^A drop out, while λ_c^A, $\tau_t^A \equiv \Delta\tilde{\tau}_t^A$, and α_a^A become country, year, and age effects. However, serial correlation, non-stationarity, and the need for PPP adjustment make the level specification unattractive.

standard approach would relate simple changes in log GDP per adult to simple changes in fertility over an interval of 20 years. However, because our country-year-age conception rates are noisy estimates from surveys, we deviate from this standard approach in order to leverage as much information as possible on the rate of long-run fertility change. Instead of the long difference, we analyze the average annual rates of change in the two variables, $\overline{g}_{ca}$ and $\overline{\Delta CR}_{ca}$, over periods of at least 20 years. To estimate these quantities using as much information as possible, we regress $100 \times \Delta \ln \left(GDPpa_{ct}\right)$ and CR_{cta} on year within each country-age cell, using the slope of the trend as the estimated average annual rate of change.[14] We then run the following regression for each 5-year age group A:

$$\overline{\Delta CR}_{ca} = \beta^{A} \overline{g}_{ca} + \alpha_{a}^{A} + \varepsilon_{ca}^{A} \tag{3}$$

As before, the single-year age effect α_a^A absorbs any age-related factors common across countries. By collapsing the country-year-age observations into country-year cells, we remove the time dimension from our panel, so the year effect τ_t^A drops out. Similarly, because equation (3) primarily analyzes variation in ΔCR_{cta} and g_{ct} that was absorbed by the country effect in equation (2), we omit λ_c^A from the long-run regression. Here, β^A represents the cross-country association of long-run economic growth with long-run fertility change, net of age-related factors. A 1-log point faster annualized rate of long-run growth is associated with a β^A higher annual rate of change in the conception rate.

For both equations (2) and (3), 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:

$$\beta^{TCR} = 5 \left(\sum_{A} \beta^{A} \right) \tag{4}$$

This summary measure is the sum of the age group coefficients, multiplied by 5 to account for the length of each age group. While heterogeneity over the age distribution is key to our investigation, β^{TCR} provides an overall measure of the association between economic growth and fertility change.

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[14] An alternative approach would take the mean of observed annual changes g_{ct} and ΔCR_{cta}, but this approach does not use all available information because of gaps in the data. For example, if data were collected only in 1970, 1971, 1990, and 1991, then the mean of the two observed annual changes would ignore developments during 1971-1990. Another alternative approach would take the annualized long difference from 1970 to 1991, but this approach loses precision because both variables are stochastic, and conception rates are measured with sampling error. Figure A2 provides a case study for further intuition.

To assess the roles of other aggregate variables in explaining any relationship between economic growth and fertility change, we report estimations of equations (2) and (3) with and without a main set of covariates. In the extended models, we control for variables available for all country-years in our dataset: the initial levels of population density and log PPP-adjusted GDP per adult, as well as the annual change (for the short-run analysis) or average annual rate of change (for the long-run analysis) in female education, urbanization, infant mortality, and armed conflict. Female education and urbanization are averaged at the country-year-age level, while infant mortality is measured at the country-year level to minimize noise.[15] We consider covariates available only for subsamples later.

For weighting and variance estimation, we make conservative choices that clarify interpretation. Sample sizes in individual WFS and DHS surveys range from fewer than 5,000 to more than 100,000 women, suggesting possible efficiency gains to weighting by cells size, but we choose to weight cells equally to ease interpretation of the results. We also cluster standard errors by country, allowing for arbitrary error covariance within country while imposing independence across countries.

3.3 Results

Figures 2-4 present the main results from the analysis of period fertility. To aid interpretation of the age-group-specific regression estimates, Figure 2 first summarizes the level of fertility and its annual rate of change across age groups. Average conception rates follow an inverted u-shape in age, peaking at 261 per 1000 among 20-24 year olds. The TCR per 1000 women is 5483, so that a woman experiencing these age-specific conception rates over her lifecycle would expect 5.5 conceptions. Despite this high level, fertility was falling throughout the sample period for all age groups. On average, conception rates in all age groups declined by 1 to 3 points per year, with a -67 annual change in the TCR, corresponding to a decadal reduction of two-thirds of a conception per woman.

These rates of fertility change serve as dependent variables in Figures 3-4, which present the regression results graphically; for additional reference, online Appendix Table A3 presents them numerically. Figure 3 reports the short-run coefficients from equation (2), with and without covariates. In both models, all short-run coefficients are positive, indicating procyclical fertility, with statisti-

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[15] To avoid endogeneity concerns, the short-run analysis relies on mortality rates among infants conceived in the previous year. We include an indicator for missing mortality data to accommodate the first cell in any country-age series. Results do not changed if we drop these cells instead.

cal significance in the prime parenting ages. The inclusion of covariates—the lagged levels of GDP per adult and population, as well as changes in conflict, female education, urbanization, and infant mortality—does not meaningfully alter the coefficients or their significance levels. 25-29 year olds show the largest short-run response to growth fluctuations; their coefficient of 0.56 in the base model implies that a one log point increase in GDP per adult raises the number of conceptions by roughly $\frac{1}{2}$ per 1000 women in the age group. Moving to neighboring age groups, the coefficients decline more than would be proportional to the level of fertility. This finding is consistent with the theoretical framework's prediction that older parents (who are closer to menopause) are less willing to forego births during a recession, although it is only suggestive evidence. Combining all age groups, the TCR increases by 8.8 per 1000 in response to a log point positive growth fluctuation.

Additional robustness checks appear in online Appendix Figure A3, which plots estimates of β^A across age groups for a range of alternative short-run models. One weights cells by their size; another reweights observations within each cell to give more weight to fertility outcomes with shorter recall periods (using a Bartlett kernel); another omits country, year, and age effects; and three others add country-specific linear, quadratic, and cubic time trends. The alternative weighting schemes and trend specifications he weighted model and the trend models deliver results very similar to those reported in Figure 3.[16] However, in the model with no country, year, or age effects, the coefficients at prime parenting ages (20-34)—while still statistically significant—shrink by roughly one-quarter, while the coefficient in the 40-44 age group grows by the same proportion.

That the omission of country, year, and age effects modifies coefficients across the age distribution in different directions is easily reconciled by the analysis of long-run rates of change, where the results are nearly opposite the short-run estimates. As shown in Figure 4, long-run economic growth and long-run fertility change are negatively correlated at prime ages but positively correlated at older ages. A comparison of women around age 30 with women in their early 40s provides the starkest contrast. In the base model, among 25-29 and 30-34 year olds, a 1-point faster average annual rise in log GDP per adult is associated with a 0.43-point *faster* average decline in conception rates: roughly equal and opposite in sign from the short-run coefficients in Figure 3. Among 40-44 year olds, the same increase in long-run growth is associated with a 0.14-point *slower* average decline in conception rates. Because the declines are concentrated in the middle of the reproductive period, these results

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[16] The robustness to downweighting fertility outcomes that occurred long ago suggests that our results are not an artifact of women failing to recall infants who were born alive but died in the neonatal period.

suggest increased spacing, rather than later starting or earlier stopping. In the extended model, the estimates are robust to controlling for the initial levels of GDP per adult and population, as well as the average rates of change in conflict, female education, urbanization, and infant mortality.

On net, the offsetting coefficients at different ages imply a long-run TCR coefficient of -6.1 in the base model, so that overall, faster long-run economic growth is associated with more rapid fertility decline. The average annual rate of change in log GDP per adult has a standard deviation of 1.8, so a one standard deviation increase in long-run growth is associated with fertility declining at a decadal rate of one conception for every nine women. Conditional on the single-year age effects, the R^2 is 0.09 for all age groups pooled and 0.16 for the 25-29 age group, implying that economic growth can account for a meaningful share of fertility change in developing countries over the long run.

Further specification checks are reported in online Appendix Figure A4, which plots age-group-specific coefficients from a range of alternative long-run models. Changing the minimum long-run time horizon from 20 years to 15 or 25 does not change the estimates; nor does reweighting conception rates using a Bartlett kernel. We also obtain similar results when we use the average of observed annual changes instead of the slope of the trend, as well as when we use GDP instead of GDP per adult. This final result confirms that our results are not driven by reverse causality.

In both the short- and long-run analyses, the log-linear specifications may mask theoretically relevant non-linearities. To examine this possibility for the short-run, we discretize the distribution of $100 \times \Delta \ln(GDPpa_{ct})$ into six bins and then run a semi-parametric version of equation (2) that replaces the continuous variable g_{ct} with bin indicators. Figure 5 presents summary estimates for the TCR; age-group-specific estimates appear in online Appendix Figure A5. An asymmetry emerges: conceptions fall sharply in deep recessions but do not rise in rapid expansions. Relative to the base category (0-5 log points), a recession of more than 10 log points decreases the total conception rate by 171 per 1000 women: nearly one-fifth of a child per women.[17] To shed light on the functional form governing the long-run relationship, we estimate local linear regressions of the average annual rate of change in the conception rate on the average annual rate of rate of change in log GDP per adult. Figure 6 reports summary estimates for the TCR; age-group-specific estimates appear in online Appendix Figure A6. The long-run results do not deviate substantially from linearity.[18]

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[17] As shown in the histogram at the bottom of Figure 5, recessions of this magnitude are rare but not unprecedented, with 3% of the sample (1,644 cells) in this category.

[18] The estimated regression functions are negative for all age groups in online Appendix Figure A6, confirming that the long-run results relate primarily to the pace of fertility decline, rather than increase.

Because women may offset past fertility adjustments, we also estimate a distributed-lag version of equation (2). Figure 7 reports summary estimates for the TCR with four lags; age-group-specific estimates appear in online Appendix Figure A7. Some but not all of the short-run response is offset through subsequent adjustments to childbearing. In response to a 1-point growth fluctuation, TCR rises by 11 at first, falls by 8 in the following year, and then fluctuates by smaller amounts. Summing across lag coefficients, the cumulative effect of a fluctuation on TCR shrinks to 3 one year after the fluctuation but settles at a significant 6-8 children per 1000 women thereafter.[19] While Figure 7 identifies interesting dynamics in the fertility response to aggregate fluctuations, two caveats are worthy of note. First, much of the immediate offset reflects the inability of currently or recently pregnant women to conceive. Second, because we study the year-to-year change in the conception rate at a fixed age, rather than the change for a fixed birth cohort, this exercise does not map exactly onto the evolution of fertility over time for a particular woman. The cohort analysis in Section 4 will address both of these issues, shedding light on the lifetime fertility effects of economic fluctuations at particular ages.

3.4 Extensions

This section summarizes a number of extensions that shed additional light on mechanisms underlying our results and their relation to theory. The online Appendix reports all results.

3.4.1 Short Run

Heterogeneity Fertility responses to growth shocks may be heterogeneous with respect to both individual and aggregate characteristics. To shed light on heterogeneity within countries, online Appendix Table A4 studies how four average characteristics of mothers change over the business cycle: age, education, urban residence, and ever-marriage.[20] The average education of mothers falls during recessions, implying that poorer, less-educated women are more responsive to growth fluctuations. Other average characteristics do not vary over the business cycle.[21] The marriage null

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[19] In online Appendix Figure A7, most age groups exhibit a similar lag structure to the TCR. An exception is the 30-34 year old age group, which displays weak offset behavior: a pattern relevant for the cohort results in Section 4.

[20] To minimize changes in sample composition from cells with no births, we run this analysis at the country-year level. We control for changes in the age structure and average characteristics of all women in the country-year cell, so the coefficient on g_{ca} captures how the composition of conceiving mothers varies with growth fluctuations, over and above any association with the composition of women at risk for conceiving.

[21] Table A4 also examines sex ratios, given Trivers and Willard's (1973) hypothesis that male fetuses are more vulnerable to the mother's condition. Growth fluctuations do not affect sex ratios, suggesting little role for fetal death.

result is surprising, given the institution's historical role in fertility limitation (Malthus 1798; Hajnal 1965; Wrigley 1981), so online Appendix Table A5 confirms that conception rates are procyclical both inside and outside marriage, and that neither the rate nor hazard of first marriage varies significantly with growth fluctuations. Across countries, online Appendix Table A6 finds no significant variation in the short-run TCR coefficient by the lagged levels of GDP per adult, contraceptive prevalence, average education, or urbanization, nor with the female labor force share. At the same time, online Appendix Table A7 finds more procyclicality in Africa and Latin America than in Asia.

Comparison with developed countries How do the fertility responses documented here compare with those in developed countries, the focus of the literature on fertility and the business cycle (Sobotka, Skirbekk, and Philipov 2011)? Because data on conception rates by year in developed countries are not readily available, online Appendix Table A8 analyzes birth rates from our WFS/DHS microdata and from the Human Fertility Database (HFD), a compilation of natality data from populations with high-quality vital registration systems. Estimates of equation (2) reveal that developing country fertility is more procyclical in absolute terms but less procyclical in relative terms.[22]

Comparison with standard aggregate data To shed light on the gains from using microdata, online Appendix Table A8 reruns the analysis using total fertility rates from the World Development Indicators (WDI), a popular cross-country dataset. For developed countries, estimates from the WDI are similar, but for developing countries, they are insignificant and close to zero, likely because the WDI's fertility data are overly smooth 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.

3.4.2 Long Run

Additional covariates Although controlling for trends in conflict, female education, urbanization, and infant mortality did not alter results in Figure 4, other relevant covariates were omitted because they were not available for all country-years. For the long-run analysis, however, yearly measurements are less important. Online Appendix Table A9 controls for the average annual rate of change in each

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[22] These regressions relate changes in 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, roughly matching the conception period for the current year's births.

of four covariates that are not available for the whole sample but may shed light on mechanisms: secondary school enrollment, female labor force participation, the sectoral composition of value added, and the extent of democracy. When we control for average rate of change in secondary enrollment (from WDI), the coefficients on average growth rise substantially, and the TCR coefficient shrinks by roughly half.[23] Therefore, trends in contemporaneous secondary school enrollment—which reflects the desirability of schooling, *not* the education of mothers—can partly explain our long-run results. In contrast, we find no evidence that trends in female labor force participation, the sectoral composition of value added, or democratization explain the results.[24]

Heterogeneity Because the long-run analysis is effectively cross-sectional, comparing countries with different long-run growth rates, the small number of countries in our sample limits our ability to explore heterogeneity. One question we can address involves the role of Africa. As online Appendix Figure A8 shows in non-parametric plots, prime-age fertility falls and older-age fertility rises with long-run growth both inside and outside Africa. Still, the full sample results are partly explained by Africa lagging behind the rest of the developing world in both growth and fertility decline.[25]

Comparison with developed countries As a companion to online Appendix Table A8, online Appendix Table A10 compares long-run results for developing and developed countries countries. Here we find a stark difference between the WFS/DHS and the HFD. Faster long-run growth is not associated with greater fertility decline in high-income, low-fertility populations, suggesting that the fertility-reducing substitution effects of long-run growth are stronger during the development process.

Comparison with standard aggregate data Online Appendix Table A10 further compares our long-run results with those from a standard aggregate fertility dataset. Here, we draw on fertility rates from the UN, which are available only in 5-year intervals (compared to the annual data from the WDI) but are disaggregated into 5-year age groups. Unsurprisingly, interpolation and smoothing

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[23] In the WDI, gross enrollment ratios are available from many more countries in our sample than net enrollment ratios, so we use the former. A well-known problem with gross enrollment ratios is that they can by biased by grade repetition, and indeed, more than one-third of the country-years in our dataset have primary school ratios in excess of 100. We therefore rely on secondary school enrollment ratios, which never exceed 100 in our sample.

[24] However, the labor force participation rate is measured noisily due to differing definitions across censuses and surveys, and it is a poor proxy for wages, which are more relevant to theories of fertility change (Galor and Weil 1996). We use the rate for women over 15, as assembled by Olivetti (2014) from ILO databases.

[25] If we include an Africa indicator in equation (3), the coefficients shrink but remain significant for key age groups: from -0.430 [0.113] to -0.227 [0.115] for 25-29 year olds and from 0.136 [0.051] to 0.123 [0.053] for 40-44 year olds.

in the UN data do not bias the long-run results for the total fertility rate. However, consistent with restrictions on age heterogeneity in demographic models, the UN data perform poorly at the oldest ages: the 40-44 coefficient in developing countries has the wrong sign. Here again, standard cross-country data miss an important nuance in the relationship between growth and fertility change.

4 Analysis of Cohort Fertility

If women fully offset short-run responses before the end of childbearing, then the observed procyclicality will not affect lifetime fertility; growth fluctuations will alter the tempo but not the quantum of fertility. Full offset may be more likely for fluctuations early in the lifecycle; younger women may have more time than older women to make up for lost childbearing opportunities. To investigate these issues, this section changes the unit of analysis to the country-cohort cell (women born in the same country and year), relating a cohort's completed fertility to its experience of economic growth over the lifecycle.

4.1 Methods

We follow Currie and Schwandt (2014) by regressing the cohort's completed fertility rate on average economic conditions experienced in each age interval A from $[15, 19)$ to $[40, 44)$, a location (in our case, country) fixed effect λ_c, and a cohort fixed effect δ_j:

$$CFR_{cj} = \sum_{A} \beta^A \overline{g}_{cj}^A + \lambda_c + \delta_j + \varepsilon_{cj} \tag{5}$$

where $\overline{g}_{cj}^A$ is the average annual change in log GDP per adult over age interval A, measured in log points. The β^A coefficients capture how completed fertility responds to within-country, within-cohort differences in economic growth experienced over the lifecycle. The isolation of within-country variation is key; the country fixed effect λ_c absorbs cross-country variation in long-run economic growth, so the β^A coefficients are identified by fluctuations. However, the underlying variation is not the same as that in the short-run period analysis; 5-year growth may reflect deeper business cycle variation with greater liquidity effects.[26] The aggregation increases precision and tractability.

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[26] Along these lines, it would be illuminating to study the sequence of growth over the 5-year interval; alternating positive and negative shocks may have different quantum effects than a series of positive shocks followed by a series of negative shocks. Unfortunately, our dataset is underpowered for an examination of this issue

4.2 Results

Figure 8 graphically displays how a cohort's completed fertility rate relates to its experience of economic growth over the lifecycle; online Appendix Table A11 presents the results numerically. Up to age 30, fluctuations have no relation with lifetime fertility, consistent with full offset of short-run responses. Offset opportunities appear to diminish thereafter, with the results indicating permanent effects of fluctuations in the 30s. Net of the long-run growth rate, a 1 log point increase in the average annual growth rate experienced during 30-34 or 35-39 raises completed fertility by roughly 30-40 children per 1000 women, regardless of whether we count all children ever born or only those that survived until the survey date.[27] Online Appendix Table A11 shows that the estimated coefficients shrink slightly but remain significant if we control for average education and share urban.

Notably, the magnitudes in Figure 8 exceed what the short-run effects would imply if they were permanent. This accumulating effect appears inconsistent with the offset patterns documented in the short-run impulse response function in Figure 7. Research on the US has found similar patterns of short-run effects accumulating over the lifecycle (Currie and Schwandt 2014), although the key margin in that context is childlessness, which does not play an important role here.[28] Three points may help explain this puzzle. First, in the short-run model with lags, 30-34 is the age group with the weakest offset pattern. Second, as discussed in Section 3, the immediate offset in Figure 7 may mechanically reflect a woman's inability to conceive during and soon after pregnancy, rather than any behavioral response. Third, fertility may respond non-linearly to a sustained and deep recession, which may be better reflected in a 5-year average than a single-year growth measure. Beyond these three points, the 95% confidence intervals contain values consistent with each other.

5 Interpretation through the Lens of Unified Growth Theory

Our empirical results demonstrate varied fertility responses to growth at different time horizons and lifecycle stages. How far can the theoretical literature on long-run growth and the demographic transition go in interpreting these findings? That literature's standard overlapping generations model posits parents choosing the quantity (and sometimes quality) of their children in a single period. We

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[27] Because the count of children ever born requires respondents to recall deceased children who were born long ago, recall error may bias it toward the count of surviving children.

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

explore a simple extension of the standard model, especially emphasizing Galor and Weil (2000), to include a lifecycle with a finite childbearing period and liquidity constraints.[29]

The literature on which we build treats fertility entirely as a choice variable; we do the same, even if some of our findings leave room for biological mechanisms. For instance, although two results—the stability of sex ratios over the business cycle and the robustness of our main findings to controlling for infant mortality—suggest that infecundity from malnutrition is not the main cause of procyclical fertility, it may still contribute. The discussion below seeks solely to square our results with existing economic theory, so it ignores biological mechanisms. For tractability, we also follow the literature in assuming continuous rather than binary fertility.

Setup Period utility is separable over parental consumption c_t, the number of children n_t, and their mean human capital h_t:

$$U\left(c_t, n_t, h_t\right) = u_c\left(c_t\right) + u_n\left(n_t\right) + u_h\left(h_t\right) \tag{6}$$

where the sub-utility functions $u_x\left(\cdot\right)$ are increasing, concave, and twice continuously differentiable, with $\lim_{x\downarrow 0} u_x'\left(x\right) = \infty$ and $\lim_{x\uparrow\infty} u_x'\left(x\right) = 0$. Parents live $t = 1, \cdots, T$ periods and maximize expected lifetime utility, discounted by factor β. They start their lives with assets A_0 and then receive stochastic wages w_t (with a period time endowment of 1) and unearned income y_t in subsequent periods.[30] In each period, they allocate assets and potential income to consumption, the quantity and quality costs of children, and savings (at gross return R), but they cannot borrow ($A_t \geq 0$).

Parents set a birth rate $b_t \in [0, 1]$ in each period, starting their lives with no children and accumulating them according to $n_t = n_{t-1} + b_t$ until they each menopause at age $M < T$. During each year of childhood up to age K, a child costs $\tau \in (0, 1)$ units of time and κ units of the consumption good, plus any education spending e_t to produce human capital. Education spending is transformed into human capital by a twice continuously differentiable human capital production function $h\left(e_t; \bar{g}\right)$, which also depends on the long-run growth rate of technology $\bar{g}$. Because we are not primarily interested in the allocation of education within the family, we simplify by assuming that parents plan a single education level e for all of their children in period 0 of the model, before the first

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[29] See also Galor and Weil (2000); Galor and Moav (2002); Hazan and Berdugo (2002); De La Croix and Doepke (2003); Doepke (2004); de La Croix (2013); and Cervellati and Sunde (2015).

[30] Because child costs depend on w_t but not y_t, one can think of these variables as women's and men's wages.

period of the lifecycle. Then from period 1 to period M, parents make a sequence of consumption and birth decisions, followed by a sequence of consumption decisions till death at T.

Optimization In light of the finite horizon, we work backward: characterizing the consumption sequence first, the birth sequence next, and education spending last. As shown in the online Theory Appendix, the first-order conditions to the lifecycle problem lead to a consumption Euler equation:

$$u_c'\left(c_t\right) = \beta R E_t\left[u_c'\left(c_{t+1}\right)\right] + \lambda_t \tag{7}$$

where λ_t is the Lagrange multiplier on the borrowing constraint. When the borrowing constraint does not bind, parents set the current marginal utility of consumption to the discounted expected marginal utility of consumption in the next period. When it does bind, they fall short of consuming enough in the current period to satisfy this condition, with a positive multiplier filling the gap.

Although the Euler equation does not directly involve fertility, the consumption smoothing motive is key to understanding the timing of births over the business cycle. This point becomes apparent upon inspection of a separate first-order condition, which equates the marginal benefit of consumption with the discounted marginal benefits of childbearing:

$$u_c'\left(c_t\right) = \frac{u_n'\left(n_{t-1}+b_t\right) + E_t\left[\sum_{s=t+1}^{T}\beta^{s-t}u_n'\left(n_s\right)\frac{\partial n_s}{\partial b_t} - \sum_{s=t+1}^{t+K}\beta^{s-t}\nu_s\left(\tau w_s+\kappa+e\right)\right] + \mu_t^0 - \mu_t^1}{\tau w_t+\kappa+e} \tag{8}$$

where μ_t^0 and μ_t^1 are the multipliers on the constraints that $0 \leq b_t \leq 1$, while ν_t is the multiplier on the period t budget constraint. The numerator reflects the current marginal benefit and future marginal benefits (net of marginal costs) of childbearing; the denominator reflects the current marginal cost.

Assuming an interior solution, the education spending plan satisfies the first order condition:

$$u_h'\left(h\left(e;g\right)\right)h_e\left(e;g\right)\left(\tfrac{1-\beta^T}{1-\beta}\right) = E_0\left[\sum_{t=1}^{M+K}\sum_{k=0}^{K}\beta^{t-1}\nu_t b_{t-k}\right] \tag{9}$$

The left-hand side reflects the discounted lifetime marginal utility of children's mean human capital. The right-hand side reflects the discounted lifetime marginal cost of the education plan (the number of children in the household) multiplied by the marginal utility of income (the Lagrange multiplier on the period budget constraint).

Mapping to the Data This simple theoretical framework captures the short- and long-run dynamics we document in the data. For the short run, equations (7)-(8) provide insight into the effects of transitory wage and income fluctuations. Because the right-hand side of equation (8) is divided by the marginal cost of childbearing—which includes w_t—a transitory wage cut incentivizes the shifting of births from the future to the present. If T is large relative to M, then serially independent fluctuations in w_t before menopause have minimal effects on expected lifetime income, so this intertemporal substitution effect is likely to dominate any income effect when the borrowing constraint does not bind. In this case, fluctuations in y_t are also unlikely to affect the birth rate. When the constraint binds, however, a transitory depression in wages or incomes decreases current consumption by equation (7), which then also incentivizes reduced childbearing by equation (8).[31] Thus, at least with serially independent shocks, a borrowing constraint is key to generating procyclical fertility.[32] The role of liquidity is consistent with the non-linearity and heterogeneity we find in the data: borrowing constraints may bind more during deep recessions, and the less-skilled may be especially likely to hit zero assets.

The durability of children adds several nuances in equation (8). The lagged number of children appears inside $u_n'(\cdot)$, placing a ceiling on the marginal utility of children for all $t > 1$. No such ceiling exists for the marginal utility of consumption, implying that births decline to zero more rapidly than consumption when parents are borrowing constrained. Also because the lagged number of children appears inside $u_n'(\cdot)$, parents may offset past adjustments in childbearing. For example, if a negative shock forced borrowing-constrained parents to forego births in period $t-1$, then the marginal gains from childbearing are high in period t. This offset is consistent with our distributed-lag estimates as well as our cohort estimates for fluctuations early in the reproductive period. Offset becomes impossible after menopause, so fluctuations toward the end of the reproductive period are more likely to have permanent effects on the number of children, as we also observe in our cohort estimates. When offset is incomplete ($\frac{\partial n_s}{\partial b_t} > 0$ for $s > t$), the benefit of current childbearing includes the marginal utility of children in the future. As a result, parents approaching menopause may tolerate greater declines in consumption to finance childbearing, a prediction consistent with the

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[31] Existing research on fertility over the business cycle has also noted offsetting liquidity and intertemporal substitution effects, albeit generally without fully specifying a model (e.g., Ward and Butz 1980; Adsera and Menendez 2011).

[32] Aguiar and Gopinath (2007) find that developing economies are characterized by permanant, not transitory, growth shocks, which would lead to a mix of short- and long-run mechanisms in the response to shocks. But Figure 5 shows that deep recessions to be key to the procyclicality of births; these recessions are autocorrelated only to the second lag.

decline in the magnitude of procyclicality after age 30.

The insights about fluctuations from equations (7)-(8) do not carry to long-run productivity growth. We are agnostic about how long-run growth affects the parents' budget constraint, but as a starting point, it is useful to assume that $\bar{g}$ reflects the expected growth rate *across generations*, as in long-run growth models, and does not affect wages or incomes in the parents' lifetimes. Galor and Weil (2000) assume that education increases human capital at a decreasing rate ($h_e > 0$, $h_{ee} < 0$) while long-run growth depletes human capital but makes education more productive ($h_{\bar{g}} < 0$, $h_{e\bar{g}} > 0$). In this case, higher $\bar{g}$ raises the left-hand side of equation (8), which leads parents to raise e. The increase in e pushes up the denominator in equation (8), so the optimal number of children declines. Among liquidity-constrained parents, rising e may also delay or increase spacing between births to allow accumulation of assets to pay child costs, so both the decline and the delay we observe in the data are consistent with the theory. That controlling for school enrollment makes the long-run coefficients less negative (see online Appendix Table A9) reinforces the hypothesized role of returns to child investment.

If $\bar{g}$ affects parents' budget constraint, then these predictions become less sharp, with the effect of long-run growth on fertility additionally depending on the balance of income effects from higher w_t and y_t and substitution effects from higher w_t. Many economic theories of the demographic transition emphasize the link between long-run growth and rising women's wages (Schultz 1985; Galor and Weil 1996), which in our framework can be seen as a shift from y_t to w_t in the composition of household income. By equation (8), such a shift incentivizes fertility reduction. But we find suggestive evidence that women's work is not a primary driver of our long-run results. Rising female labor force participation does not explain our long-run coefficients, although rising participation is not the same as the wage (i.e., the opportunity cost of children), which is unavailable for most of our sample. Goldin (1995) points out that female labor force participation is high early in the development process, but wages are low and work is compatible with childcare: for example, work on the family farm close to home. A rising opportunity cost of children may be better reflected in the size of the service sector, which employs women outside the home at higher wages. But the share of services in the economy also fails to explain our long-run coefficients.[33]

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[33] However, sectoral composition is not a perfect proxy for the the ease of combining work and family. The latter may improve within the service sector as an economy grows, for example because of more generous parental leave policies, more childcare availability, or changing social norms.

One complication for the child investment theory is that it relates long-run economic growth to the the *level* of fertility, while our analyses examine *changes* in fertility. But if parents adapt to the new economic environment slowly, then long-run growth will be associated with gradual fertility decline. In this sense, our long-run results may reflect how sustained growth leads parents to gradually update their expectations regarding the return to human capital investment. Expectations are also key to understanding our short-run results; couples avoid conception during recessions presumably due to concerns about liquidity after birth, not at the time of conception.

The discussion has so far ignored the factors that generate Malthusian fertility dynamics in models of long-run growth. Galor and Weil (2000) include a subsistence consumption constraint and also assume $h\left(0;\bar{g}\right)>0$, admitting an optimum with $e=0$. Both assumptions lead to corner solutions that are useful for understanding regimes in which fertility and population rise with productivity growth in the long run (Lee 1997; Ashraf and Galor 2011). Our long-run results do not fit this characterization, so we have focused on a regime in which subsistence and education spending constraints do not bind: the era of demographic transition and sustained economic growth.

6 Conclusion

Over the last half-century, the developing world saw rising living standards and falling fertility, but empirical evidence on the link between the two is surprisingly sparse. Combining hundreds of survey datasets, this paper sheds new light on growth-fertility relationships, with careful attention to time horizons and lifecycle dynamics. Three main empirical results emerge. First, fertility is procyclical in the short run, falling during recessions. Second, fertility declines and delays with long-run economic growth. Third, across birth cohorts within a country, higher economic growth late in the reproductive period predicts higher completed fertility. These results are broadly consistent with an extension of long-run growth models with endogenous fertility to include a lifecycle with liquidity constraints.

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 (Lee 1997; Sobotka, Skirbekk, and Philipov 2011). Distributed lag models and cohort analyses suggest that economic fluctuations affect both the tempo (timing) and quantum (lifetime cumulation) of fertility. The weight of the evidence suggests a role for liquidity constraints, but beyond this implication, the mechanism behind procyclicality 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. Because we only measure conceptions that resulted in live birth, abortion may play a role. But mechanisms beyond conscious choice may also be at work. Stress may decrease coital frequency among cohabiting couples, and migration for labor market opportunities may temporarily split couples (Timaeus and Graham 1989). Crisis-related malnutrition may also reduce fecundity or *in utero* survival (Bongaarts 1980), although we fail to find evidence of this mechanism in our tests.

The short-run patterns stand in stark contrast to the relationship between long-run trends in income and fertility, which is negative on average but heterogeneous across age groups. The main takeaway is that some force that accompanies long-run economic growth leads to faster declines in childbearing, as reflected in the negative long-run coefficient for the total conception rate, and also to increased birth spacing, as reflected in the positive long-run coefficient for 40-44 years olds. This force is related to rising secondary school enrollment, but *not* declining child mortality, rising adult female education or labor force participation, structural transformation, or democratization. Theories positing that long-run economic growth raises the return to child investment (Galor and Weil 2000) may therefore go a long way in explaining the long-run results.

As for Malthus (1798), his theory performs poorly for the episode we study. Fertility declined with sustained productivity growth, reinforcing a rise in living standards and therefore contradicting the core of his argument. The procyclicality of fertility might appear more supportive, but Malthus never considered liquidity, which is likely a key force behind it. He was perhaps more prescient in viewing fertility control as a practice of “civilized nations” (see Chapter 4), which one could charitably (though not exclusively) interpret as positing that it becomes more prevalent with economic development.

While our results help clarify the relationship between aggregate income growth and fertility change in developing countries, 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 leave open the question of whether and how fertility affects growth, which has long concerned researchers and policymakers (Coale and Hoover 1958); recent findings suggest such effects are real but modest in size (Ashraf, Weil, and Wilde 2013; Miller and Babiarz 2016).[34] Methodologically,

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[34] The effect of fertility on economic growth is beyond the scope of this paper, so we ruled out first-order effects by

they highlight the importance of careful measurement, showing how one can use large amounts of retrospective survey data to improve on standard cross-country datasets.

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studying growth in GDP per adult rather than GDP per capita. We also obtained similar results when we studied growth in GDP, without dividing by population.

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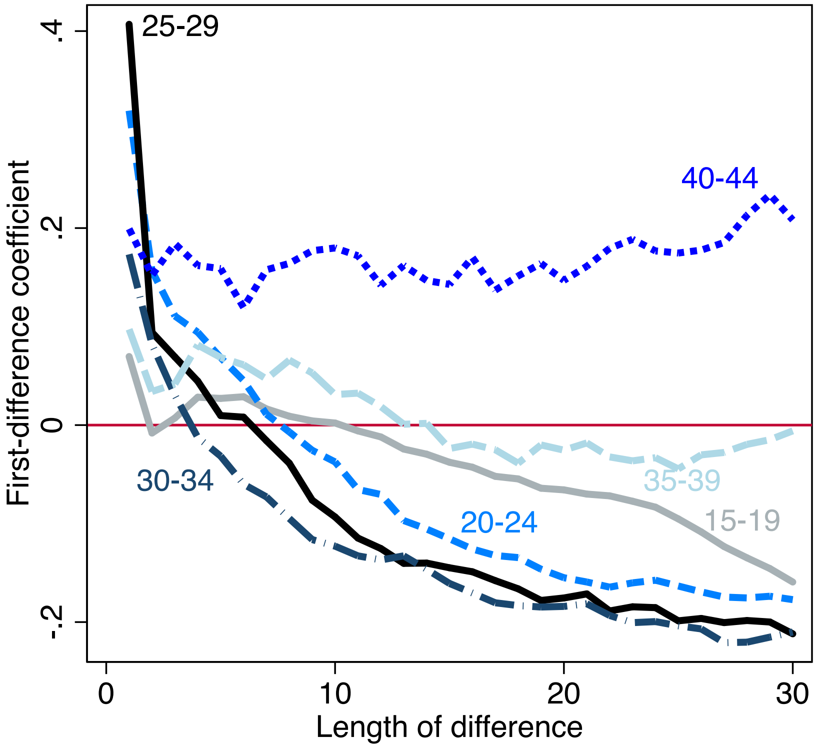
Table 2: Summary Statistics

	Period analysis		Cohort analysis
	Full sample	20-year sample	
	(1)	(2)	(3)
Fertility rates (per 1000)			
Age-specific conception rate	191 (95)	199 (91)	
Completed fertility rate, ever-born			5951 (1284)
Completed fertility rate, surviving			4862 (870)
Macroeconomic conditions			
Country GDPpa, PPP	4711 (4218)	4476 (4087)	4229 (3292)
Change in log GDPpa, log pts.	1.0 (6.1)	1.0 (5.8)	0.7 (1.6)
Cell characteristics			
Average years of education	4.6 (5.7)	4.0 (2.9)	3.6 (2.4)
Percent urban at survey	40 (21)	38 (22)	37 (22)
Number of women	2,374,019	2,279,955	242,886
Number of cells	67,050	58,992	935
Number of countries	76	65	62

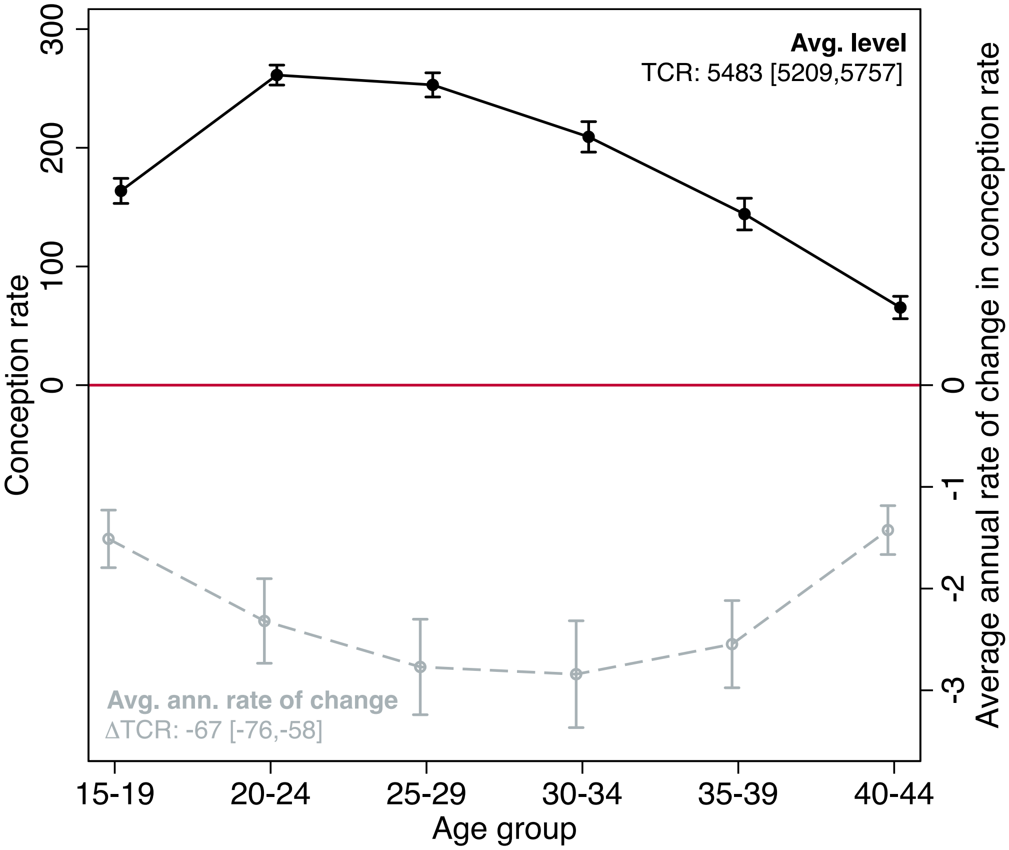
Notes: Period sample consists of country-year-age cells; cohort sample consists of country-cohort cells. Ages and cohorts are categorized in single years. "Conception rate" only includes conceptions that resulted in live birth. "GDPpa" is gross domestic product per adult age 15-64. For the cohort sample, macroeconomic conditions are first averaged over each cohort's reproductive lifecycle and then summarized across cohorts.

Figure 1: Economic Growth and Fertility Change over Varying Time Horizons



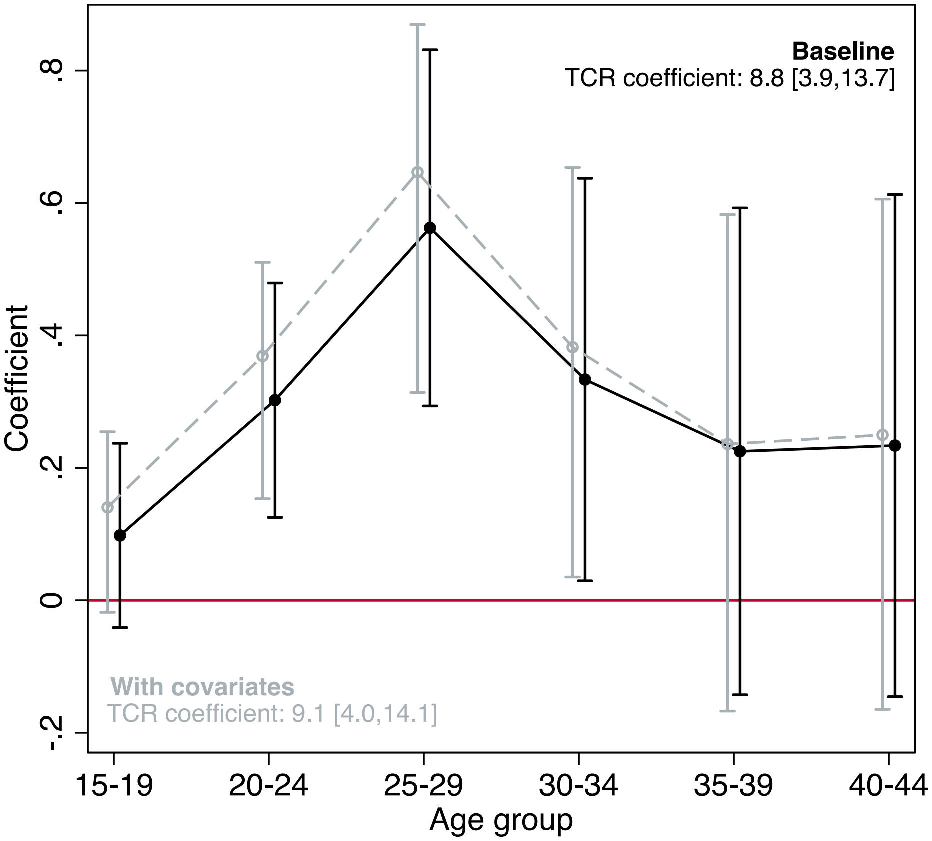
Notes: For each 5-year age group, the figure plots coefficients from regressions of the change in the conception rate from year t − Δ to year t on the change in 100 × log GDP per adult over the same period, controlling for single-year age indicators. Separate regressions were run for each integer value of Δ from 1 to 30.

Figure 2: Age-Specific Conception Rate Levels and Changes



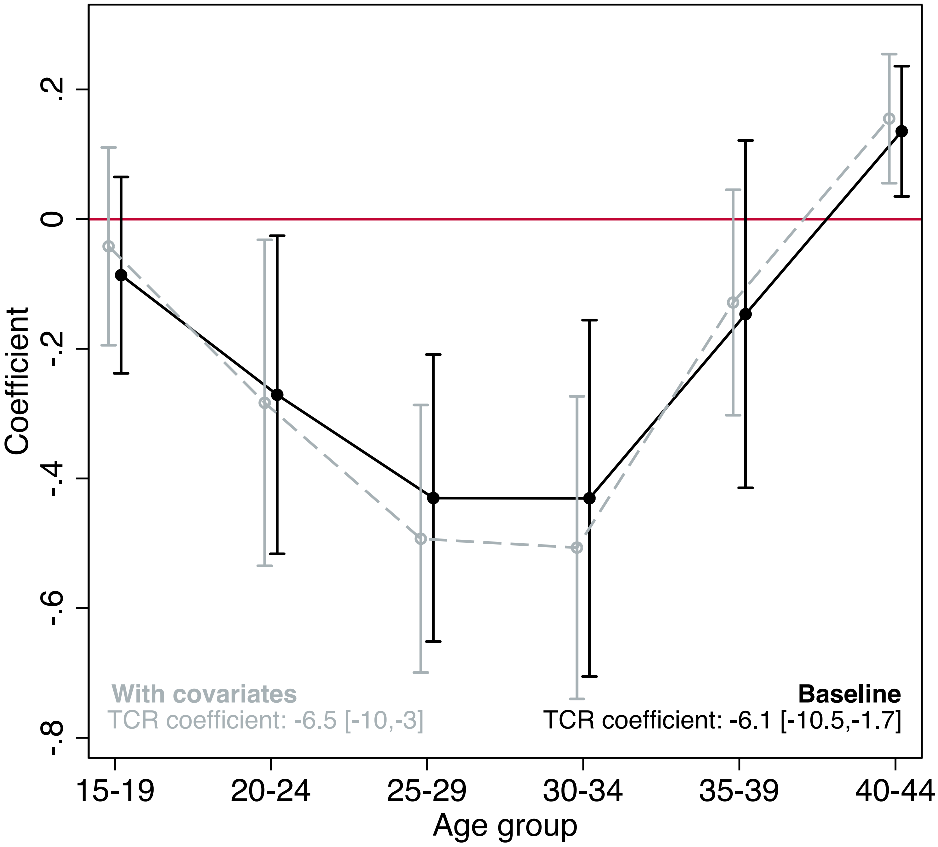
Notes: Means and 95% confidence intervals for the level of the age-specific conception rate (across 58,992 country-year-age cells) and its annual rate of change (across 1,595 country-age cells). "TCR" refers to the total conception rate per 1000; estimates equal 5 times the sum of age-group-specific estimates. Confidence intervals reflect standard errors clustered by country.

Figure 3: Short-Run Estimates



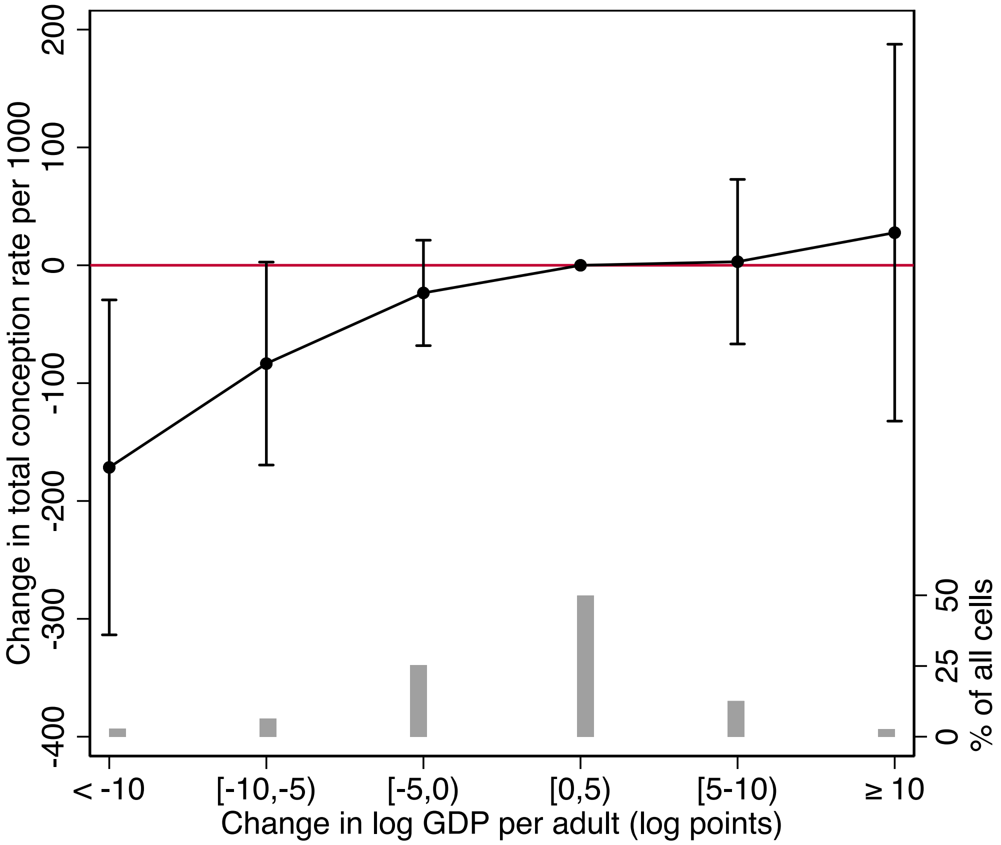
Notes: Coefficients and 95% confidence intervals from regressions of annual changes in the age-specific conception rate on annual changes in 100 × log GDP per adult, controlling for country, year, and single-year age indicators. In the gray plot, the model also controls for the lagged levels of GDP per adult (PPP) and population density; changes in conflict, female education, urbanization, and infant mortality; and an indicator for missing mortality information (less than 3% of all cells). "TCR" refers to the total conception rate per 1000; estimates equal 5 times the sum of age-group-specific estimates. Confidence intervals reflect standard errors clustered by country.

Figure 4: Long-Run Estimates



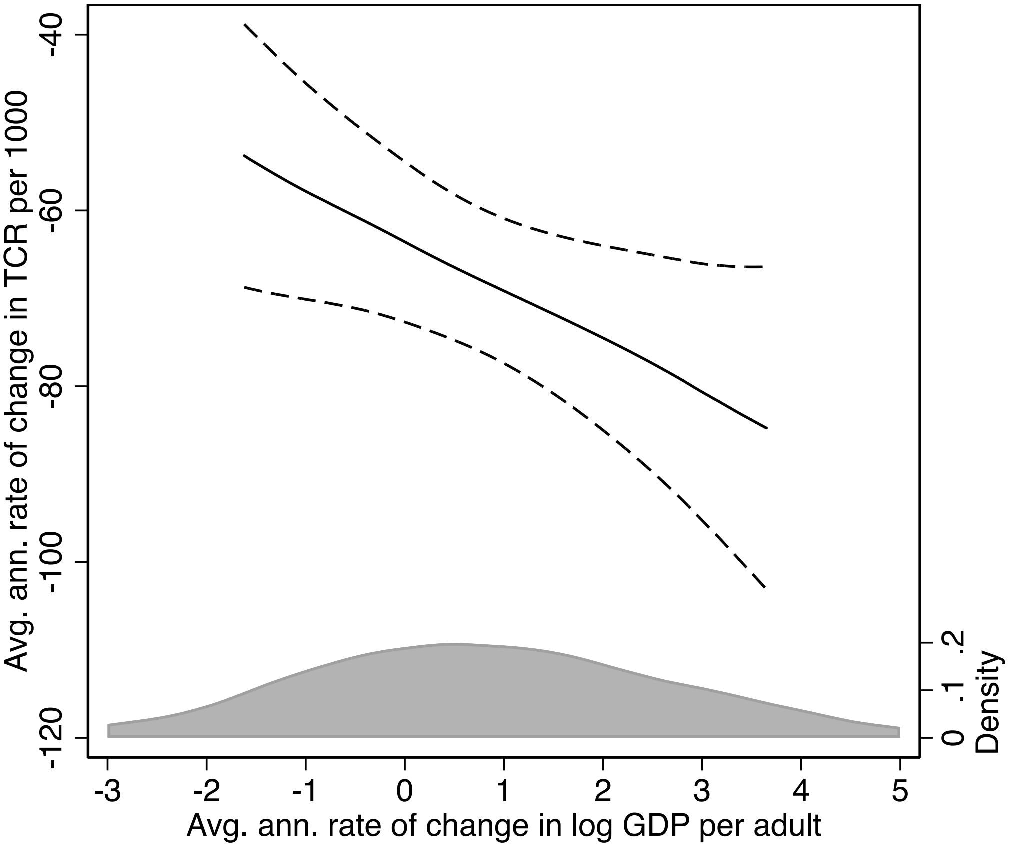
Notes: Coefficients and 95% confidence intervals from regressions of the average annual rate of change in the age-specific conception rate on average annual rate of change in 100 × log GDP per adult, controlling for single-year age indicators. In the gray plot, the model also controls for the lagged levels of GDP per adult (PPP) and population density, as well as annual rates of change in conflict, female education, urbanization, and infant mortality. "TCR" refers to the total conception rate per 1000; estimates equal 5 times the sum of age-group-specific estimates. Confidence intervals reflect standard errors clustered by country.

Figure 5: Non-Linear Short-Run Estimates



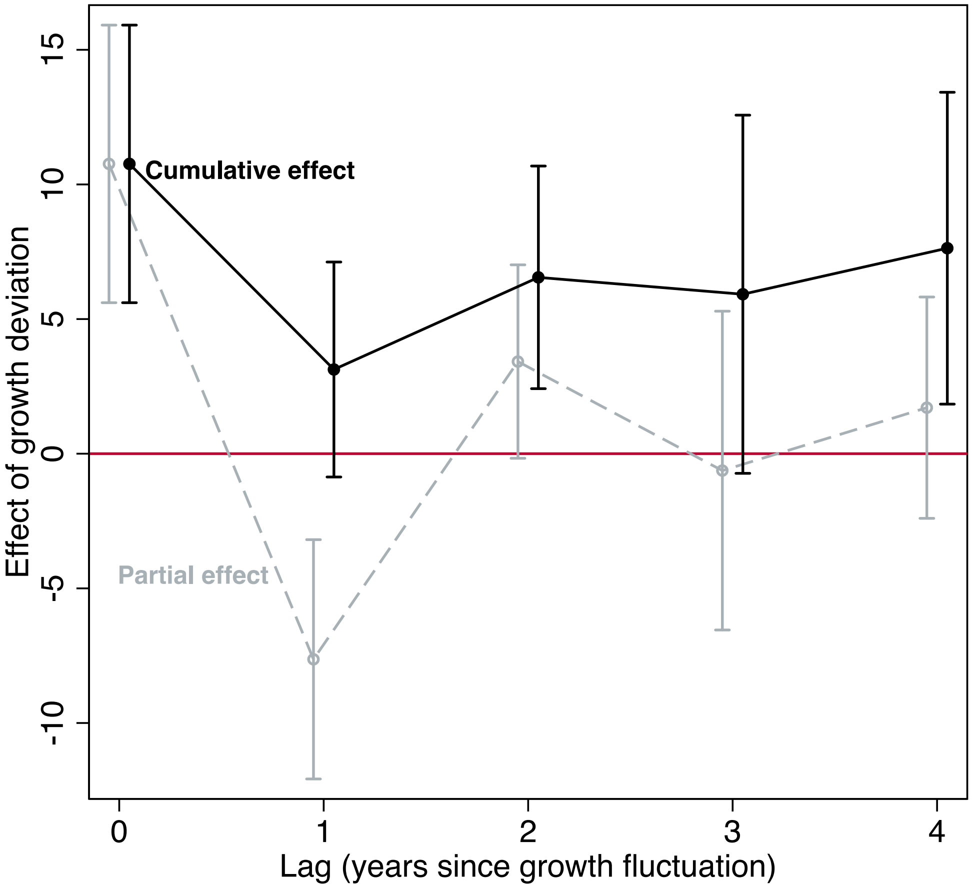
Notes: Total conception rate estimates and 95% confidence intervals based on age-group-specific regressions of annual changes in the age-specific conception rate on binned annual economic growth, controlling for country, year, and age fixed effects. Each estimate reflects the sum of the age-group-specific estimates, multiplied by 5. Omitted category is [0,5). Confidence intervals reflect standard errors clustered by country. For reference, a histogram of the binned growth variable appears at the bottom.

Figure 6: Non-Linear Long-Run Estimates



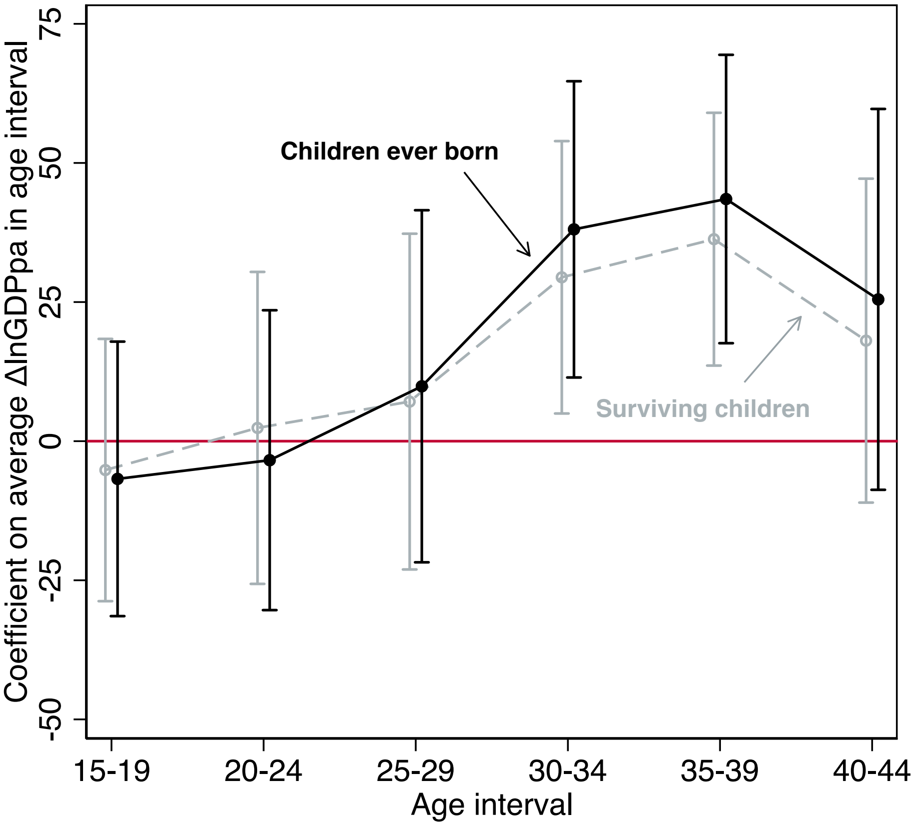
Notes: Total conception rate estimates and 95% confidence intervals based on age-group-specific local linear regressions, bandwidth = 2. The domain of each local linear regression runs from the age group's 5th to 95th percentile of the average annual rate of change in log GDP per adult. The regression function plotted is obtained by summing the age-group-specific estimates (for the domain in which they overlap) and multiplying by 5. Confidence intervals are based on standard errors block-bootstrapped by country. For reference, a kernel estimate (bandwidth = 1) of the density of long-run growth appears at the bottom.

Figure 7: Distributed Lag Model



Notes: Total conception rate estimates and 95% confidence intervals based on an age-group-specific distributed lag model of annual changes in the age-specific conception rate on current and lagged annual changes in 100 × log GDP per adult, controlling for country, year, and age fixed effects. Confidence intervals based on standard errors clustered at the country level. Sample includes observations that have both lagged conception rates and lagged growth rates.

Figure 8: Economic Growth over the Lifecycle and Completed Fertility



Notes: Coefficients and 95% confidence intervals from regressions of the number of children ever born (black) or the number of surviving children (grey) per 1000 women on average annual growth conditions during each age interval, controlling for country and cohort indicators. Cohorts were over age 45 when surveyed.

Online Appendix (Not For Publication)

Theory Appendix

In the theoretical framework of Section 5, each household first chooses e to maximize:

$$U = E_0 \sum_{t=1}^{T} \beta^{t-1} \left\{ u_c\left(c_t\right) + u_n\left(n_t\right) + u_h\left(h_t\right) \right\}$$

and then chooses $\{c_t, b_t, A_{t+1}\}_{t=1}^{T}$ to maximize:

$$U = \sum_{t=1}^{T} E_t \beta^{t-1} \left\{ u_c\left(c_t\right) + u_n\left(n_t\right) + u_h\left(h_t\right) \right\}$$

subject to:

$$\begin{aligned}
n_t &= n_{t-1} + b_t \\
n_0 &= 0 \\
b_t &\in [0,1] \\
c_t &= w_t \left(1 - \tau \sum_{k=0}^{K} b_{t-k}\right) - \kappa \sum_{k=0}^{K} b_{t-k} - e \sum_{k=0}^{K} b_{t-k} + \left(\left(1+r\right) A_t - A_{t+1}\right) \\
h_t &= \mathbf{1}[n_t > 0] h\left(e\right) \\
A_0 & \quad \text{given} \\
A_{T+1} &= 0 \\
A_{t+1} &\geq 0
\end{aligned}$$

The current value formulation of the Lagrangian is:

$$\mathcal{L} \equiv \sum_{t=1}^{T} \beta^{t-1} E_t \left\{ \begin{array}{l} u_c\left(c_t\right) + u_n\left(n_t\right) + u_h\left(h_t\right) + \lambda_t A_{t+1} + \left(\mu_t^0 - \mu_t^1\right) b_t + \\ \nu_t \left[w_t \left(1 - \tau \sum_{k=0}^{K} b_{t-k}\right) - \kappa \sum_{k=0}^{K} b_{t-k} - e \sum_{k=0}^{K} b_{t-k} + \left(\left(1+r\right) A_t - A_{t+1}\right) - c_t \right] \end{array} \right\}$$

where ν_t is the Lagrange multiplier on the period budget constraint, λ_t is the Lagrange multiplier on the borrowing constraint, and μ_t^0 and μ_t^1 are the Lagrange multipliers on births being between 0 and 1, respectively.

The first order conditions for consumption (in periods 1 to T) and births (in periods 1 to M) are:

$$u_c'(c_t) = \nu_t$$

$$-\nu_t + \lambda_t + \beta\left[(1+r)\,E_t\nu_{t+1}\right] = 0$$

$$\sum_{s=t}^{T}\beta^{s-t}E_t u_n'(n_s)\frac{\partial n_s}{\partial b_t} - \sum_{s=t}^{t+K}\beta^{s-t}E_t\nu_s\left\{\tau w_s + \kappa + e\right\} + \mu_t^0 - \mu_t^1 = 0$$

which imply equation (7):

$$u_c'(c_t, n_t, h) = \beta(1+r)\,E_t\left[u_c'(c_{t+1}, n_{t+1}, h)\right] + \lambda_t$$

and equation (8):

$$u_c'(c_t) \quad = \quad \frac{u_n'(n_{t-1}+b_t) + \sum_{s=t+1}^{T}\beta^{s-t}E_t\left\{u_n'(n_s)\frac{\partial n_s}{\partial b_t} - \mathbf{1}_{\{s-t\le K\}}\nu_s(\tau w_s + \kappa + e)\right\} + \mu_t^0 - \mu_t^1}{\tau w_t + \kappa + e}$$

The first order condition for education (in period 0) is:

$$\sum_{t=1}^{T}\beta^{t-1}E_0\left\{u_h'(h(e;g))\,h_e(e;g)\right\} \quad = \quad E_0\left\{\sum_{t=1}^{M+K}\sum_{k=0}^{K}\beta^{t-1}\nu_t b_{t-k}\right\}$$

The left-hand side has no uncertainty, so we can remove the expectations sign and, noting that $\sum_{t=1}^{T}\beta^{t-1} = \sum_{t=0}^{T-1}\beta^t = \frac{1-\beta^T}{1-\beta}$, rewrite as equation (9):

$$u_h'(h(e;g))\,h_e(e;g)\left(\frac{1-\beta^T}{1-\beta}\right) \quad = \quad E_0\left\{\sum_{t=1}^{M+K}\sum_{k=0}^{K}\beta^{t-1}\nu_t b_{t-k}\right\}$$

Data Appendix

Table A1: Number of WFS/DHS Surveys per Country

Albania	1	Ghana	7	Pakistan	4
Armenia	3	Guatemala	2	Panama	1
Azerbaijan	1	Guinea	3	Paraguay	2
Bangladesh	8	Honduras	2	Peru	9
Benin	5	India	3	Philippines	5
Bolivia	5	Indonesia	8	Rwanda	5
Brazil	2	Jamaica	1	Sao Tome and Principe	1
Burkina Faso	4	Jordan	5	Senegal	8
Burundi	2	Kazakhstan	2	Sierra Leone	1
Cambodia	4	Kenya	7	South Africa	1
Cameroon	5	Korea, Rep.	1	Sri Lanka	1
Central African Republic	1	Kyrgyz Republic	2	Swaziland	1
Chad	2	Lesotho	4	Syria	1
Colombia	7	Liberia	3	Tajikistan	1
Comoros	2	Madagascar	4	Tanzania	5
Congo, Dem. Rep.	2	Malawi	4	Thailand	1
Congo, Rep.	2	Maldives	1	Togo	3
Costa Rica	1	Mali	3	Trinidad and Tobago	2
Cote d'Ivoire	4	Mauritania	1	Tunisia	2
Dominican Republic	8	Mexico	2	Turkey	4
Ecuador	2	Moldova	1	Uganda	5
Egypt	8	Morocco	4	Ukraine	1
El Salvador	1	Mozambique	3	Uzbekistan	1
Ethiopia	3	Namibia	4	Venezuela	1
Fiji	1	Nepal	5	Vietnam	1
Gabon	2	Niger	4	Zambia	5
Gambia	1	Nigeria	5	Zimbabwe	5

Table A2: Country Composition of the Analysis Samples

Country	Period		Cohort	Country	Period		Cohort
	Full sample	Analysis sample			Full sample	Analysis sample	
Albania	✓	✓	✓	Madagascar	✓	✓	✓
Armenia	✓			Malawi	✓	✓	✓
Azerbaijan	✓			Maldives	✓		✓
Bangladesh	✓	✓	✓	Mali	✓	✓	✓
Benin	✓	✓	✓	Mauritania	✓		
Bolivia	✓	✓	✓	Mexico	✓	✓	✓
Brazil	✓	✓	✓	Moldova	✓		
Burkina Faso	✓	✓	✓	Morocco	✓	✓	✓
Burundi	✓	✓	✓	Mozambique	✓	✓	✓
Cambodia	✓	✓	✓	Namibia	✓	✓	✓
Cameroon	✓	✓	✓	Nepal	✓	✓	✓
Central African Rep..	✓	✓	✓	Niger	✓	✓	✓
Chad	✓	✓	✓	Nigeria	✓	✓	✓
Colombia	✓	✓	✓	Pakistan	✓	✓	✓
Comoros	✓	✓	✓	Panama	✓	✓	
Congo, Dem. Rep.	✓	✓	✓	Paraguay	✓	✓	✓
Congo, Rep.	✓	✓	✓	Peru	✓	✓	✓
Costa Rica	✓	✓		Philippines	✓	✓	✓
Cote d'Ivoire	✓	✓		Rwanda	✓	✓	✓
Dominican Republic	✓	✓	✓	Sao Tome and Principe	✓	✓	✓
Ecuador	✓	✓	✓	Senegal	✓	✓	✓
Egypt	✓	✓	✓	Sierra Leone	✓	✓	✓
El Salvador			✓	South Africa	✓	✓	✓
Ethiopia	✓	✓	✓	Sri Lanka			✓
Fiji	✓			Swaziland	✓	✓	✓
Gabon	✓	✓	✓	Syria	✓		
Gambia	✓	✓		Tajikistan	✓	✓	
Ghana	✓	✓	✓	Tanzania	✓	✓	✓
Guatemala	✓	✓	✓	Thailand			✓
Guinea	✓	✓	✓	Togo	✓	✓	✓
Honduras	✓	✓	✓	Trinidad and Tobago	✓	✓	✓
India	✓	✓	✓	Tunisia	✓	✓	
Indonesia	✓	✓	✓	Turkey	✓	✓	✓
Jamaica	✓	✓		Uganda	✓	✓	✓
Jordan			✓	Ukraine	✓		
Kazakhstan	✓			Uzbekistan	✓		
Kenya	✓	✓	✓	Venezuela	✓	✓	
Korea, Rep.	✓			Vietnam			✓
Kyrgyz Republic	✓	✓		Zambia	✓	✓	✓
Lesotho	✓	✓	✓	Zimbabwe	✓	✓	✓
Liberia	✓	✓	✓				

Table A3: Economic Growth and Conception Rates in the Short- and Long-Run

	Mean of conception rate per 1000 in...		Short run regressions		Long run regressions	
	Levels (1)	Changes (2)	Basic (3)	Extended (4)	Basic (5)	Extended (6)
Ages 15-19	164	-1.5	0.10	0.12	-0.09	-0.03
			[0.07]	[0.07]	[0.09]	[0.08]
Ages 20-24	261	-2.3	0.30	0.33	-0.27	-0.25
			[0.09]	[0.09]	[0.13]	[0.13]
Ages 25-29	253	-2.8	0.56	0.59	-0.43	-0.46
			[0.14]	[0.14]	[0.11]	[0.11]
Ages 30-34	209	-2.8	0.33	0.34	-0.43	-0.48
			[0.16]	[0.16]	[0.14]	[0.12]
Ages 35-39	144	-2.5	0.22	0.21	-0.15	-0.11
			[0.19]	[0.19]	[0.14]	[0.09]
Ages 40-44	65	-1.4	0.23	0.22	0.14	0.16
			[0.19]	[0.20]	[0.05]	[0.05]
TCR	5483	-67	8.77	9.07	-6.15	-5.82
			[2.50]	[2.59]	[2.23]	[1.81]
# cells	58,992	1,595	56,926	56,926	1,595	1,595

Notes: Point estimates and standard errors associated with Figures 2-4. Columns (3)-(4) regress the annual change in the age-specific conception rate on the annual change in 100 × log GDP per adult, controlling for country, year, and single-year age effects; columns (5)-(6) regress the average annual rate of change in the age-specific conception rate on average annual rate of economic growth, controlling for single-year age effects. "Extended" models also control for the initial level of GDP per adult (PPP) and population density; and the change or trend in female education, urbanization, infant mortality, and conflict. Column (4) also an indicator for missing mortality information (3% of all cells). "Conception rate" only includes conceptions that resulted in live birth; "TCR" refers to the total conception rate per 1000; estimates equal 5 times the sum of age-group-specific estimates. Brackets contain standard errors clustered by country.

Table A4: Cyclicality in the Composition of Births

		Average characteristics of...				
		Mothers				Children
	Concep. rate	Age	Education	% urban	% ever mar.	% male
	(1)	(2)	(3)	(4)	(5)	(6)
Δ log GDPpa	0.24	-0.0001	-0.0022	-0.013	-0.009	0.012
× 100	[0.07]	[0.001]	[0.0009]	[0.013]	[0.014]	[0.016]
Outcome mean	201	23	3.5	35	92	51
Outcome SD	(52)	(3)	(2.5)	(19)	(10)	(3)
# cells	2,831	2,831	2,831	2,831	2,831	2,831

Notes: Regressions of annual changes in average characteristics on annual changes in 100 × log GDP per adult, controlling for country and year fixed effects, as well as changes in age composition, average years of education, percent urban, and percent married among all women in each cell. "Conception rate" only includes conceptions that resulted in live birth. Brackets contain standard errors clustered by country.

Table A5: Can Marriage Explain the Procyclicality of Conceptions?

	Conception rate			Marriage	
	Overall	Pre-marital	Post-marital	Rate	Hazard
	(1)	(2)	(3)	(4)	(5)
Δ log GDPpa	0.23	0.14	0.33	-0.05	-0.13
× 100	[0.07]	[0.09]	[0.16]	[0.06]	(0.12)
Outcome level mean	201	97	270	52	195
Outcome level SD	(52)	(36)	(78)	(23)	(73)
Number of cells	2831	2830	2831	2831	2830

Notes: Regressions of the changes in outcomes on annual changes in 100 × log GDP per adult, controlling for country and year fixed effects, as well as changes in the age composition of each cell. All rates are per 1000. Columns (2) and (5) have smaller sample sizes because 1 cell has no never-married women. Brackets contain standard errors clustered by country.

Table A6: Aggregate Heterogeneity in the Procyclicality of Conceptions

	Lagged GDPpa, PPP (1)	Lagged contraceptive prevalence (2)	Female labor force share in 1990 (3)	Lagged average years of education (4)	Lagged share urban at survey (5)
Coefficient below	8.46	8.58	9.95	8.83	8.80
variable's median	[3.19]	[3.32]	[3.62]	[3.42]	[3.37]
Coefficient above	9.68	10.22	8.33	9.24	7.86
variable's median	[2.65]	[3.24]	[3.15]	[1.94]	[1.78]
p-value for difference	0.741	0.725	0.725	0.911	0.779
Number of cells	56,926	48,092	56,926	56,926	56,926

Notes: Total conception rate coefficients based on regressions of annual changes in the age-specific conception rate on annual changes in 100 × log GDP per adult, controlling for country, year, and age fixed effects. Coefficients are estimated by 5-year age group and then summed and multiplied by 5 to obtain TCR coefficient. Brackets contain standard errors clustered by country. Sample sizes vary because data on some of the aggregate variables 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 from WFS/DHS survey data.

Table A7: Regional Heterogeneity in Procyclicality

		p-values: coefficients equal within pair		
		Africa	C/W Asia	S/SE Asia
	(1)	(2)	(3)	(4)
Africa	9.43			
	[2.96]			
Central/Western Asia	4.53	0.01		
	[2.96]			
South/Southeast Asia	-2.46	0.18	0.44	
	[8.43]			
Latin America/Caribbean	10.81	0.69	0.09	0.12
	[2.33]			
p-value: all coefficients equal	0.15			
Number of cells	56,926			

Notes: Total conception rate coefficients based on full-sample regressions of annual changes in the age-specific conception rate on annual changes in 100 × log GDP per adult interacted with region indicators, controlling for country, year, and age fixed effects. 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. We do not interact the year and age effects with region indicators to conserve statistical power. 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.

Table A8: Comparison of Procyclicality Results with Other Datasets

	Country-years in the WFS/DHS Mean 2005 GDPpa, PPP = 5,239 Mean GDPpa growth = 0.91			Country-years in the HFD Mean 2005 GDPpa, PPP = 46,993 Mean GDPpa growth = 2.41		
	WFS/DHS		WDI	HFD		WDI
	Mean rate (1)	Regression (2)	Regression (3)	Mean rate (4)	Regression (5)	Regression (6)
Ages 15-19	138	0.163		28	0.173	
		[0.078]			[0.062]	
Ages 20-24	258	0.145		103	0.397	
		[0.097]			[0.135]	
Ages 25-29	261	0.475		126	0.179	
		[0.108]			[0.086]	
Ages 30-34	224	0.340		83	0.189	
		[0.107]			[0.066]	
Ages 35-39	161	0.358		35	0.141	
		[0.151]			[0.029]	
Ages 40-44	80	0.155		8	0.030	
		[0.277]			[0.008]	
Total fertility rate per 1000	5601	8.19	0.28	1920	5.55	6.44
		[2.63]	[0.23]		[1.14]	[1.31]
Num. of cells	57,126	55,479	2,460	23,310	23,130	760

Notes: "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 include country, year, and age fixed effects. 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 $<$ 20 yrs. WFS/DHS countries are listed in Table A1; 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.

Table A9: Alternative Long-Run Covariates

	Secondary school gross enrollment rate		Sectoral composition of value added		Female lab. force participation		POLITY IV score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ages 15-19	-0.06	-0.02	-0.06	-0.05	-0.11	-0.11	-0.14	-0.09
	[0.10]	[0.11]	[0.08]	[0.10]	[0.10]	[0.09]	[0.07]	[0.07]
Ages 20-24	-0.43	-0.36	-0.33	-0.37	-0.27	-0.27	-0.38	-0.38
	[0.16]	[0.17]	[0.13]	[0.17]	[0.14]	[0.15]	[0.11]	[0.11]
Ages 25-29	-0.42	-0.33	-0.46	-0.52	-0.42	-0.44	-0.48	-0.49
	[0.14]	[0.17]	[0.12]	[0.13]	[0.15]	[0.15]	[0.11]	[0.13]
Ages 30-34	-0.29	-0.12	-0.35	-0.42	-0.42	-0.45	-0.42	-0.41
	[0.14]	[0.15]	[0.15]	[0.20]	[0.17]	[0.17]	[0.14]	[0.16]
Ages 35-39	-0.08	0.06	-0.08	-0.05	-0.39	-0.41	-0.12	-0.08
	[0.15]	[0.16]	[0.15]	[0.19]	[0.16]	[0.16]	[0.13]	[0.13]
Ages 40-44	0.20	0.28	0.14	0.17	0.07	0.05	0.14	0.14
	[0.07]	[0.07]	[0.06]	[0.08]	[0.08]	[0.09]	[0.05]	[0.05]
TCR	-5.35	-2.42	-5.69	-6.16	-7.74	-8.12	-7.00	-6.57
	[2.92]	[3.09]	[2.50]	[3.16]	[3.00]	[2.96]	[2.16]	[2.30]
Covariate?		✓		✓		✓		✓
# cells	1,297	1,297	1,424	1,424	1,261	1,261	1,532	1,532

Notes: Regressions of the average annual rate of change in the age-specific conception rate on the average annual rate of economic growth. Each pair of columns restricts to the subsample with non-missing information on the average annual rate of change in the specified covariate. The even-numbered columns report models that include an age-specific coefficient on the average annual rate of change in the covariate. "TCR" refers to the total conception rate per 1000; estimates equal 5 times the sum of age-group-specific estimates. Brackets contain standard errors clustered by country.

Table A10: Comparison of Long-Run Results with Other Datasets

	Country-ages in the WFS/DHS		Country-ages in the HFD	
	WFS/DHS	UN	HFD	UN
	(1)	(2)	(3)	(4)
Ages 15-19	-0.116	-0.008	0.191	0.36
	[0.069]	[0.090]	[0.160]	[0.152]
Ages 20-24	-0.286	-0.354	-0.181	0.511
	[0.126]	[0.109]	[0.482]	[0.263]
Ages 25-29	-0.476	-0.562	-0.673	-0.184
	[0.116]	[0.148]	[0.314]	[0.247]
Ages 30-34	-0.423	-0.529	-0.073	-0.329
	[0.132]	[0.158]	[0.177]	[0.234]
Ages 35-39	-0.220	-0.332	-0.030	-0.275
	[0.142]	[0.107]	[0.176]	[0.228]
Ages 40-44	0.152	-0.076	-0.024	-0.130
	[0.069]	[0.066]	[0.083]	[0.121]
Total fertility	-6.84	-9.30	-3.95	-2.33
rate per 1000	[2.27]	[2.52]	[3.58]	[3.35]
Num. of cells	1601	317	510	96

Notes: “WFS” = World Fertility Survey; “DHS” = Demographic and Health Survey; “HFD” = Human Fertility Database; “UN” = United Nations World Population Prospects, 2015 Revision. Coefficients from regressions of the average annual rate of change in the conception rate on the average annual rate of economic growth. The unit of observation is a country-age cell, and the dependent variable is the average annual rate of change in age-specific birth rate. Total fertility rate estimates equal 5 times the sum of age-group-specific estimates. Brackets contain standard errors clustered by country. WFS/DHS countries are listed in Table A1; HFD countries include Austria, Bulgaria, Canada, Finland, France, Germany, Hungary, Iceland, Japan, Netherlands, Norway, Portugal, Sweden, Switzerland, Taiwan, 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.

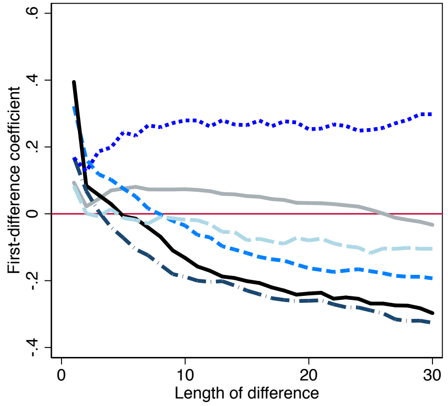
Table A11: Economic Growth over the Lifecycle and Completed Fertility

	Children Ever Born		Surviving Children	
	(1)	(2)	(3)	(4)
Avg. change in 100 × log GDPpa during ages...				
15-19	-7	-15	-5	-12
	[13]	[10]	[12]	[10]
20-24	-3	-15	2	-8
	[14]	[12]	[14]	[13]
25-29	10	1	7	-1
	[16]	[15]	[16]	[13]
30-34	38	26	29	18
	[14]	[12]	[12]	[11]
35-39	43	35	36	28
	[13]	[12]	[12]	[10]
40-44	25	34	18	26
	[17]	[12]	[15]	[12]
Cohort avg. ed.		-226		-226
		[54]		[54]
Cohort % urban		-4.7		-4.7
		[5.3]		[5.3]
Cohort FE	✓	✓	✓	✓
Country FE	✓	✓	✓	✓
Fertility measure	Ever-born	Ever-born	Surviving	Ever-born
Num. cells	935	935	935	935

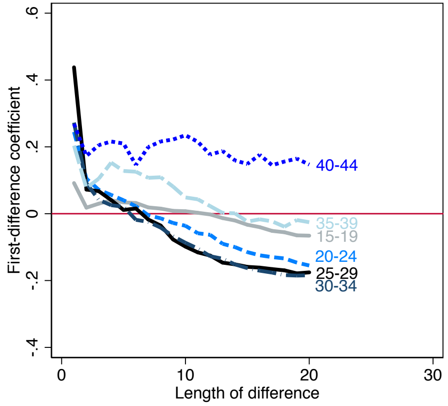
Notes: Sample includes single-age cohorts over age 45 when surveyed. Dependent variable is the number of children per 1000 women. Brackets contain SEs clustered by country.

Figure A1: First-Difference Models with Varying Time Horizons, Constant Samples

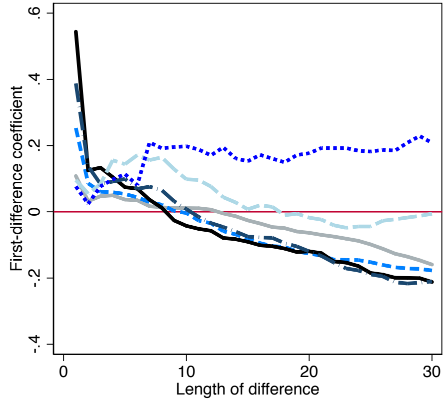
A. No single-year age effects



B. Country-age cells spanning ≥ 20 years

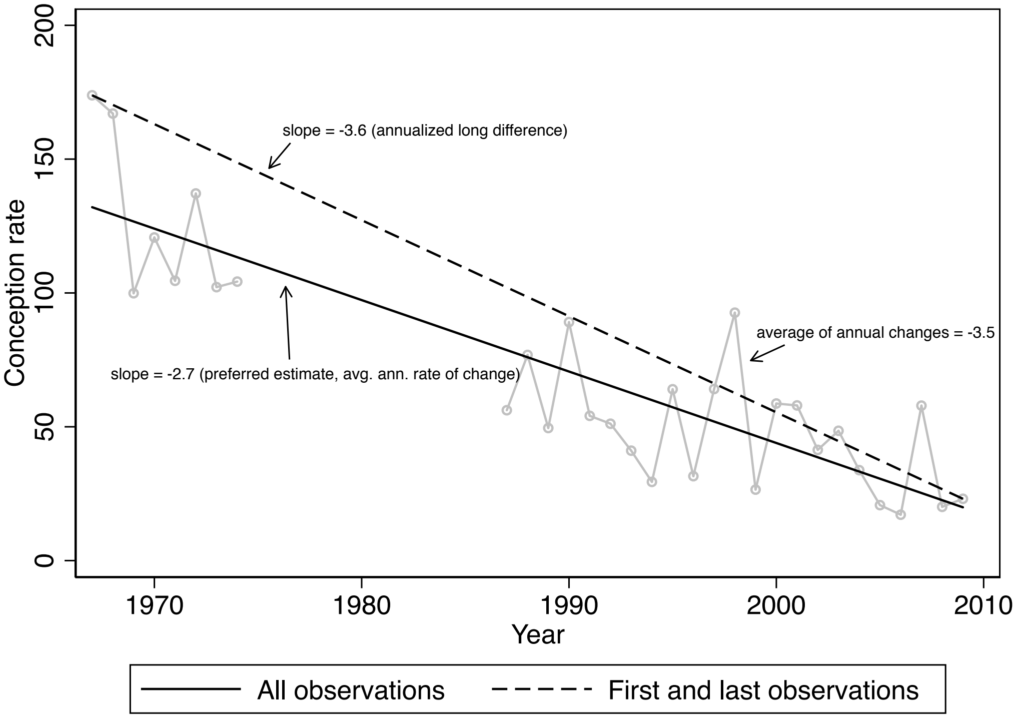


C. Country-age cells spanning ≥ 30 years



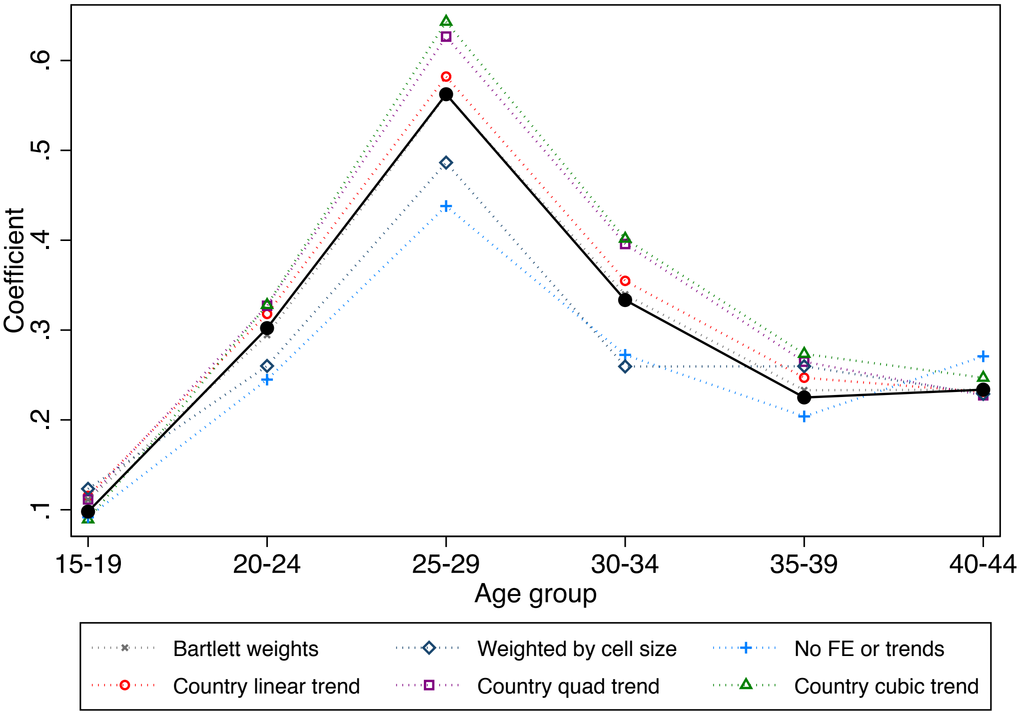
Notes: Reproduces Figure 1 without age effects or using samples that do not change for different time horizons. For each 5-year age group, each panel plots coefficients from regressions of the change in the conception rate from year t − Δ to year t on the change in 100 × log GDP per adult over the same period, controlling for single-year age indicators.

Figure A2: Estimating the Average Annual Rate of Fertility Change: 40 year olds, Nepal



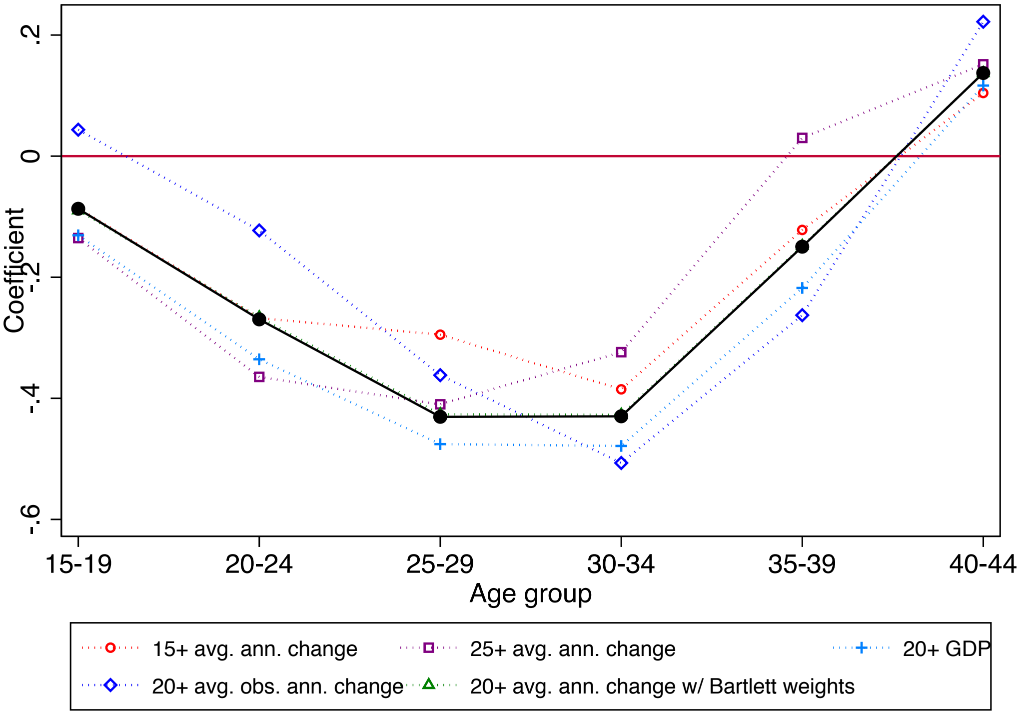
Notes: The figure plots estimated conception rates at age 40 over time in Nepal, with two trend lines, one estimated using all years and one estimated using just the first and last year of the series. We use the slope of the "all observations" trend as our estimate of the average annual rate of change because the other trend line (which is equivalent to the annualized long difference) uses less data, and the average of annual changes ignores trends during the data gap in the late 1970s and early 1980s.

Figure A3: Alternative Short-Run Models



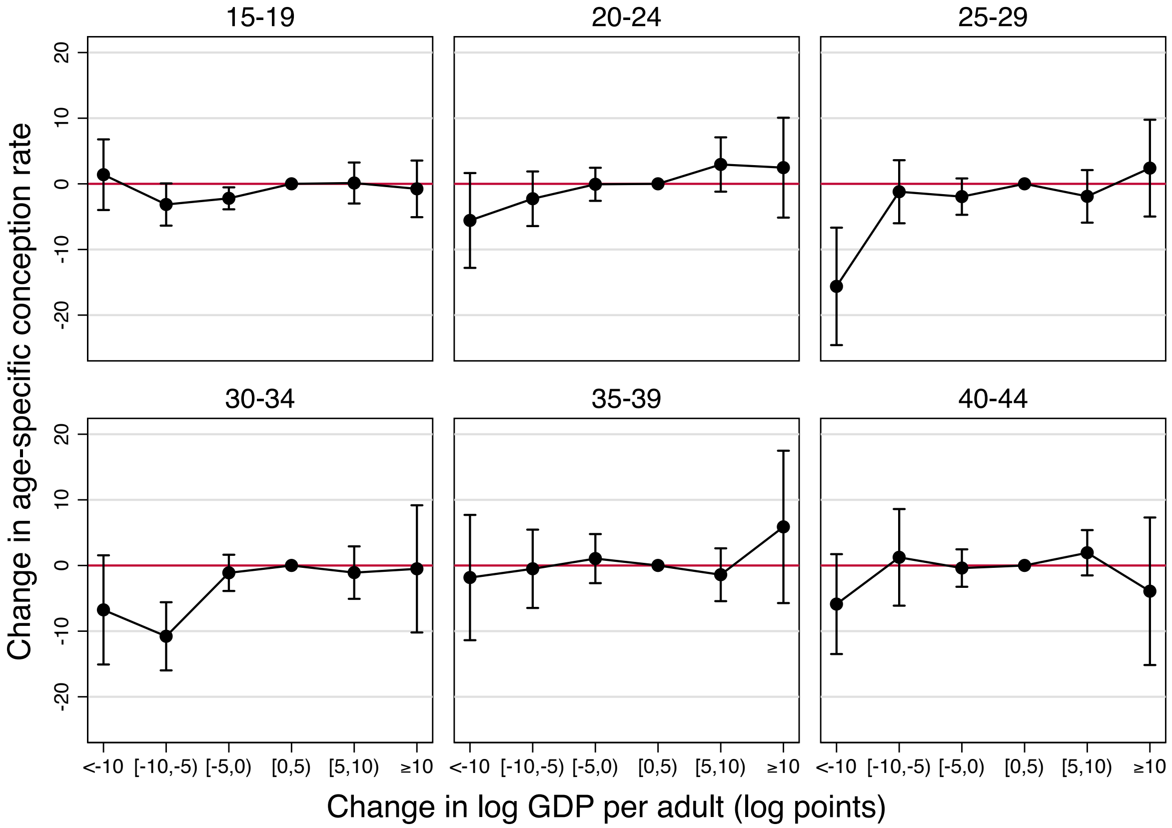
Notes: Age-group-specific coefficients from regressions of the change in the conception rate on the change in log GDP per adult. The thick black plot represents the coefficients from the short-run model reported in Figure 3. "Bartlett" uses a Bartlett kernel to downweight longer recall periods. The remaining models add country-specific polynomials in time to the baseline model.

Figure A4: Alternative Long-Run Models



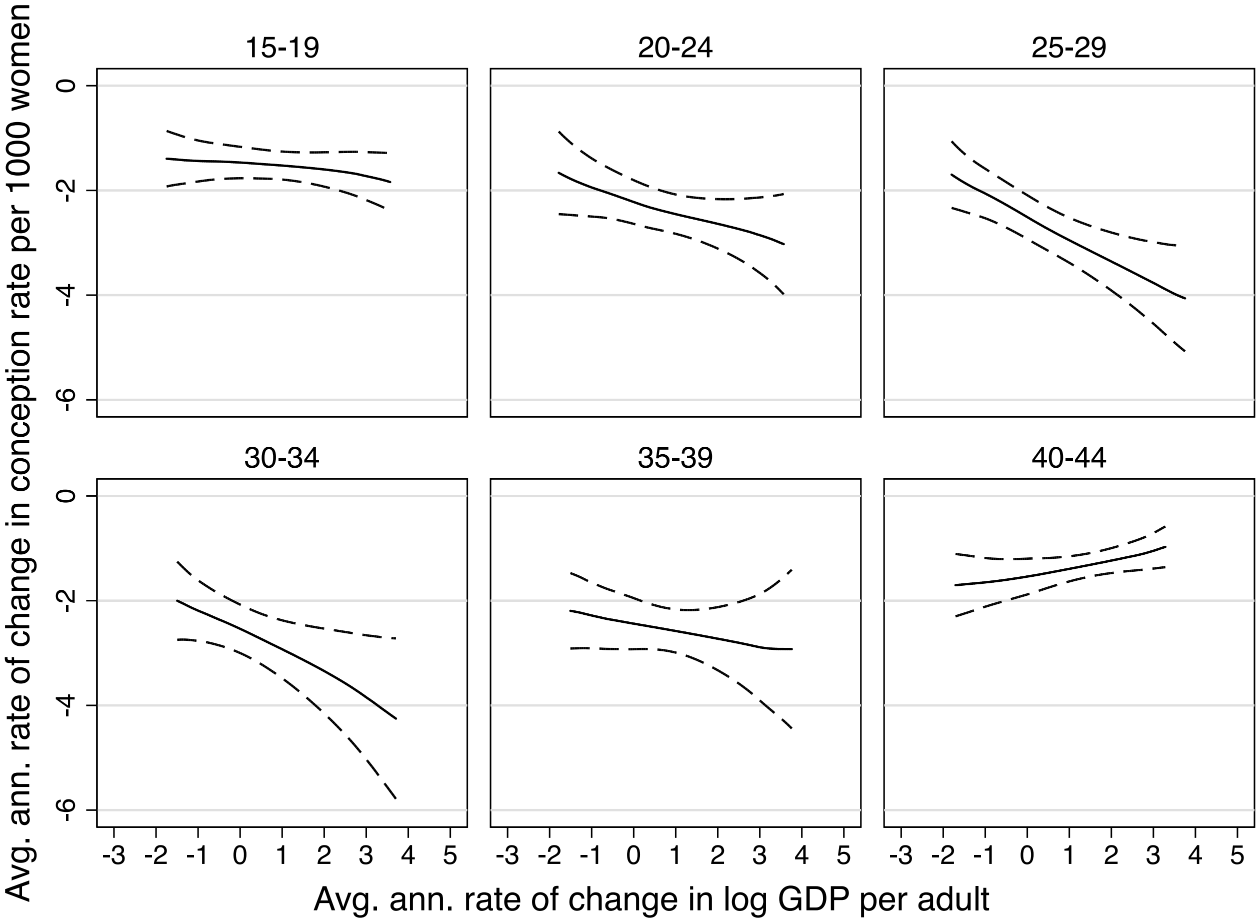
Notes: The figure compares results from different methods of computing the average annual rate of change. The thick black plot represents the coefficients from the long-run model reported in Figure 4. "15+" and "25+" use alternative minimum time horizons (15 and 25 years) to estimate the slope of the annual trend. "20+ avg. obs. ann. change" uses the average of observed annual changes (leaving out gaps in the panel) instead of the slope of the annual trend. "20+ Bartlett weights" downweights observations with longer recall periods, and "20+ GDP" uses GDP instead of GDP per adult.

Figure A5: Non-Linear Estimates by Age Group, Short Run



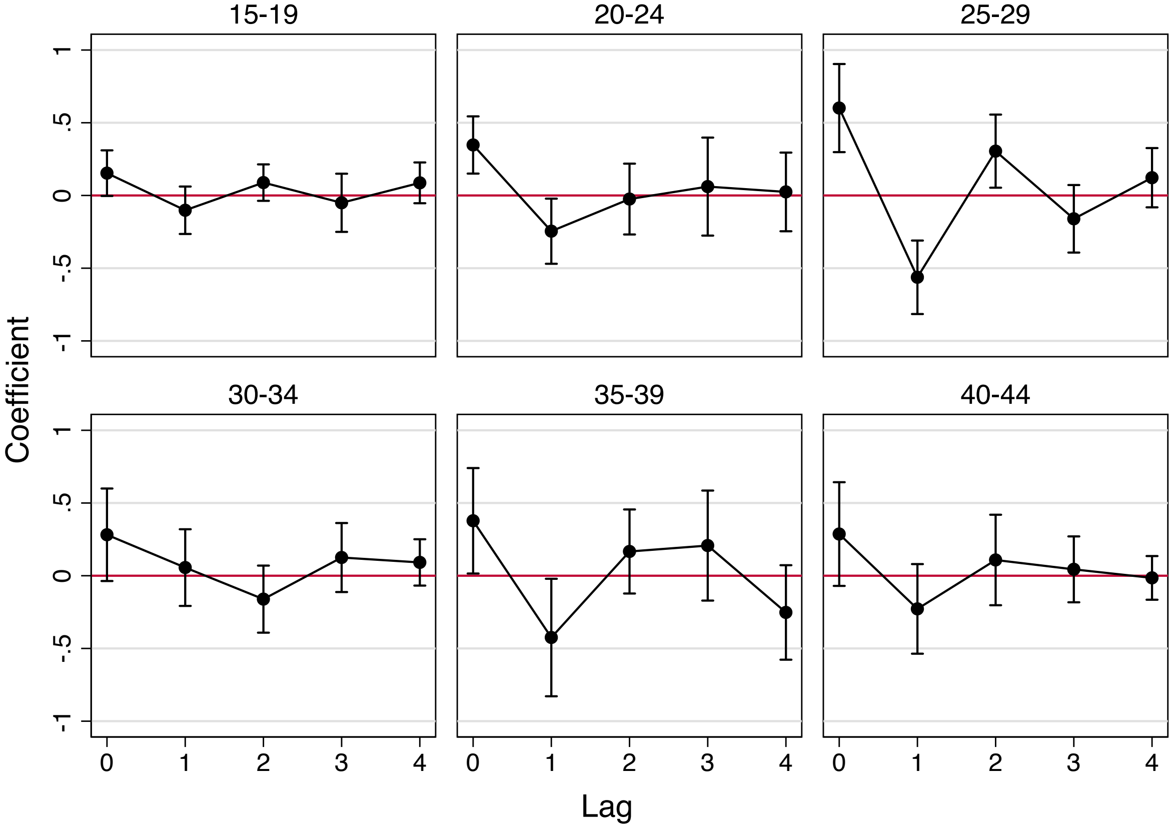
Notes: Semi-parametric results summarized in Figure 5, here shown by age group with 95% confidence intervals. Coefficients from regressions of annual changes in the age-specific conception rate on binned annual economic growth, controlling for country, year, and age fixed effects. Confidence intervals are clustered at the country level.

Figure A6: Non-Linear Estimates by Age Group, Long Run



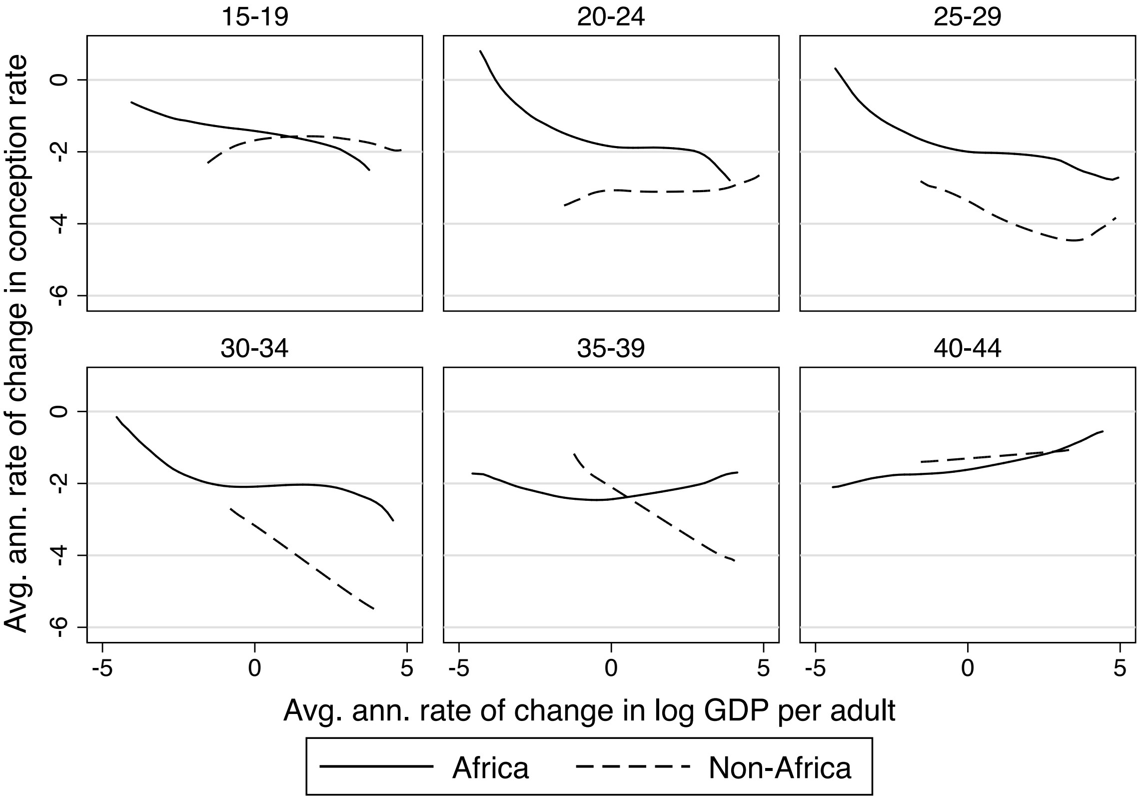
Notes: Non-parametric results summarized in Figure 6, here shown by age group with 95% confidence intervals. Local linear regressions; the dependent variable is the estimated trend in conception rates within a country-age cell, while the independent variable is the estimated trend in log GDP per adult in the same cell. Bandwidth equals 2, and confidence intervals are block bootstrapped at the country level.

Figure A7: Distributed Lag Models by Age Group



Notes: Distributed lag model summarized in Figure 7, here shown by age group with 95% confidence intervals. Coefficients from regressions of annual changes in the age-specific conception rate on current and lagged annual changes in 100 × log GDP per adult, controlling for country, year, and age fixed effects. Confidence intervals are clustered at the country level. Sample includes observations that have both lagged conception rates and lagged growth rates.

Figure A8: Non-Linear Estimates by Age Group and Region, Long Run



Notes: Replicates Figure A6, splitting the sample into African and non-African countries. Local linear regressions; the dependent variable is the estimated trend in conception rates within a country-age cell, while the independent variable is the estimated trend in log GDP per adult in the same cell. Bandwidth equals 2, and confidence intervals are block bootstrapped at the country level.