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. We analyze how fertility change related to economic growth during this episode, using data on 2.3 million women from 255 surveys in 81 countries. We find different responses to fluctuations and long-run growth, both of them heterogeneous over the lifecycle. Fertility was procyclical but also declined and delayed with long-run growth; fluctuations late (but not early) in the reproductive period affected lifetime fertility. The results are consistent with economic 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 population growth slowed thereafter, mainly because fertility plummeted in the developing world, from six children per woman in the 1950s and 60s to fewer than three today (United Nations 2015).[1] While the causes of this decline are the subject of much debate (Lam 2011), economic threories of the escape from the Malthusian trap ascribe a fundamental role to economic growth and its potential effects on the returns to child investment and women's work (Galor and Weil 1996, 2000). But evidence on the relationship between economic growth and fertility change during this important episode in world demographic history is surprisingly incomplete. Did fertility decline as a result of economic growth in the developing world or in spite of it? And given ongoing worries about the environmental consequences of population growth (Ehrlich and Ehrlich 2013), how can economic growth in the developing world be expected to shape fertility trends in the future?

This paper seeks to empirically characterize the relationship between economic growth and fertility change in the developing world since 1950, with an eye toward (1) assessing the role of growth in driving fertility dynamics and (2) matching the facts with leading economic theories of growth and demographic change. We argue that careful attention to time horizons and lifecycles is crucial to developing an accurate account of this 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*. Depending on the type and temporal scope of the data used, failure to account for these issues may result in incorrect inferences about the role of growth in the secular decline of fertility. The time and lifecycle nuances also speak to a range of theoretical issues in models of fertility choice and the macroeconomy. Existing research pays limited attention to these

[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 Deverloped Regions.

issues, particularly as they relate to 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, 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 lifecycle fertility, 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 empirically.[3] Even more poorly understood is the relationship between long-run growth and fertility timing.[4]

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 datasets, 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

[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. Murtin (2013) finds a non-monotonic relationship between GDP per capita and the crude fertility rate, 1870-2000, but does not distinguish fluctuations from long-run growth. All use fertility aggregates and do not consider timing.

[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.

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.

is typically restricted by demographic models. We also use the survey data to calculate cohort measures of fertility and investigate within-country heterogeneity—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.

As motivation for these empirical analyses, we explore a lifecycle extension of the parental choice problem from the theoretical literature on long-run growth and the demographic transition, in which liquidity-constrained parents with uncertain incomes and wages make consumption, childbearing, and child investment choices over a finite reproductive period. The theoretical framework highlights how procyclical fertility can coexist with a negative long-run relationship between economic growth and fertility change; how this long-run relationship may vary over the lifecycle because of adjustment in the timing of childbearing; and how income or wage fluctuations toward the end of the reproductive period can have permanent effects on fertility, while the effects of earlier fluctuations may be offset by subsequent adjustments in childbearing decisions.[5]

In line with this framework, Table 1 reveals that growth-fertility relationships are positive, negative, or zero, depending on time and lifecycle horizons. 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, reinforcing a liquidity interpretation. 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 substitution 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 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 predicts an annual decline of 0.4 pregnancies per 1000. 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—consistent with theoretical predictions regarding offset opportunities early and late in the reproductive period. We show that many of these nuances are obscured in standard cross-country datasets, while others are altogether impossible to study, underscoring the benefits of combining hundreds of surveys.

The analyses of short- and long-run growth differ substantially in their statistical interpretation, in that the short-run analysis uses a demanding regression specification that isolates within-country variation, while the long-run analysis must rely on cross-country variation in rates of change. Indeed, the short-run results are robust to including a range of fixed effects, trends, and covariates, suggesting that they reflect a causal effect of aggregate fluctuations. Causality is harder to infer from the long-run results, which reflect correlations between long-run growth and other trends that incentivize lower fertility. But notably, the long-run results are not explained by the initial levels of GDP per adult and population density; nor by rates of change in adult female education, adult female labor force participation, the sectoral composition of value added, urbanization, infant mortality, conflict, and democratization. Instead, we find only one variable that explains part of the negative long-run

[5]See Foster (1993) for a related model of how short- and long-run economic-demographic relationships can differ.

association: the rate of change in school enrollment (among teens, not mothers). Because rising enrollment suggests rising returns to human capital investment, these results are consistent with human capital-based theories of unified growth.

Our findings complement or extend several bodies of research. Perhaps their most obvious connection is to recent studies that ask whether children can be characterized as normal goods, 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 that question 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 2007; Baird, Friedman, and Schady 2011)—and on the cumulative mortality effects of economic shocks over the lifecycle (Cutler, Huang, and Lleras-Muney 2016). The results also improve the empirical basis for theories of growth and the demographic transition (Galor and Weil 2000; Galor and Moav 2002; Hazan and Berdugo 2002; De La Croix and Doepke 2003).

Finally, we contribute to a large literature that studies the correlates of income levels and growth rates across countries. An active area of research in this literature focuses on human capital (Caselli 2005); recent advances have taken advantage of the increasing availability of comparable micro-datasets from multiple countries (Young 2013; Lagakos et al. 2017). Far less research deals with the facts on population processes and how they relate to the macroeconomy in developing countries, even though these population processes may be important determinants of human capital investment. Two recent advances on this front compile disparate microdata to investigate how the career costs of children evolve during the development process (Kleven and Landais 2016; Aaronson et al. 2017). Our contribution deals with the determinants rather than effects of fertility.

The paper's results appear to pertain to the phase after an economy escapes the Malthusian trap but before it attains high living standards and low fertility. In the Malthusian era, sustained productivity growth led to higher population density rather than rising living standards and declining fertility (Ashraf and Galor 2011). In the modern era, the balance of income and substitution effects from long-run growth may differ. Indeed, in a complementary analysis of data from developed countries, we find similar short- but not long-run results. Thus, the paper clarifies how to place the developing world's postwar experience in the timeline of long-run growth and demographic change.

2 Lifecycle Considerations in Models of Demography and Growth

In the standard overlapping generations formulation, models of long-run economic growth and the demographic transition posit parents making choices regarding the quantity (and sometimes quality) of their children in a single period. We explore a simple lifecycle extension of these models to study how fertility behavior responds to fluctuations and long-run growth over a finite reproductive period.

Following standard practice (Jones, Schoonbroodt, and Tertilt 2010), we model parents' utility as separable over own consumption c_t, the number of children n_t, and their mean human capital h_t:

$$U\left(c_t, n_t, h_t\right) = u_c\left(c_t\right) + u_n\left(n_t\right) + u_h\left(h_t\right) \tag{1}$$

However, we treat t as a period rather than a generation, so that $U\left(\cdot\right)$ becomes a period utility function. Parents live $t = 1, \cdots, T$ periods and can bear children until they reach menopause at age $M < T$. We assume that each sub-utility function $u_x\left(\cdot\right)$ is increasing, concave, and twice continuously differentiable, with $\lim_{x \downarrow 0} u_x'\left(x\right) = \infty$ and $\lim_{x \uparrow \infty} u_x'\left(x\right) = 0$. Parental choices maximize expected utility, discounted by factor β.

Parents 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. Because w_t factors into the time cost of children, but y_t does not, one can also think of these variables as reflecting women's and men's labor income, respectively. Some models include subsistence consumption constraints to accommodate Malthusian dynamics, but we do not, since we are mainly interested in fertility behavior after the emergence of sustained economic growth. Subsistence constraints can be key to understanding why fertility typically rises before starting its decline, but we abstract from this issue fertility trended downward during the sample period in over 90% of the country-age cells in our sample. We do impose a borrowing constraint ($A_t \geq 0$), which may be key to understanding the effects of fluctuations. In each period, parents allocate assets and potential income to own consumption, quantity and quality costs of children, and savings (which earn gross return R).

Parents set a birth rate $b_t \in [0, 1]$ in each period, starting their lives with no children and accumulating them according to: $n_t = n_{t-1} + b_t$.[6] 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

[6]Continuous fertility follows much of the literature and allows us to derive intuitive first-order conditions.

e_t to produce human capital. Education spending is transformed into human capital by a (twice continuously differentiable) human capital production function $h(e_t; \bar{g})$, which we allow to depend on the long-run growth rate of technology $\bar{g}$. We defer discussion of the form of $h(\cdot)$ until we consider the education spending decision and its implications for fertility.

Because our primary interest is not 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 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. In light of the finite horizon, we work backward: characterizing the consumption sequence first, the birth sequence next, and education spending last. The Theory Appendix contains derivations.

The first-order conditions to the lifecycle problem lead to a standard consumption Euler equation:

$$u'_c(c_t) = \beta R E_t \left[u'_c(c_{t+1})\right] + \lambda_t \tag{2}$$

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:

$$u'_c(c_t) = \frac{u'_n(n_{t-1} + b_t) + \sum_{s=t+1}^{T} \beta^{s-t} E_t \left[u'_n(n_s) \frac{\partial n_s}{\partial b_t} - \mathbb{1}_{\{s-t \leq K\}} \nu_s (\tau w_s + \kappa + e)\right] + \mu_t^0 - \mu_t^1}{\tau w_t + \kappa + e} \tag{3}$$

where μ_t^0 and μ_t^1 are Lagrange multipliers on the constraints that the birth rate be at least 0 and at most 1. The rest of numerator reflects the current marginal benefit and future maginal benefits (net of marginal costs) of childbearing; the denominator reflects the current marginal cost of childbearing.

Equations (2)-(3) provide insight into the effects of transitory wage and income fluctuations.[7]

[7] Aguiar and Gopinath (2007) find that developing economies are charaterized by permanant, not transitory, growth shocks, which would lead to a mix of short- and long-run mechanisms. But our empirical analysis finds deep recessions to be key to the procyclicality of births, and these recessions are autocorrelated only to the second lag.

Because the right-hand side of equation (3) 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 fluctuations in w_t before menopause have minimal effects on expected lifetime income, so this intertemporal substitution effect is likely to dominate any income effects 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 (2), which then also incentivizes reduced childbearing by equation (3).[8] This possibility also implies non-linearity and heterogeneity: borrowing constraints may bind more during deep recessions, and the poor may be especially likely to hit zero assets.

The durability of children adds several nuances in equation (3). 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. Demographers refer to intertemporal substitution of births of this type as a tempo effect.[9] 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. In fact, offset becomes impossible after menopause, so wage and income shocks toward the end of the reproductive period may be more likely to have permanent effects on the number of children. As a result, parents approaching menopause may tolerate greater declines in consumption to finance childbearing.

The insights about fluctuations from equations (2)-(3) do not necessarily 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. Assuming an interior solution, the education spending plan satisfies the first order condition:

$$u_h'\left(h\left(e;g\right)\right)h_e\left(e;g\right)\left(\tfrac{1-\beta^T}{1-\beta}\right) = E_0\left[\sum_{t=1}^{M+K}\sum_{k=0}^{K}\beta^{t-1}\nu_t b_{t-k}\right] \tag{4}$$

[8] 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).

[9] In the very short run, some of the tempo effect will be due to postpartum infecundity.

where ν_t is the Lagrange multiplier on the period t budget constraint. 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, which leads parents to rasie e. The increase in e pushes up the denominator in equation (3), so the optimal number of children declines.[10] Among liquidity-constrained parents, rising e may delay or increase spacing between births to allow accumulation of assets to pay child costs.[11] In this sense, long-run growth can affect both the quantum and tempo of fertility.

Thus, a central mechanism of unified growth theory—in which technology growth reduces fertility by increasing the return to child investment—remains intact, even in a model that admits procyclical fertility in the short run. This prediction relates long-run economic growth to the the *level* of fertility, while many of our analyses examine *changes* in fertility, but this gap is easy to address theoretically. If parents adapt to the new economic environment slowly, then long-run growth will be associated with long-run (rather than instantaneous) fertility decline. A similar prediction obtains if higher $\bar{g}$ incrementally raises the return to education spending from its most recent value, or if the return to child investment depends on the level of technology, rather than its growth rate.

If $\bar{g}$ affects parents' budget constraint, then these predictions become less sharp. In this case, the effect of long-run growth on fertility additionally depends 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 (3), such a shift incentivizes fertility reduction. If this mechanism is at work, then fertility will become more countercyclical as growth takes off.

For parsimony, we have not directly considered the proximate determinants of fertility that underlie fertility responses to growth. Intentional changes in childbearing, as captured in the framework, may be achieved through some mix of traditional birth control (including marriage timing), modern contraception, and abortion. Other proximate determinants, such as unintentional changes in coital frequency (e.g., from stress or migration) or infecundity (e.g., from malnutrition), are less natural in our choice framework but still relate to its emphasis on liquidity constraints and intertemporal

[10] Galor and Weil also assume $h(0; \bar{g}) > 0$, admitting an optimum with $e = 0$. The corner solution is useful for understanding regimes with rising fertility, but we disregard it here to focus on a regime with long-run fertility decline.

[11] In a related mechanism, if parents could augment their human capital in adulthood, then growth-related increases in time investment would concentrate early in the lifecycle, competing with childcare time and delaying fertility.

substitution. Our empirical analysis examines marriage timing but not other mechanisms because of data limitations. Related to this point, we have not explicitly modeled child mortality. Our empirical analysis examines child mortality but finds no evidence that it explains our results.

3 Data

Our analysis requires careful measurement of economic growth and fertility. For the former, 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).

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. 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. Respondents provided full birth histories, listing all of their children ever born, with information on birth date and survival status.[12] 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. To

[12] 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.

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). We generate two types of fertility rates: period, summarizing fertility outcomes across ages in a given year, and cohort, summarizing the lifetime fertility outcomes of women born in the same year.

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.[13] As such, we do not directly analyze childbearing behavior but instead use approximate dates of conception for fetuses that survived gestation: a limitation, given that economic conditions may affect the probability of fetal death.[14] 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.[15] Pooling all ages 15-44, age-specific conception rates have a mean of 199 per 1000. The annual change in log GDP per adult, which approximates the annual growth rate, averages 1.0 log points, 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.

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

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

[14]The term "conception rate" is thus a slight abuse of demographic terminology, but one that follows Currie and Schwandt (2014) in their work on economic conditions and fertility. The focus on the timing of conception rather than birth also follows Currie and Schwandt.

[15]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.

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 in the two samples.

For covariates, analyses of heterogeneity, alternative measures of fertility, and comparisons with developed countries, we draw on several 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. Other covariates, like average female education, the infant mortality rate, and the urbanization rate, are estimated from the WFS/DHS microdata. For comparison with developed countries, we use the Human Fertility Database, which brings together vital registration data from wherever they are of high quality.

4 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.

4.1 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. For each 5-year age group A from $[15, 19)$ to $[40, 44)$, we run:

$$CR_{cta} - CR_{c,t-\Delta,a} = \beta^A \left(Y_{ct} - Y_{c,t-\Delta}\right) + \alpha_a^A + \varepsilon_{cta}^A \quad (5)$$

where $Y_{ct} = 100 \times \ln(GDPpa_{ct})$. Because the distribution of ages within each 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 age within the age group. We estimate equation (5) 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.

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 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 several noteworthy implications, both statistical and economic. First, the annual first-difference coefficients estimated with equation (5) 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. Third, the implied procyclicality alongside long-run associations of varied signs is consistent with the theory outlined in Section 2, although the subsequent analysis will need to address robustness to covariates and statistical significance.

4.2 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 (5) to fully disentangle the short- and long-run relationships by including a country effect, which absorbs the country's long-run average rate of change in 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:

$$\Delta CR_{cta} = \beta^A g_{ct} + \lambda_c^A + \tau_t^A + \alpha_a^A + \varepsilon_{cta}^A \tag{6}$$

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 age effects, which in first differences serve to control for correlated level trends.[16] 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 (5).[17] The 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 $100 \times \Delta \ln(GDPpa_{ct})$ and CR_{cta} on year within each country-age cell, using the slope of the trend as the estimated average annual rate of change.[18] We then run the following regression for each 5-year age group A:

$$\overline{\Delta CR}_{ca} = \beta^A \overline{g}_{ca} + \alpha_a^A + \varepsilon_{ca}^A \tag{7}$$

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 (7) primarily analyzes variation in ΔCR_{cta} and g_{ct} that was absorbed by the country effect in equation (6), we omit λ_c^A from the long-run regression. Here, β^A represents the cross-country association of long-run economic

[16]Equation (6) 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:

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

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.

[17]Without complicated interaction terms, a distributed lag model with a large number of lags would be insufficiently flexible for studying short- and long-run relationships that take on different signs.

[18]An alternative approach would simply take the mean of observed annual changes g_{ct} and ΔCR_{cta}, but this approach would 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 1970-91 difference in levels, but this approach would lose precision because $GDPpa_{ct}$ and CR_{cta} are stochastic and measured with idiosyncratic error.

growth with long-run fertility change, net of age-related factors. A country with a 1-log point faster rate of long-run growth experiences a β^A higher rate of change in the conception rate.

For both equations (6) and (7), 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:

$$\beta^{TCR} = 5\left(\sum_A \beta^A\right) \tag{8}$$

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.

To assess the roles of other aggregate variables in explaining any relationship between economic growth and fertility change, we report estimations of equations (6) and (7) 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 change (for the short-run analysis) or average 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.[19] 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. However, 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.

4.3 Main Results

Table 3 reports the main results of the analysis of period fertility. The first two columns summarize the level of fertility and its rate of change. In column (1), average conception rates follow an inverted u-shape in age, peaking at 261 per 1000 among 20-24 year olds. TCR, the number of conceptions

[19]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.

expected of a hypothetical cohort of 1000 women experiencing these age-specific conception rates over their lifecycles, is 5483, or 5.5 conceptions per woman. Despite this high level, fertility was falling throughout the sample period, as revealed in column (2). On average, conception rates in all age groups declined by 1 to 3 points per year, with a -67 annual change in TCR, corresponding to a decadal reduction of two-thirds of a conception per woman.

These rates of fertility change serve as dependent variables in the remainder of Table 3. Columns (3)-(4) report the short-run coefficients from equation (6), first without the main covariates and then with them. In the basic model without covariates, all of the short-run coefficients are positive, indicating procyclical fertility, with statistical significance in the prime parenting ages. The largest coefficient of 0.56 implies that a one log point increase in GDP per adult raises the number of conceptions by roughly $\frac{1}{2}$ per 1000 25-29 year olds. Moving from 25-29 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, TCR increases by 8.8 per 1000 in response to a log point positive growth fluctuation.

Alternative regression specifications leave these results intact. In column (4), the addition of covariates in the extended model does not meaningfully alter the coefficients or their significance levels. For completeness, we report the coefficients on these covariates in Appendix Table A2. Changes in female education, urbanization, and infant mortality all have significant relationships with conception rate changes at various ages, yet none meaningfully explains the procyclicality of conceptions. Additional robustness checks are reported in Appendix Figure A2, which plots age-group-specific coefficients from 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. Both the weighted model and the trend models deliver results very similar to those reported in Table 3. 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 the final two columns of Table 3, long-run economic growth and long-run fertility change are negatively correlated at prime ages but positively correlated at older ages. Column (5) reports the basic model without covariates, revealing these marked contrasts across the age distribution. A comparison of women around age 30 with women in their early 40s provides the starkest contrast. 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 coefficient in column (3). Meanwhile, 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 suggest increased spacing, rather than later starting or earlier stopping, consistent with liquidity constraints in the theoretical framework. On net, the offsetting coefficients different ages imply a long-run TCR coefficient of -6.1, so that overall, faster long-run economic growth is associated with more rapid fertility decline. The average 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 large share of fertility change in developing countries over the long run.

These long-run results remain intact across alternative regression specifications. In column (6), estimates are robust to controlling for the initial level of GDP per adult and the average rates of change in conflict, female education, urbanization, and infant mortality. Appendix Table A2 reports the coefficients on these covariates. Pooling all age groups, the incremental contribution of long-run growth to the R^2 is 0.08 (from 0.32 to 0.40), compared with 0.03 for the average rate of change in female education. Further specification checks are reported in Appendix Figure A3, 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.

4.4 Exploring the Procyclicality of Fertility

4.4.1 Non-Linearities

All of the preceding models assume linearity, but the theoretical framework's emphasis on liquidity constraints suggests that conception rates may respond differently to booms and busts, and these responses may be non-linear in the size of the economic fluctuation. To assess such non-linearities in the short-run results, we discretize the distribution of $100 \times \Delta \ln (GDPpa_{ct})$ into six bins and then run a semi-parametric version of equation (6) that replaces the continuous variable g_{ct} with bin indicators. We prefer this approach to non-parametric regression because it allows us to control for country, year, and age effects while still measuring the change in log GDP per adult in its original units. Results are summarized in Figure 2, with Panel A plotting the age-group-specific coefficients and Panel B plotting the implied TCR coefficients with 90% and 95% confidence intervals. Confidence intervals for the age-group-specific coefficients are displayed in Appendix Figure A4.

In Figure 2, a clear asymmetry emerges, with conceptions falling sharply in deep recessions but not rising 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. 25-29 year olds are hardest hit, with conceptions declining 16 per 1000 during these extreme recessions. As shown in the histogram in Panel B, recessions of this magnitude are rare but not unprecedented, with 3% of the sample (1,644 cells) in this category.

4.4.2 Lags

The theoretical framework also makes clear that women may offset past fertility adjustments, suggesting that we should include lagged growth rates as additional covariates in equation (6). Figure 3 extends the model with four lags; alternative lag lengths produced similar results.[20] Panel A reports results for each age group, showing pronounced offset behavior in the year following a growth fluctuation. In response to a 1-point positive fluctuation, conceptions among 25-29 year olds rise 0.53 per 1000 in the same year but fall 0.40 per 1000 in the following year. Both coefficients are statistically significant, as shown in Appendix Figure A5, which draws the impulse response functions with confidence intervals. Most other age groups display the same pattern, although the confidence intervals

[20]To focus on the growth fluctuations that identified the results in Table 3, we only use the sample that has both lagged growth rates and lagged conception rates.

are sometimes too wide for a definitive interpretation, especially at longer lags. One notable exception is the impulse response function for 30-34 year olds, which displays the weakest offset behavior. This pattern will be relevant for the cohort results in Section 5.

Aggregation across age groups allows us to characterize the impulse response function with less noise. Panel B of Figure 3 reports the implied TCR coefficients for the contemporaneous and lagged effects. In response to a 1-point growth fluctuation, TCR rises 10.8 at first but then falls 7.6 in the following year. These coefficients reflect the partial effect of past economic fluctuations on the current change in the conception rate. The running sum of the coefficients, plotted in black, reveals that the effect of a fluctuation dissipates over time but does not disappear. In particular, 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. Some but not all of the short-run fertility response to economic fluctuations is offset through subsequent adjustments to childbearing. Importantly, 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 choices over time for a particular woman. The cohort analysis in Section 5 will address this issue.

4.4.3 Heterogeneity

Although we have focused on aggregate rates, our theoretical framework has implications for differential fertility: if procyclicality is due to liquidity constraints, then it should be strongest in liquidity constrained groups like the poor. To shed light on heterogeneity within countries, we study how four average characteristics of mothers change over the business cycle: age, education, urban residence, and ever-marriage.[21] To minimize changes in sample composition from cells with no births, we run the analysis at the country-year level, for the same countries and years in the main sample. We control for changes in the age structure and the average characteristics of all women in the country-year cell, so that the coefficient on g_{ca} captures how growth fluctuations influence the composition of conceiving mothers, over and above any association with the composition of women at risk for conceiving.

Table 4 presents the results, lending support to the liquidity hypothesis. Column (1) first shows that the country-year aggregation leads to similar estimates of procyclicality as before, with a sta-

[21] Education and urban residence correspond to the time of the survey—at the end of the birth history—while age and marriage are contemporaneous to the year of conception risk.

tistically significant coefficient 0.24 for the crude birth rate—implying a TCR coefficient of 7.3. The next four columns present the results for maternal characteristics, with a single noteworthy result: a significant positive relationship between growth fluctuations and the average education of mothers. A log point positive growth fluctuation is associated with a decrease in average education of 0.002 years.[22] This finding implies that less-educated women are more responsive to growth fluctuations: consistent with a role for credit constraints and unsupportive of the idea that only more-educated women can control their fertility.[23] Other average characteristics of mothers do not vary significantly with growth fluctuations. The marriage null result is surprising, given the historical importance of marriage as a method of fertility limitation (Hajnal 1965; Wrigley 1981).[24] In the final column of Table 4, we focus on an average characteristic of children, rather than mothers—the fraction male—based on the hypothesis by Trivers and Willard (1973) that male fetal mortality is more sensitive than female to maternal condition. Growth fluctuations do not affect the sex composition of births, suggesting that our results reflect changes in conceptions rather than fetal deaths.

While the analyses in Table 4 speak to who responds most to growth fluctuations within a country, heterogeneity across countries is also of interest. Appendix Tables A4 and A5 investigate heterogeneity by aggregate characteristics and region, respectively. Suprisingly, Appendix Table A4 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, Appendix Table A5 reveals marginally significant regional variation, with countries in Africa, Latin America, and the Caribbean exhibiting stronger procyclicality than those in Asia. In fact, conception rates are unresponsive to economic fluctuations in South and Southeast Asia.

4.4.4 Comparisons with Developed Countries and Alternative Datasets

The suggestive evidence on regional variation raises the question of how the fertility response to fluctuations in WFS/DHS countries compares with that in developed countries, which have been the focus of the literature on fertility and the business cycle (Sobotka, Skirbekk, and Philipov 2011).

[22] If we replace the growth rate with an indicator for recession ($g_{ct} < 0$), we obtain a coefficient of 0.02, suggesting that the average education of mothers increases by 0.02 years (0.5% of the average education level and 25% of its annual rate of change) during a downturn.

[23] If we compute separate conception rates for more- and less-educated women, we find procyclicality in both groups, with a larger magnitude among the less-educated.

[24] Appendix Table A3 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.

Because data on conception rates by year in developed countries are not readily available, Appendix Table A6 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 (6) reveal that developing country fertility is somewhat more procyclical in absolute terms but somewhat less procyclical in relative terms.[25]

For an additional point of comparison, Appendix Table A6 also reruns the analysis using total fertility rates from the World Development Indicators, a popular dataset in cross-country research. For the developed country sample, estimates from the WDI are similar to those implied by the HFD. But for the developing country sample, the WDI estimates are insignificant and close to zero, likely because the WDI's fertility data are heavily smoothed for countries with low-quality vital registration systems. Researchers using this popular cross-country dataset would have incorrectly concluded that fertility is far more procyclical in richer, lower-fertility countries.

4.5 Exploring the Long-Run Link Between Growth and Fertility Decline

4.5.1 Non-Linearities

While theory gives no clear prediction regarding non-linearities in the long-run relationship, more flexible estimation may yield interesting results here as well. Because equation (7) includes no country or year effects, and the age effects are of minimal importance, we rely on a bivariate regression smoother to characterize non-linearities in the long run. Figure 4 displays local linear regressions of the average annual rate of change in the conception rate on the average annual rate of economic growth, using a bandwidth of 2 log points.

Panel A graphs the regression function for each age group (over the 5^{th} to 95^{th} percentiles of the age group's distribution of long-run growth), providing two new insights. First, unlike the short-run results, the long-run results do not deviate substantially from linearity. Second, conception rates trended downward regardless of age or long-run growth; the estimated regression functions are uniformly negative. Consequently, the positive long-run coefficient for the 40-44 age group reflects slower fertility decline in faster-growing countries. Appendix Figure A6 reports confidence intervals.

To generate the implied regression function for TCR, Panel B aggregates these results over the

[25] 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.

intersection of the age-group-specific domains. The dotted and dashed lines represent 90% and 95% confidence intervals, block-bootstrapped at the country level. Consistent with the patterns in Panel A, the average rate of fertility change declines linearly in the average growth rate. At the 10^{th} percentile of the average growth rate—where the economy shrank by 1.6% per year—TCR declined at an annual rate of 60 conceptions per 1000 women. At the 90^{th} percentile—where the economy grew by 3.2% per year—TCR declined at a 33% faster rate: 80 conceptions per 1000 women annually.

4.5.2 Mechanisms

Although controlling for trends in conflict, female education, urbanization, and infant mortality did not alter results in Table 3, other relevant covariates were omitted because they are not available for all country-years. For the long-run analysis, however, yearly measurements are less important than for the short-run analysis. Even with gaps in the data, one can compute informative estimates of the average annual rate of change in a covariate. In Table 5, we control for the average annual rate of change in each 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. For each of these covariates, we report two regressions: one including the average annual rate of change in the covariate, one omitting it but using the restricted sample with a non-missing average annual rate of change. We compute the average annual rate of change with the methods described in Section 3, only using country-year-age cells that have data on both the conception rate and the covariate.

Our theoretical framework emphasizes the hypothesis by Galor and Weil (2000) that long-run growth raises the return to human capital investment, which increases investment per child and therefore the marginal cost of children. A test of this theory is difficulty because it would ideally use data on schooling (or returns to schooling) 1-2 decades after the fertility outcome. As an imperfect substitute, we rely on school enrollment at the time of the fertility outcome, under the assumption that parents' expectations regarding their children's returns are heavily influenced by the current desirability of schooling. 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. The average rate of change in secondary enrollment is also closely related to the average rate of economic growth in our sample; a 1-log point higher average rate of growth predicts that secondary enrollment rises 0.1 percentage points faster per year. When we control for this covariate in column (2), the coefficients on average growth rise substantially. Because all but one of these coefficients are negative, they are attenuated by the inclusion of the rate of change in secondary enrollment; the TCR coefficient shrinks by roughly half. Therefore, trends in contemporaneous secondary school enrollment can partly explain our long-run results. Importantly, contemporaneous enrollment reflects the desirability of schooling, *not* the education of mothers. The results in Table 3 already established that maternal education does not explain the results.

A separate theory posits that the technological progress associated with economic growth raises the returns to women's work (Galor and Weil 1996), increasing the costs of childbearing and therefore pushing fertility downward. To examine this possibility, we first use the labor force participation rate of women over age 15, assembled by Olivetti (2014) from ILO databases. Columns (3)-(4) show no meaningful change in the long-run results from the inclusion of the average rate of change in this covariate. One complication is that the female labor force participation rate does exactly reflect the opportunity cost of women's time. 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, and may therefore create more of a work-fertility tradeoff. Panel data on the sectoral composition of the labor force are extremely sparse, so we instead use data on the sectoral composition of value added (agriculture, manufacturing, services, and other). Here again, in columns (5)-(6), controlling for trends in these sectoral composition variables fails to change the long-run results. Overall, our tests fail to find evidence that women's work plays an important role. Data on wages or the sectoral composition of the labor force would improve these tests but are unavailable for most of our sample.

As a final exploration into the mechanisms driving the long-run results, we control for trends in the Polity IV score, a measure of democratic institutions. Democracy does not play a key role in economic theories of the fertility transition, but demographer Dyson (2013) suggests a possible link. Whatever the theory, columns (7)-(8) reveal that trends in democratization do not explain the association between long-run growth and long-run fertility change.

Both here and in the long-run model of Table 3, it is interesting to note whether long-run changes in covariates actually have a relation with long-run growth. Pooling all cells from each analysis, Table A7 regress the average annual rate of change in each covariate on the long-run growth rate. Trends in all covariates from Table 3 (urbanization, adult female education, infant mortality, and conflict) are unrelated to long-run growth. Of the covariates in Table 5, however, all but one exhibit long-run relationships with growth. Secondary school enrollment trends upward with long-run growth; shares of value added in manufacturing and services also trend upward, while agriculture trends downward; and Polity scores trend downward. Changes in female labor force participation are uncorrelated with long-run growth, consistent with a u-shape.

4.5.3 Comparisons with Developed Countries and Alternative Datasets

As a companion to Section 4.4.4, Appendix Table A8 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 does not appear to be associated with more 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.[26]

Also following Section 4.4.4, Appendix Table A8 compares results for both datasets with results for the same samples using a standard aggregate fertility dataset. Here, we draw on fertility rates from the UN, which are available for 5-year age groups in 5-year intervals, instead of total fertility rates from the WDI. The five-year intervals make these data appropriate only for studying longer-run change, not annual fluctuations, but the age disaggregation is appealing. Unsurprisingly, interpolation and smoothing in the UN data do not bias the long-run results for the total fertility rate, which are similar to those for the WFS/DHS and HFD data. However, consistent with restrictive demographic modeling assumptions on age heterogeneity, the UN data perform poorly at the end of the reproductive lifespan: the coefficient for the 40-44 age group 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 in the long run.

[26] If we pool the WFS/DHS and HFD samples, we still find that the association between long-run growth and long-run fertility change is significantly negative in the 20s and significantly positive in the 40s.

5 Analysis of Cohort Fertility

If women fully offset the short-run effects 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. As noted in the theoretical framework, full offset is more likely for fluctuations early in the lifecycle; women approaching menopause may not have time to make up for lost childbearing opportunities. To investigate these issues, this section changes the unit of analysis to the country-cohort cell, defined as all women born in the same year in the same country, and relates the cohort's completed fertility rate with its experience of economic growth over the lifecycle.

5.1 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 $[40, 44)$, adjusting for the cohort's average age when surveyed $\overline{a}_{cj}$, a country fixed effect λ_c, and a cohort fixed effect δ_j:

$$CFR_{cj} = \sum_A \beta^A \overline{g}_{cj}^A + \theta \overline{a}_{cj} + \lambda_c + \delta_j + \varepsilon_{cj} \tag{9}$$

where $\overline{g}_{cj}^A$ is the average annual change in log GDP per adult over age interval A, measured in log points. Together, the β^A coefficients capture how completed fertility responds to within-country, within-cohort differences in economic growth experienced over the lifecycle.

The country fixed effect λ_c absorbs cross-country variation in long-run economic growth, so that the β^A coefficients reflect the persistent influence of the short-run fluctuations. However, the underlying variation is not exactly the same as that in the short-run period analysis. On the one hand, five year growth may be more similar to long-run growth; on the other, it may reflect deeper business cycle variation with greater liquidity effects. Nevertheless, aggregated into five year age intervals in this way, the model delivers more precise and concise estimates.

5.2 Results

Table 6 reports how a cohort's completed fertility rate relates to its experience of economic growth over the lifecycle. The first three columns use our primary measure of completed fertility, the number of children ever born per 1000 women. Columns (1) omits the country fixed effect from equation (9) and finds that economic growth is negatively associated with the completed fertility rate across the age distribution. This result is consistent with the Galor and Weil (2000) prediction regarding the long-run growth rate and the level of fertility.

When we include the country fixed effect in columns (2) and (3) to isolate the effects of fluctuations around the long-run growth rate, the estimated coefficients change dramatically. 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. Considering the theoretical prediction that parents will make smaller adjustments to fertility when those adjustments are more likely to be permanent, this age pattern lines up well with the rapid decline of the short-run coefficients after the late 20s. 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 40 children per 1000 women. The estimated coefficients shrink slightly but remain significant when we control for cohort average education and share urban (column [3]) or only count children who survived until the survey date (column [4]).

Puzzlingly, however, any of these magnitudes far exceed effects that the short-run effects would imply if they were permanent. This accumulating effect appears inconsistent with the dissipation of the short-run effects in Figure 3. 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.[27] 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, fertility may respond non-linearly to a sustained and deep recession, which may be better reflected in a five-year average than a single-year growth measure. Third, the 95% confidence intervals for the short-run effects (with our without offset) and the completed fertility effects contain values consistent with each other.

An alternative approach to estimating the fertility impact of economic conditions over the lifecycle would use the level of GDP per adult rather than its growth rate. In this approach, the country and cohort fixed effects absorb cross-country and cross-cohort variation in the levels of development and fertility but fail to address trends. In other words, levels-on-levels results would reflect a mix of short- and long-run associations, making them difficult to interpret. For completeness, we carry

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

out this approach in the final two columns of Table 6, and the results are mixed as expected. A specification *without* country fixed effects (column [5]) leads to both positive and negative significant coefficients, which has no coherent explanation. *With* country fixed effects (column [6]), coefficients are either close to zero or significantly negative, suggesting that long-run trends dominate short-run effects in this specification.

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 in the short run is not clear. One possibility involves couples taking 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 other 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 (Bongaarts 1980). How to distinguish these possibilities is a fruitful direction for future research.

The short-run patterns stand in stark contrast to the relationship between long-run trends in income per head 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.

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).[28] Perhaps most generally, our results highlight the importance of careful measurement, showing how one can use large amounts of retrospective survey data to improve on standard cross-national datasets.

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Table 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. "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.

Table 3: 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	Changes	Basic	Extended	Basic	Extended
	(1)	(2)	(3)	(4)	(5)	(6)
Ages 15-19	164	-1.2	0.10	0.12	-0.09	-0.03
			[0.07]	[0.07]*	[0.09]	[0.08]
Ages 20-24	261	-1.9	0.30	0.33	-0.27	-0.25
			[0.09]***	[0.09]***	[0.13]**	[0.13]*
Ages 25-29	253	-2.4	0.56	0.59	-0.43	-0.46
			[0.14]***	[0.14]***	[0.11]***	[0.11]***
Ages 30-34	209	-2.4	0.33	0.34	-0.43	-0.48
			[0.16]**	[0.16]**	[0.14]***	[0.12]***
Ages 35-39	144	-2.6	0.22	0.21	-0.15	-0.11
			[0.19]	[0.19]	[0.14]	[0.09]
Ages 40-44	65	-2.9	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	56,926	56,926	56,926	1,595	1,595

Notes: Columns (1)-(4) use country-year-age cells; columns (5)-(6) use country-age cells. Columns (3)-(4) regress the annual change in the age-specific conception rate on the annual change in 100 $\times$ 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: 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 × 100	0.24	-0.0001	-0.0022	-0.013	-0.009	0.012
	[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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: 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

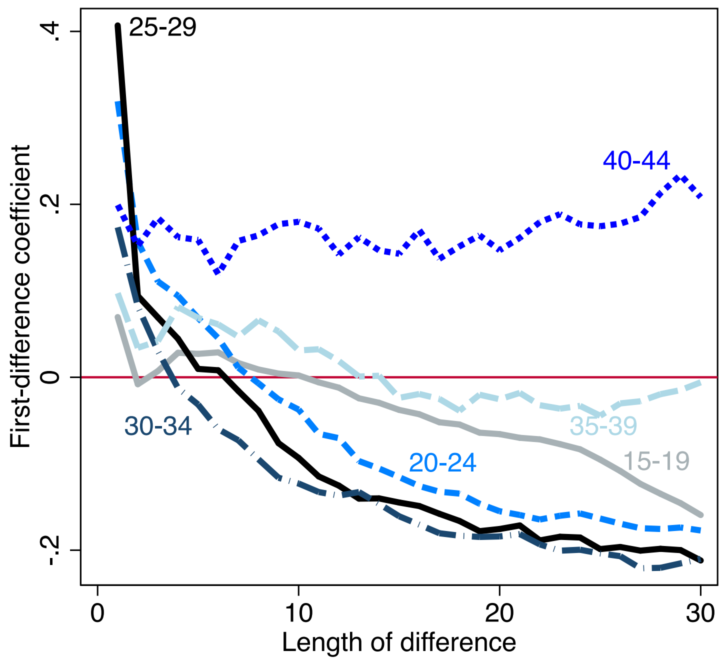
Notes: Regressions the average annual rate of change in the age-specific conception rate on the average annual rate of economic growth, as reported in columns (5)-(6) of Table 2. Each pair of columns restricts to the subsample with non-missing information on the average annual rate of change in the specified 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Economic Growth and Completed Fertility Across Cohorts Aged 45+

	Economic conditions measured as average...					
	Annual change in 100 × log GDPpa				100 × log GDPpa, PPP	
	(1)	(2)	(3)	(4)	(5)	(6)
Avg. economic conditions during ages...						
15-19	-55	-7	-15	-5	2.9	-0.9
	[18]***	[13]	[10]	[12]	[3.9]	[2.3]
20-24	-46	-3	-15	2	2.9	0.9
	[21]**	[14]	[12]	[14]	[4.3]	[2.8]
25-29	-66	10	1	7	-2.5	-3.6
	[17]***	[16]	[15]	[16]	[3.4]	[1.6]**
30-34	-42	38	26	29	-7.4	-4.2
	[14]***	[14]**	[12]**	[12]**	[3.8]*	[1.7]**
35-39	-46	43	35	36	6.8	1.9
	[20]***	[13]*	[12]***	[12]***	[3.7]*	[1.6]
40-44	-46	25	34	18	-11.4	-1.0
	[29]	[17]	[12]**	[15]	[3.3]***	[1.4]
Cohort avg. ed.			-226			
			[54]***			
Cohort % urban			-4.7			
			[5.3]			
Cohort FE	✓	✓	✓	✓	✓	✓
Country FE		✓	✓	✓		✓
Fertility measure	Ever-born	Ever-born	Ever-born	Surviving	Ever-born	Ever-born
Num. cells	935	935	935	935	935	935

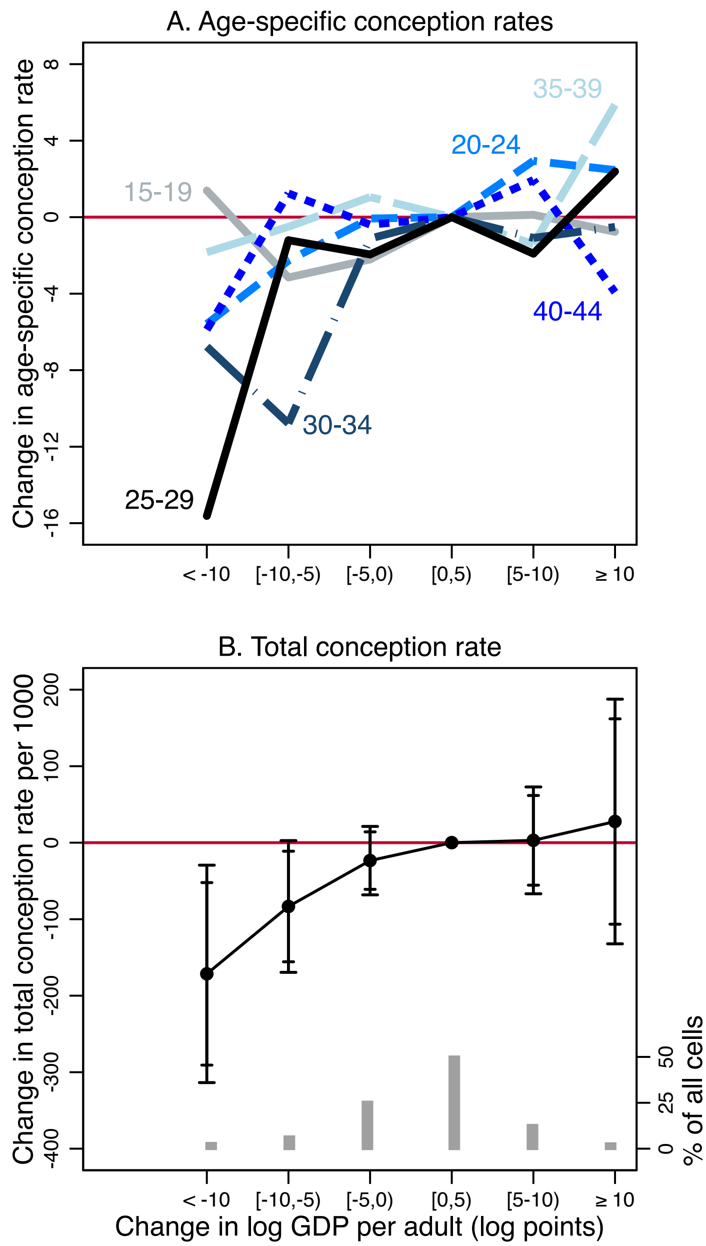
Notes: Dependent variable is the number of children per 1000 women. All regressions control for the average age (45-49) of the cohort when surveyed. Brackets contain SEs clustered by country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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



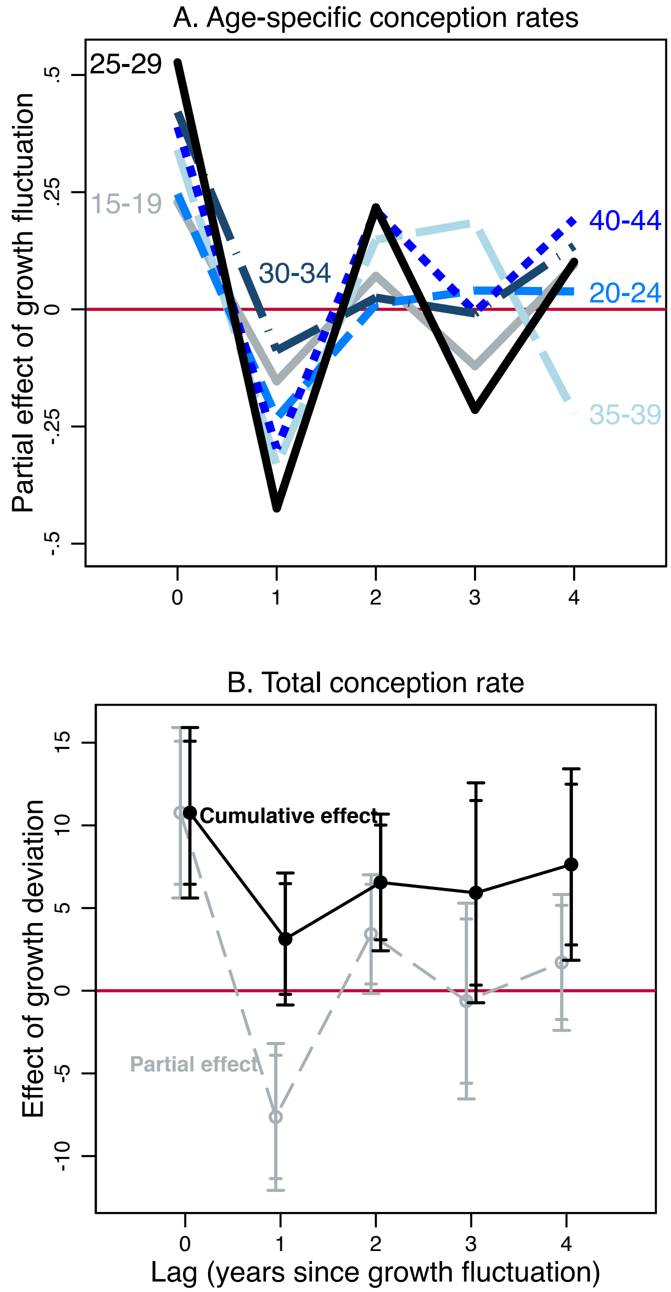
Notes: For each 5-year age group, the figure plots coefficients from regressions of the change in the conception rate from year $t - \Delta$ to year t on the change in 100 $\times$ log GDP per adult over the same period, controlling for single-year age indicators. Separate regressions were run for each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

Figure 2: Non-Linear Short-Run Estimates



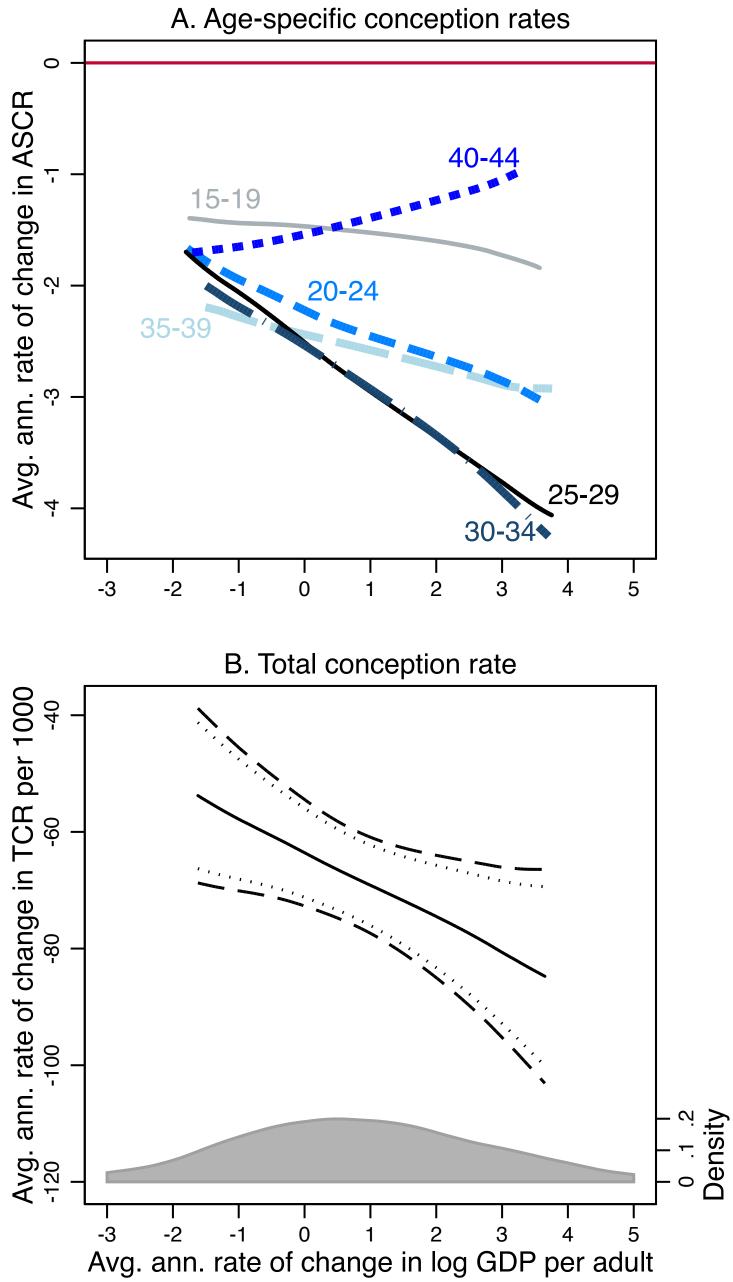
Notes: Panel A shows coefficients for each age group from regressions of annual changes in the age-specific conception rate on binned annual economic growth, controlling for country, year, and age fixed effects. Panel B shows implied estimates and CIs for the total conception rate per 1000 women, obtained by summing the age-group-specific estimates and multiplying by 5. Omitted category is [0,5). Major caps are 95% CIs; minor caps are 90% CIs. CIs clustered by country.

Figure 3: Distributed Lag Models



Notes: Panel A shows coefficients for each age group from regressions of annual changes in the age-specific conception rate on current and lagged annual changes in 100 $\times$ log GDP per adult, controlling for country, year, and age fixed effects. Panel B shows implied estimates and CIs for the total conception rate per 1000 women. Partial effects equal 5 times the sum of age-group-specific estimates; cumulative effects are the running sum of partial effects. Major caps are 95% CIs; minor caps are 90% CIs. CIs clustered by country.

Figure 4: Non-Linear Long-Run Estimates



Notes: Panel A shows local linear regression estimates for each age group, bandwidth = 2. The domain of each plot runs from the age group's 5th to 95th percentile of the average annual rate of change in log GDP per adult. Panel B shows implied regression function for the total conception rate per 1000 women, obtained by summing the age-group-specific estimates (for the domain in which they overlap) and multiplying by 5. CIs (dashed = 95%, dotted = 90%) are block bootstrapped by country. At the bottom of Panel B is a kernel density estimate for all country-age cells, bandwidth = 1.

Online Appendix (Not For Publication)

Theory Appendix

In the theoretical framework of Section 2, 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 (2):

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

and equation (3):

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

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 (4):

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

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

List includes all 255 World Fertility Surveys and Demographic and Health Surveys that could be matched with growth rates from the Penn World Table.

Table A2: Extended Model Results from Table 2

Age group:	15-19	20-24	25-29	30-34	35-39	40-44
	(1)	(2)	(3)	(4)	(5)	(6)
A. Short-run regression (Table 2, column 4)						
Δ ln(GDPpa)	0.12	0.33	0.59	0.34	0.21	0.22
× 100	[0.07]*	[0.19]***	[0.14]***	[0.16]**	[0.19]	[0.20]
Lagged ln(GDPpa)	1.34	0.56	0.94	1.39	-1.11	-0.37
× 100, PPP	[0.66]**	[0.79]	[0.78]	[0.97]	[0.95]	[1.26]
Δ avg. yrs. ed.	-9.34	-9.81	-6.53	-3.86	-1.94	-2.57
	[1.57]***	[1.92]***	[2.14]***	[2.11]*	[2.17]	[1.98]
Δ pct. urban	-0.01	0.17	0.04	-0.25	-0.36	-0.22
	[0.16]	[0.22]	[0.19]	[0.15]	[0.19]*	[0.17]
Δ conflict	-1.48	2.23	0.13	-1.25	1.84	3.00
	[1.87]	[3.07]	[2.74]	[3.72]	[3.53]	[3.20]
Δ IMR_{t-1}	0.02	0.19	0.27	0.04	-0.01	0.04
	[0.03]	[0.05]***	[0.08]***	[0.08]	[0.09]	[0.09]
Lagged Pop	0.002	0.005	-0.007	-0.004	0.001	0.018
Density	[0.005]	[0.007]	[0.004]*	[0.006]	[0.008]	[0.008]**
B. Long-run regression (Table 2, column 6)						
Trend ln(GDPpa)	-0.03	-0.25	-0.46	-0.48	-0.11	0.16
× 100	[0.08]	[0.13]*	[0.11]***	[0.12]***	[0.09]	[0.05]***
Initial ln(GDPpa)	-0.36	-1.28	-1.38	-1.11	-0.40	0.12
× 100, PPP	[0.26]	[0.28]***	[0.27]***	[0.34]***	[0.37]	[0.22]
Trend avg. yrs. ed.	-5.29	-6.03	-8.06	-10.76	-7.41	-6.57
	[3.85]	[4.28]	[3.56]**	[4.91]**	[4.63]	[2.73]**
Trend pct. urban	0.39	0.13	0.00	0.31	0.46	-0.14
	[0.38]	[0.64]	[0.43]	[0.42]	[0.40]	[0.20]
Trend conflict	2.2	8.86	12.29	19.95	19.82	4.12
	[12.38]	[11.27]	[12.33]	[20.21]	[19.73]	[8.13]
Trend IMR	-0.09	-0.02	0.10	0.08	0.02	-0.02
	[0.13]	[0.15]	[0.15]	[0.33]	[0.23]	[0.12]
Initial Pop	-0.005	-0.006	-0.007	-0.007	-0.004	-0.0009
Density	[0.002]***	[0.002]**	[0.002]***	[0.002]***	[0.002]**	[0.0010]

Notes: Each panel represents a single regression; each column provides coefficients for a separate age group. Panel A regresses the annual change in the age-specific conception rate on the covariates shown, controlling for country, year, and single-year age effects. Panel B regresses the trend in the age-specific conception rate on the covariates shown. The infant mortality rate is per 1000 live births; population density is population per square kilometer. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A3: 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A4: Aggregate Heterogeneity in the Procyclicality of Conceptions

	Lagged GDPpa, PPP	Lagged contraceptive prevalence	Female labor force share in 1990	Lagged average years of education	Lagged share urban at survey
	(1)	(2)	(3)	(4)	(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 $\times$ 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A5: 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 $100 \times$ 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A6: 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	Regression	Regression	Mean rate	Regression	Regression
	(1)	(2)	(3)	(4)	(5)	(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	5601	8.19	0.28	1920	5.55	6.44
rate per 1000		[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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A7: Does Long-Run Growth Predict Long-Run Change in Covariates?

	A. Covariates in Table 2					
	% Urban	Fem. avg. yrs. ed.	Infant mort. rate	Conflict		
	(1)	(2)	(3)	(4)		
ln(GDPpa)	-0.042	0.002	0.005	-0.001		
trend× 100	[0.031]	[0.003]	[0.077]	[0.001]		
Num. cells	1,595	1,595	1,595	1,595		
	B. Covariates in Table 5					
	Sec. sch.	FLFP	% VA in agriculture	% VA in manuf.	% VA in services	POLITY score
	(5)	(6)	(7)	(8)	(9)	(10)
ln(GDPpa)	0.106	-0.036	-0.176	0.111	0.065	-0.033
trend× 100	[0.039]***	[0.041]	[0.054]***	[0.033]***	[0.035]*	[0.014]**
Num. cells	1,297	1,261	1,424	1,424	1,424	1,532

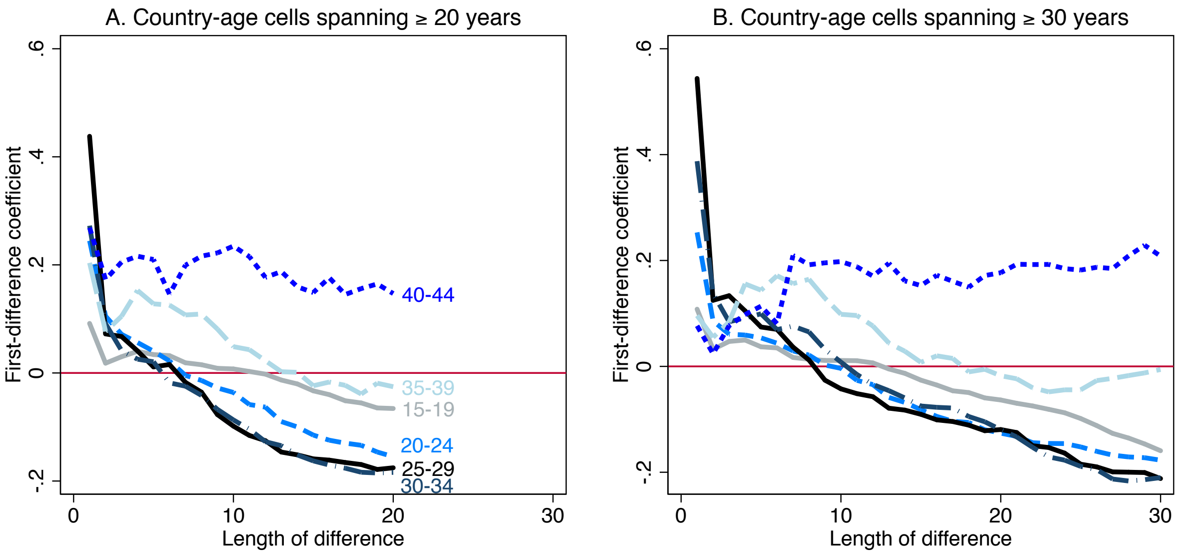
Notes: Bivariate regressions of the average rate of change in the specified variable on the average rate of change in log GDP per adult over 20+ years. The specified variables were used as covariates in the long-run analyses in Tables 2 and 5. Samples include all country-age cells used in the companion analyses in Tables 2 and 5. Brackets contain SEs clustered by country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A8: 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

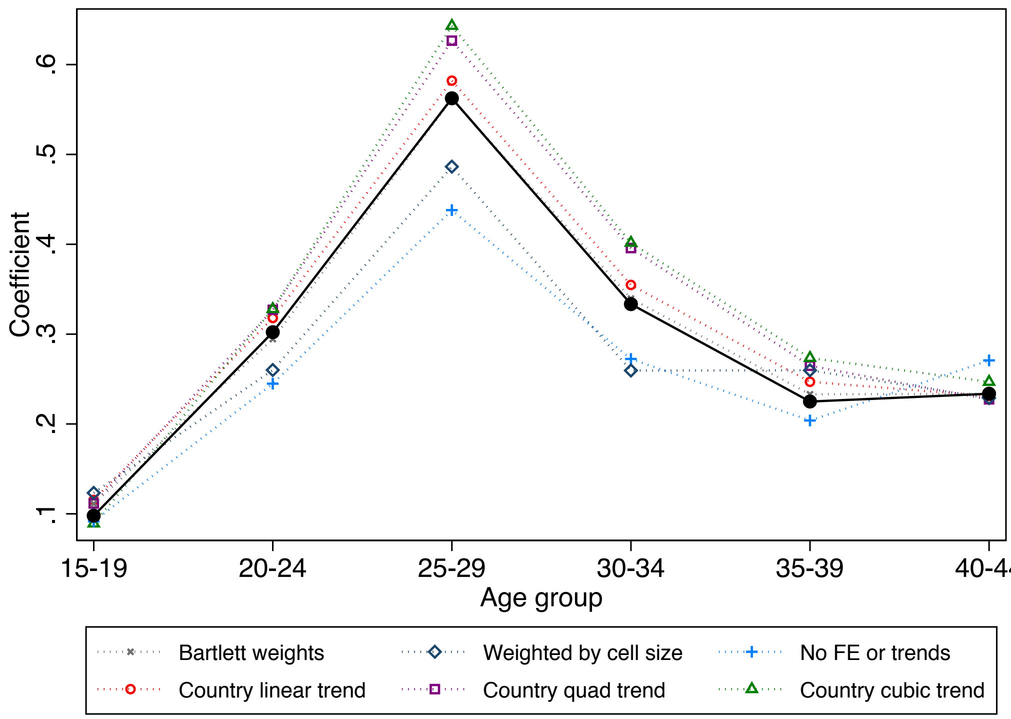
Notes: "WFS" = World Fertility Survey; "DHS" = Demographic and Health Survey; "HFD" = Human Fertility Database; "UN" = United Nations *World Population Prospects*, 2015 Revision. Coefficients from regressions of the average annual rate of change in the conception rate on the average annual rate of economic 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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



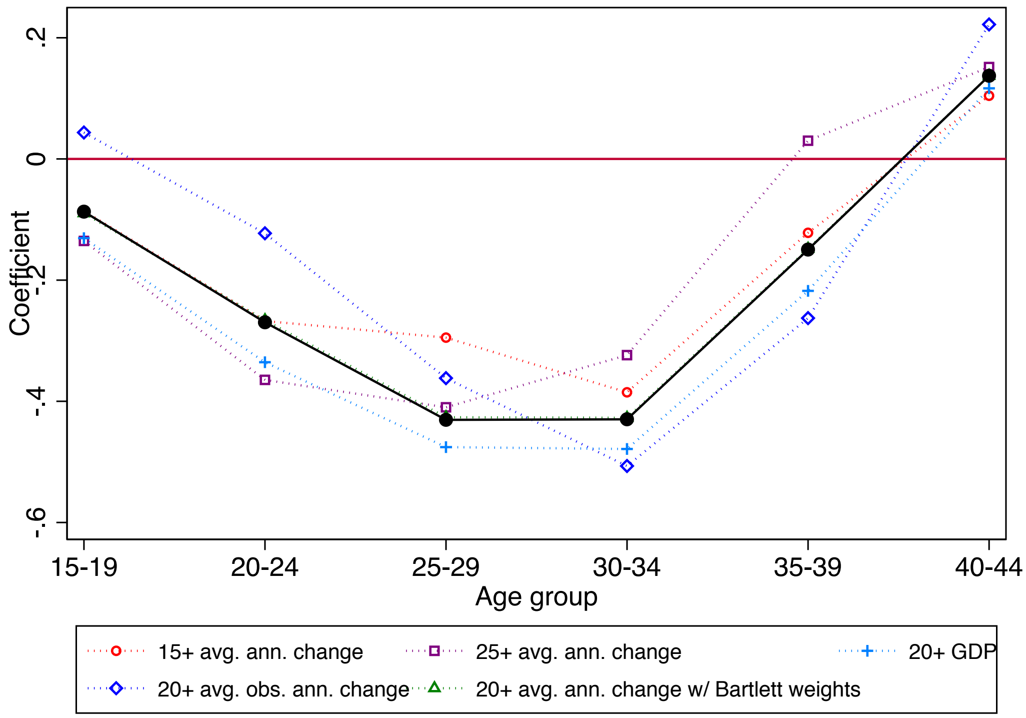
Notes: Reproduces Figure 1 using samples that do not change for different time horizons. For each 5-year age group, each panel plots coefficients from regressions of the change in the conception rate from year $t - \Delta$ to year t on the change in 100 $\times$ log GDP per adult over the same period, controlling for single-year age indicators. Separate regressions were run for each integer value of Δ from 1 to 20 (Panel A) and 1 to 30 (Panel B).

Figure A2: Alternative Short-Run Models



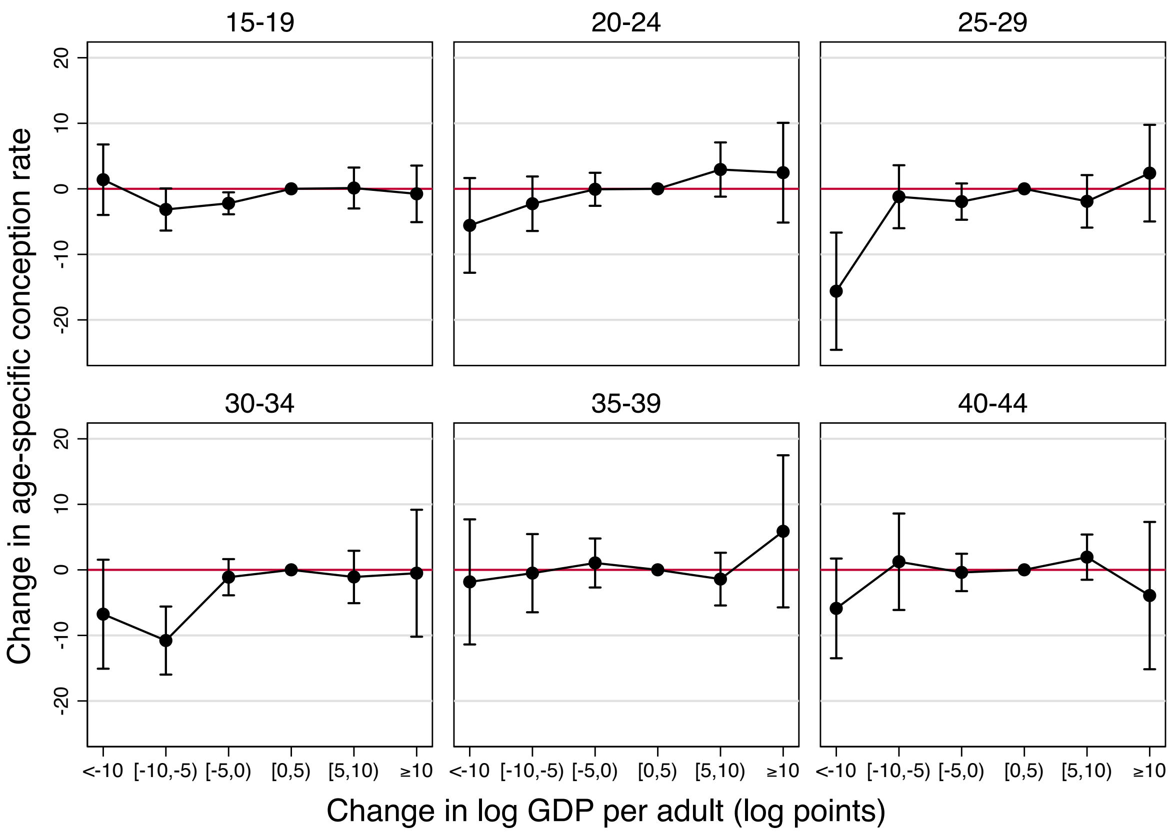
Notes: Age-group-specific coefficients from regressions of the change in the conception rate on the change in log GDP per adult. The thick black plot represents the coefficients from the long-run model reported in Table 2. "Bartlett" uses a Bartlett kernel to downweight longer recall periods. The remaining models add country-specific polynomials in time to the baseline model.

Figure A3: Alternative Long-Run Models



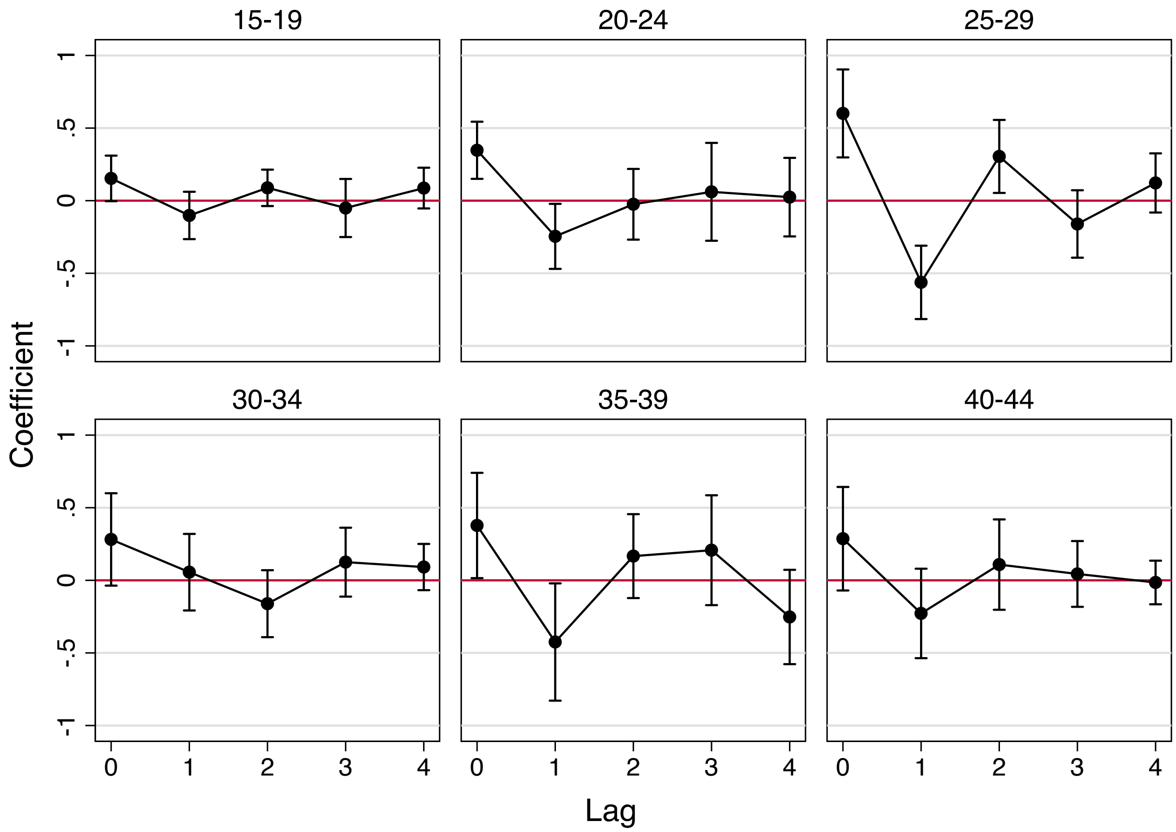
Notes: The figure compares results from different methods of computing the average annual rate of change. The thick black plot represents the coefficients from the long-run model reported in Table 2. "15+" and "25+" use alternative minimum time horizons (15 and 25 years) to estimate the slope of the 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 A4: Non-Linear Estimates by Age Group, Short Run



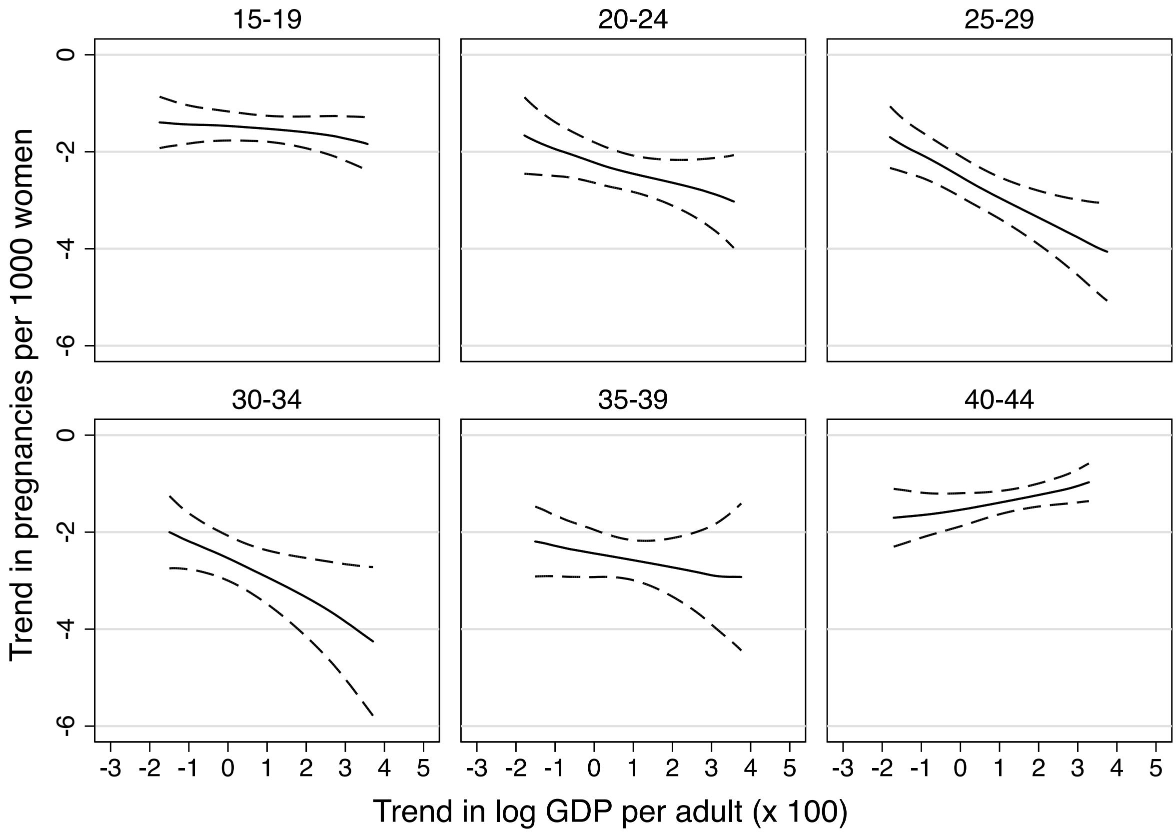
Note: Binned estimates reported in Figure 1, Panel A, here with 95% confidence intervals. Coefficients from regressions of annual changes in the age-specific conception rate on binned annual economic growth, controlling for country, year, and age fixed effects. Confidence intervals are clustered at the country level.

Figure A5: Distributed Lag Models by Age Group, Short Run



Note: Distributed lag model reported in Figure 3, Panel A, here 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.

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



Note: Local linear regression estimates with 95% confidence intervals. 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.