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Achieving sustainable population: Fertility decline in many developing countries follows modern contraception, not economic growth

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Abstract

The human population is projected to increase by 2.4 billion to 2100, endangering, for example, food security and biodiversity. Population growth depends strongly on fertility level, lowering of which is often assumed to depend on economic growth. Here we test this hypothesis using data from 136 developing countries, 1970–2014. We formed four country groups at different initial economy, and used graphical analyses, with estimates of variation. Falling fertility rates 1970–2000 showed little or no association with economy (GDP or household consumption). Fertility decreased regardless of whether the economy grew, was stagnant, or declined. But falling fertility was closely associated with increasing use of modern contraception, which was largely independent of changes in economy. Fertility decline hence was not caused by economic development, but followed contraceptive use. Family planning programs, with advice on family size and modern contraception, offer promising routes to sustainably low fertility where it has not yet been achieved.

KEYWORDS
conservation, demography, gross domestic product, household consumption, population growth

1 | INTRODUCTION

The human population is projected by the UN, United Nations (2022a) to increase from at present 8 to 10.4 billion by 2100. The rapid population growth is likely to impair human conditions, biodiversity, climate, food and freshwater resources (e.g., Crist et al., 2017). Population growth depends strongly on fertility rates, which need to be lowered to ensure long-term conservation of ecosystems and species (Bongaarts & O'Neill, 2018; Cafaro et al., 2022; Dasgupta, 2019; Ripple et al., 2017).

The total fertility rate (TFR) is the average number of children women would bear if surviving to the end of reproductive life, with the same probability of childbearing in each age interval as now prevails. Based on past and present global declines in TFR, the UN, United Nations (2022a) assumes in its medium projection that TFR in all countries converges to near replacement level (2.1 children) toward 2100. But altering the assumptions of models, especially the fertility level, markedly change the projections of future population size (Abel et al., 2016; Bradshaw & Brook, 2014; UN, United Nations, 2022a). Adequate population policies therefore depend on accurate knowledge about factors influencing TFR.

In the demographic transition, decline in mortality precedes fertility decrease (e.g., Livi-Bacci, 2017; Poston & Bouvier, 2017). In many western countries, TFR began to decline from about 1870 (Roser, 2022), following improved health, education and economy related to industrialization. In the third world TFR began to fall from about 1965, with marked variation among countries (Roser, 2022; UN, United Nations, 2022a). TFR depends on many factors, such

as child mortality, economy, education, family planning programs, female empowerment and schooling, social norms and religiosity (Bongaarts, 2016; Bongaarts & Hodgson, 2022; Colleran et al., 2014; de Silva & Tenreyro, 2017; Götmark & Andersson, 2020; KC & Lutz, 2017; Lee, 2020; Skirbekk, 2022). These factors are often correlated (Götmark & Andersson, 2020), hampering understanding of causation. Demographers tend to focus on the influence of family planning and culture, economists on household costs and gains (Bongaarts, 2016; Colleran et al., 2014; de la Croix, 2013; Lee, 2015). Many economists emphasize the role of increases in gross domestic product (GDP), income and consumption for TFR decline, whereas demographers usually emphasize behavior and fertility norms (Balbo et al., 2013; Barrett et al., 2020; Bongaarts, 2016; Shenk et al., 2013; van den Broeck & Maertens, 2015).

Theory developed by economists (e.g., Becker et al., 1990; Becker & Lewis, 1973) relates TFR decline to economic growth, assuming that parents derive utility from their own consumption, children and child quality ("human capital," e.g., education level). Boosting child quality involves costs for parents. As family incomes rise, demand increases for quality rather than number of children, leading to investment in human capital and smaller families. Economic research also considers opportunity costs of childbearing (Balbo et al., 2013; Pande et al., 2020; van Balen, 2010). Raising children takes time and can reduce family income in modern economies, leading parents to have fewer children ("motherhood wage penalty"). Lee (2015) summarized relevant economic theory, concluding that hypotheses remain to be empirically tested with long-term data, which is our goal here.

In a broad early study of TFR and developing countries, Chesnais (1992) concluded "There is thus no ambiguity about the matter: the secular fertility decline occurs only after profound economic changes" (p. 385). In 2010–2015, among countries in six global regions, TFR declined while GDP per capita increased, and the association was relatively strong in the three developing regions Asia, Latin America and Sub-Saharan Africa (Götmark & Andersson, 2020). Many recent studies based on models using countries as units conclude that fertility decline is partly due to economic growth (e.g., Caudell, 2015; Herzer et al., 2012; Madsen et al., 2018; Ranganathan et al., 2015). Also within-country studies (Shenk et al., 2013; van den Broeck & Maertens, 2015) found that economic factors such as land ownership, occupation, and employment opportunities for women, were strongly associated with fertility differences among individuals. In a survey of Swedish public opinion about causes of fertility decline in developing countries, improved living conditions, including better economy, was suggested by 25% of respondents. Fewer suggested increased education (19%), contraception (10%) or family planning (2%) (Wetzler, 2022). The influence of economy on fertility is of great interest, as economic growth is a goal for almost all nations (Krugman et al., 2018) despite its limitations (Dasgupta et al., 2022; O'Sullivan, 2020; Pilling, 2018), and developing countries are expected to grow economically (Sachs, 2015; UN, United Nations, 2022b).

The empirical analysis here spans 1970–2014, a period with globally strong economic growth (Krugman et al., 2018) and declining fertility (Roser, 2022; UN, United Nations, 2019). We analyze fertility decline among developing countries and compare its associations with economy and modern contraception (reviews in Bongaarts, 2016; Bongaarts & Hodgson, 2022). Contraception is often viewed as a "proximate" cause of fertility decline, but the degree to which it directly affects TFR is debated (see, for instance, Livi-Bacci, 2017, pp. 187–191). Inter-birth intervals have increased in developing countries (Casterline & Odden, 2016), contributing to reduced TFR. Contraceptives in several developing countries seem to be used especially for spacing, but not necessarily for limiting births (Abdi et al., 2020; Ali & Cleland, 2010; Egeh et al., 2019). Among four proximate factors influencing TFR (marriage/cohabitation, contraception, induced abortion, and postpartum infecundability, Bongaarts, 2015), contraception is clearly important for family planning and population policies of developing countries (Bongaarts, 2016; Singh et al., 2022). It is therefore motivated to study also long-term changes in TFR and the use of contraceptives in these countries.

Below we test if falling TFR is associated with rising economy as predicted by economic theory, or if it is more strongly related to family planning and use of modern contraceptives. We use data from 1970 to 2014 for developing countries on GDP per capita, household consumption per capita, and prevalence rate of modern contraceptives (CPR).

2 | MATERIALS AND METHODS

2.1 | Data

We use Microsoft Excel 2020 for analyses and graphs. TFR for countries are from UN, United Nations (2019) and for 5-year periods. We relate changes in TFR to changes in three national factors: gross domestic product (GDP) per capita, household consumption per capita, and prevalence rate of modern contraceptives (CPR). Since our main aim is to analyze changes in TFR from 1970 onwards in developing countries with high initial fertility, we focus on all countries with TFR greater than 3.0 in 1970, in total 136 countries (Table 1, and Supplementary Table A in Data S1). Some of the 136 countries lack data for one or two of the three other factors. Numbers of countries therefore differ between analyses as explained below.

GDP (flow of currency) is not wealth, which also includes stock (Dasgupta, 2007) and can include other forms of capital (Dasgupta et al., 2022). We complement the GDP per capita approach with analysis of household consumption per capita. Data for GDP are from the Maddison Project (2018) denoted "cgdppc" and representing "Real GDP per capita in 2011 US $, multiple benchmarks (suitable for cross-country income comparisons)." Such data are available for 110 of the 136 countries. We calculate mean GDP per capita for 5-year periods 1970–2014. Eight countries lack data from 4 of 5 years in the first period; we then use the value for the remaining year. Seven countries lack data for the second period; we instead use the mean value of the

TABLE 1 Regional distribution, economy, contraception and number of countries analyzed[a]

	Asia and Oceania	Latin America, Caribbean	Arab States	Sub-Saharan Africa	Eastern Europe	West Europe and related
Initially selected (136 countries)	37	30	20	44	3	2
GDP analysis (110)	23	23	19	40	3	2
Very low (28)	5	0	1	22	0	0
Low (34)	11	7	6	10	0	0
Intermediate (25)	4	10	5	4	2	0
Relatively high (23)	3	6	7	4	1	2
Consumption analysis (58)	8	12	8	28	0	2
Very Low-Low (19)	2	0	3	14	0	0
Intermediate (22)	4	3	5	10	0	0
Relatively high (17)	2	9	0	4	0	2
Contraception analysis (47)	12	17	10	7	1	0
Very Low-Low (16)	3	2	4	7	0	0
Intermediate (17)	5	5	6	0	1	0
Relatively high (14)	4	10	0	0	0	0

[a]Countries are listed in Supplementary Table A in Data S1 and Table 1.

first and third five-year period. The 26 countries (of 136) lacking data were mainly small island or mainland states (Supplementary Table A in Data S1). Mean population size of the 110 countries included was 57.5 million (median 13.1 million), and for the 26 excluded countries it was 5.4 (median 0.6 million, see Supplementary Table A in Data S1).

For household consumption per capita, we use data and estimates from the World Bank (2020) with the same 5-year periods as for TFR and GDP. The data represent household (private) final consumption expenditure per capita in constant 2010 US $, based on the market value of all goods and services, including durable products such as cars, purchased by households (for details, see World Bank, 2020). Data are available for 58 of the 136 countries. The first one or two 5-year periods lack data for 11 countries; we used the mean for the remaining countries as estimates for the periods. Removal of the 11 countries does not markedly affect the result (below, Figure 3a, and see extra Figure in Supplementary Table B in Data S1, sheet Household consumption). To make the results fully comparable with those based on GDP per capita, we repeated the GDP analysis using the 58 countries from the consumption analysis (see Section 3).

Contraceptive prevalence rate (CPR) data are from UN, United Nations (2019). CPR is recorded for "generally married or in-union women", where "a union involves a man and a woman regularly cohabiting in a marriage-like relationship." CPR is the proportion (%) of "women of reproductive age who are married or in a union and who are currently using a method of contraception." We use data for women or couples "using any modern method" (defined as including sterilization, IUD, implant, injectable, pill, condom, vaginal barriers, lactational amenorrhea method, emergency contraception, or other, e.g. contraceptive patch or vaginal ring). A limitation is that sexually active unmarried women and those not in union are lacking in the data. We only include modern methods as they are most effective and emphasized in the UN Sustainable Development Goals (UN, United Nations, 2022b). Data are available for 47 of the 136 countries (see Supplementary Table B in Data S1).

To compare the results with those for GDP and household consumption, we repeated these latter analyses using the same set of 47 countries (see Section 3). Data for CPR starts with the 10-year period 1970–1980, when only a single year (value) was available for many countries, then follows one 6-year period and five 5-year periods. CPR value was missing for three countries in the last five-year period, and we used mean value of the remaining 44 countries for this period. Removal of the three countries does not markedly affect the result (below, Figure 4, and see extra Figure in Supplementary Table B in Data S1, sheet Contraceptive prevalence). Data for CPR are based on surveys that are not repeated regularly, but sometimes several values were available for a period; we then use the mean.

2.2 | Statistical analyses

As in many other multi-national studies, the units of analyses, countries, are neither drawn by random sampling from the world population of countries, nor can they be regarded as statistically independent units (Dodson et al., 2022; Götmark & Andersson, 2020), so they do not meet requirements for statistical inference. For robustness we therefore avoid standard errors and other inferential statistics and instead use simple means, $\overline{X} = \sum X_i/n$, and standard deviations, $SD = n^{-1} \sqrt{\sum} (X_i - \overline{X})^2$. We also present the most important results in graphs, for visual clarity showing only mean values. Standard deviations for these means are shown in Supplementary Figures S1–S13 and below in Figure 2.

For analysis of the longitudinal relationship of TFR to other factors, we separated countries into 3 or 4 groups which differ in general level of

a factor over time (see Table 1, three groups when the number of countries was smaller, data also in Supplementary Table B in Data S1). For analysis of the role of GDP per capita, we computed its mean for each of the 110 countries over the whole period 1970–2014 (mean of nine 5-year periods) and ranked the countries by their mean GDP per capita. The outcome suggested four sufficiently large groups for analysis (Table 1): group Very Low (28 countries), with annual means between 600 and 2000 US $ per capita (656–1918); Low (34 countries), with means of 2000–5000 (2036–4905); Intermediate (25 countries), with means of 5000–10,000 (5102–9696); and Relatively High (23 countries), with means >10,000 US $ per capita (10,095–27,294, and two outliers: Kuwait 61,731 and Qatar 106,204 US $ per capita).

For analysis together with TFR we use each country group's change in GDP per capita 1970–2014. We compute mean GDP per capita for each 5-year period and country group (below, Figures, and Supplementary Table B in Data S1). This gives a series of nine values (nine 5-year periods 1970–2014). In graphs of TFR (*y*-axis) and mean GDP per capita (*x*-axis), we show for each country group how these two variables change over time 1970–2014.

In the same way, we analyze changes in TFR together with household consumption per capita, and with contraceptive prevalence rate, CPR (Figures below, and Supplementary Table B in Data S1). For these latter two factors, data are available from fewer countries. We therefore use only three country groups as they would otherwise be very small. We also analyze CPR together with GDP per capita to clarify whether CPR depends on GDP (Figure below, and Supplementary Table C in Data S1).

Sizes of country groups for all factors in six global regions are in Table 1. Sub-Saharan Africa had the highest number of countries, and Asia and Latin America are well represented, but European and related western countries are fewer since nearly all of them had TFR <3 in 1970. Compared to the analysis with GDP, representation of countries from Latin American and Sub-Saharan Africa is proportionally slightly higher in the household consumption analysis (Table 1). For CPR, Sub-Saharan countries are fewer, but the region is well represented in the subgroup Very low/Low.

Family planning here means "attempts by couples to regulate the number and spacing of births" (Poston & Bouvier, 2017), with choices "central to gender equality and women's empowerment" (UNFPA, 2022). The indicators for the UN's (2022) Sustainable Development Goals 3 (on health) and 5 (on gender) include "family planning satisfied with modern methods" (Goal 3), and "informed decisions…regarding contraceptive use" (Goal 5). In contrast, a family planning *program* is "a systematic effort, often government-sponsored, to provide the information, supplies, and services for modern fertility control" (Poston & Bouvier, 2017). "Sustainable population" denotes an economy protecting resources, biodiversity and reasonable standards of living for people (Dasgupta, 2019, see also Hickel, 2018). Such a World population may be 6 billion in one of the highest estimates of Dasgupta (2019), and maximally 3 billion in Lianos and Pseiridis (2016) analysis.

3 | RESULTS

3.1 | Fertility and GDP per capita

Among 136 developing countries with high or relatively high TFR in 1970 (3.0 or more), data on GDP per capita were available for

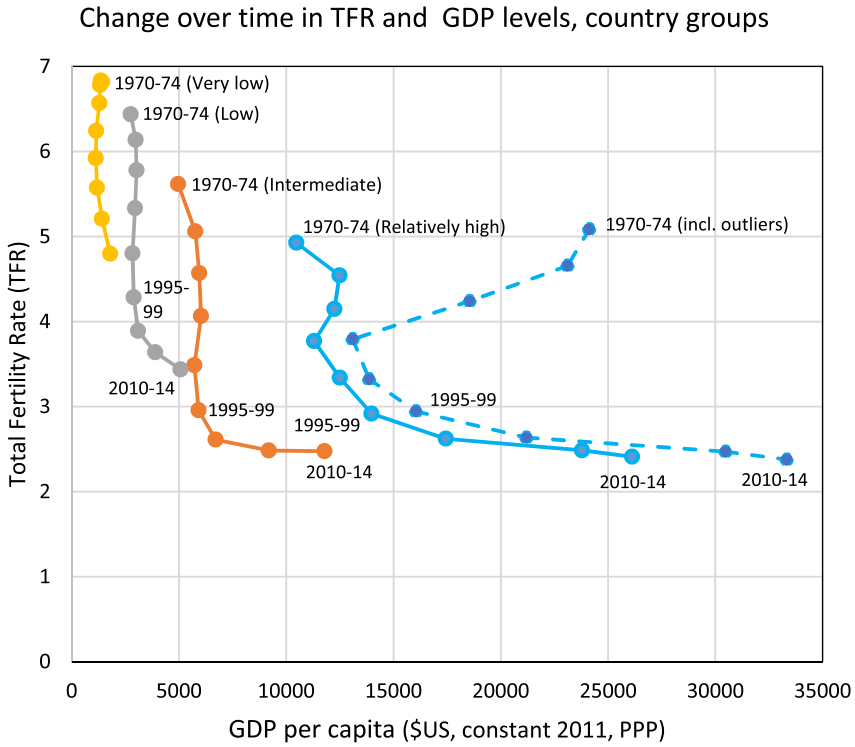

FIGURE 1 Changes 1970–2014 in total fertility rate (TFR) and economy (GDP per capita) in four groups of developing countries at different initial levels of economy: "Very low" (28 countries), "Low" (34), "Intermediate" (25) and "Relatively high" (21). During the first 30 years (1970–1999) fertility decreased markedly in all groups although the economy was almost constant or even declined between successive periods [Dots are means of successive 5-year periods for the countries in each group. The dashed blue line includes two outliers, rich oil states Qatar and Kuwait. The large first dot for "Very low" includes the first three 5-year periods, when both TFR and GDP remained almost constant. Variation (SD) about the means is shown in Supplementary Figures S1–S13] [Colour figure can be viewed at wileyonlinelibrary.com]

110 countries, divided into four groups. In all four groups TFR declined on average by about 1.5–2.5 child per woman during the first 30 years (1970–1999, Figure 1). This large decrease took place although GDP per capita remained almost constant in developing countries at "Very low," "Low" and "Intermediate" GDP levels. In the "Relatively high" GDP country group, results depend strongly on two outliers, the rich oil states Qatar and Kuwait. When they are included in Figure 1 (dashed line), mean GDP per capita declined markedly 1970–1984 during the oil crises, and so did TFR.

GDP per capita in the Very low group remained low over the entire period 1970–2014 (Figure 1). Yet, its mean TFR declined from 6.8 to 4.8. TFR declined greatly also in the Low and Intermediate groups 1970–1999 although GDP per capita stayed almost constant (Figure 1). On the other hand, 2000–2014 when GDP per capita increased in these two groups, there were only modest declines in TFR. This is so also in the Relatively high group. Most of its TFR decline took place 1970–1999, as in the other three groups. Table 2 shows mean changes in TFR and GDP per capita during the two periods 1970–1999 and 2000–2014.

These results show that TFR declined strongly in spite of little change in GDP per capita 1970–1999. In all four groups, TFR declined markedly even during periods when GDP per capita decreased (Figure 1). Moreover, when GDP increased markedly 2000–2014 there was only modest decline in TFR. Increasing economy (GDP per capita) therefore was not a major cause of the great reductions in TFR that occurred among developing countries 1970–2014.

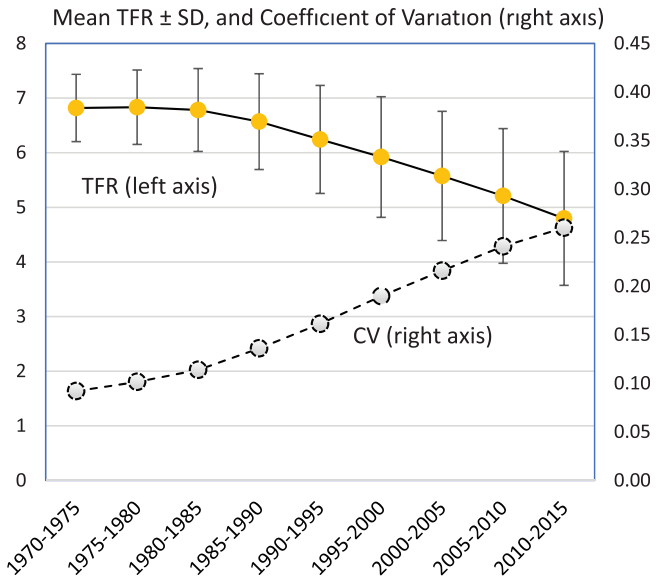

FIGURE 2 In group Very low, variation among countries in total fertility rate (TFR) increased 1970–2015, as shown by increasing standard deviation, SD (vertical bars) and coefficient of variation, CV. Most of the 28 countries experienced strongly declining TFR, but it changed little or not at all in a few countries (see Section 4). [Colour figure can be viewed at wileyonlinelibrary.com]

There is another interesting trend in group Very low, where TFR variation among countries increased over time (Figure 2). Whereas TFR on average declined by 2.02 among the 28 countries in this group, it changed little or not at all in 5 African countries (mean decline 0.56; see Section 4).

3.2 | Fertility and consumption per capita

To control if the lack of relationship between fertility and economic growth at country level depends on our use of GDP per capita as a measure, we repeat the analysis instead using household consumption per capita. Fewer countries with data are available for this analysis: 58 among the initial 136 (110 in GDP analyses). To maintain reasonably large country groups, we form three groups that differ in consumption level; Very low/Low, Intermediate, and Relatively high household consumption per capita (for grouping, see sheets in Supplementary Table B in Data S1).

Figure 3a shows that TFR declined 1970–2014 in similar manner for group Very low/Low as it did for group Very low GDP in Figure 1. Likewise, group Intermediate in Figure 3a is similar to group Low GDP in Figure 1. Also with household consumption per capita as the measure of economy, TFR decline was therefore unrelated to economic growth in these two groups of countries. In group Relatively high, fertility decline was associated with increasing consumption per capita (Figure 3a). This group of 17 countries contains among others Ireland and Israel, and nine from Latin America.

As the number of countries were fewer here than in the GDP analysis, for comparison we repeated the latter using the same countries as in the consumption analysis (Figure 3b). The results were similar for GDP per capita and household consumption per capita (Figure 3a,b).

In conclusion, among developing countries with initially high fertility, the decline in fertility 1970–2014 was not mainly caused by increasing economic development, whether measured by per capita GDP or household consumption.

3.3 | Fertility and contraceptive prevalence rate

In analyzing whether fertility decline is related to changes in the use of modern contraceptives, we could use 47 of the 136 countries, divided into three groups differing in initial level of contraceptive use. [Time periods differ slightly from the analyses with economy above, as surveys of contraceptive prevalence rate (CPR) have been irregular, see Material and methods]. As shown in Figure 4, falling fertility is consistently associated with increasing contraceptive use 1970–2015. In all three country groups, TFR declined almost linearly with increasing CPR.

To control whether the 47 countries used in the contraception analysis were perhaps atypical compared to those used in the previous economy analyses, we re-analyzed TFR together with per capita GDP and household consumption for this group of

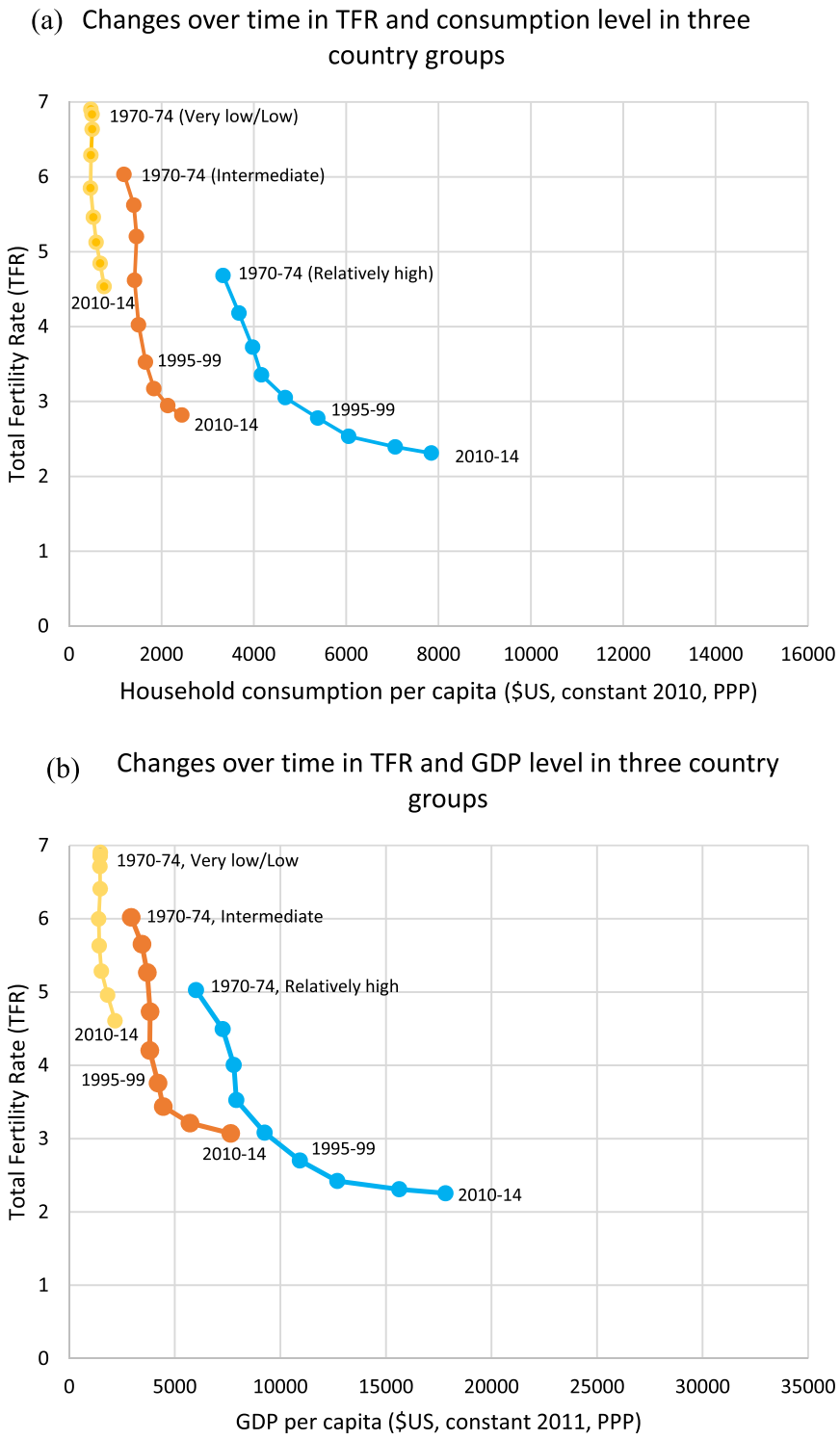

FIGURE 3 (a) Changes in total fertility rate (TFR) and household consumption per capita 1970–2014, in 5-year periods. The three groups of countries differ in consumption level, from left to right: "Very low/low" (19 countries), "Intermediate" (22 countries) and "Relatively high" GDP (17 countries). Fertility fell markedly in the first two groups in spite of low economic growth, and consumption per capita even decreased in the very low/low group during much of the period. In the group Relatively high, fertility declined while consumption increased. Dots represent 5-year mean values. (b) Changes in TFR and GDP per capita 1970–2014. Countries and country groups are as in (a) above [Colour figure can be viewed at wileyonlinelibrary.com]

47 countries. There was no indication that the CPR countries are atypical: they have similar relations as the groups in Figure 1 between TFR and GDP, and in Figure 3 between TFR and consumption (see Supplementary Figures S14 and S15).

Was the increasing use of modern contraception a consequence of better economy? To test this possibility, we plot CPR in relation to GDP per capita in Figure 5. It shows that CPR increased largely independently of GDP 1970–1999. When CPR rose strongly during that period, GDP per capita even declined in the Very low/Low group, and it increased only modestly in the two other country groups. Increasing use of modern contraceptives therefore was not mainly a consequence of economic growth. Whether this was so also after 1999, when GDP as well as contraceptive use increased, is not clear from this analysis.

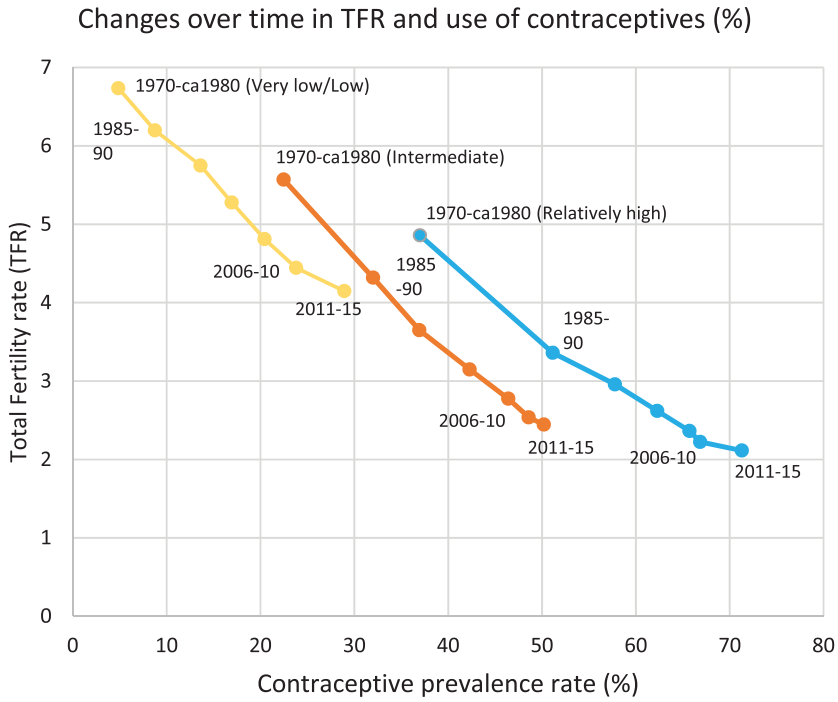

FIGURE 4 Total fertility rate (TFR) and contraceptive prevalence rate (CPR) 1970–2015 in three groups of developing countries, differing in initial levels of CPR. From left to right, "Very low/Low" CPR (16 countries), "Intermediate" (17) and "Relatively high" (14). The relationship between fertility and CPR is approximately linear in all three country groups [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Changes[a] in total fertility rate (TFR) and GDP per capita in four groups of countries at different economy levels. Changes in GDP per capita are modest 1970–99, larger 2000–2014

Country group (Economy level)	Early period, 1970–1999		Recent period, 2000–2014	
	TFR change	GDP change	TFR change	GDP change
Very Low	−0.18	−60	−0.37	225
Low	−0.43	−150	−0.28	727
Intermediate	−0.53	190	−0.16	1955
Relatively high	−0.43	701	−0.19	4050

[a]Mean change per 5-year period 1970–99 (5 periods) and 2000–2014 (3 periods).

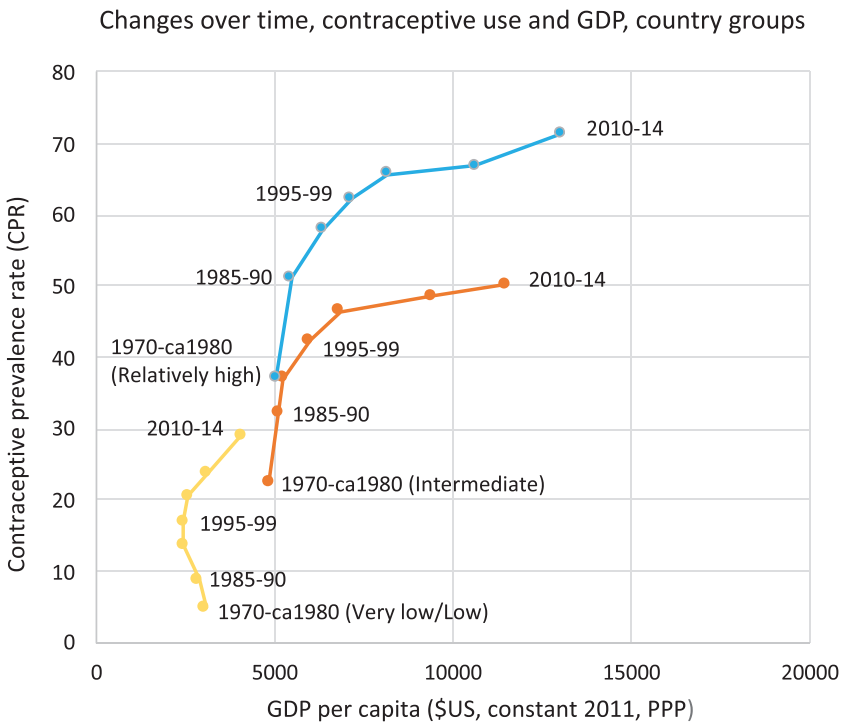

FIGURE 5 Contraceptive prevalence rate (CPR) and GDP per capita 1970–2014 in three groups of countries differing in level of GDP per capita. From left to right: "Very low/Low" (16 countries), "intermediate" (16 countries) and "Relatively high" GDP (14 countries). During the first 30 years (1970–1999), contraceptive use increased markedly in the three groups although GDP per capita increased only modestly, or even declined (Very low/Low). After 1999, both GDP and contraceptive use increased. (Data in Supplementary Table C in Data S1) [Colour figure can be viewed at wileyonlinelibrary.com]

4 | DISCUSSION

The results show that large fertility declines among developing poor countries 1970–99 were not caused by economic growth, in terms of per capita GDP (Figure 1) or household consumption (Figure 3). There was little or no association between changes in economy and fertility in the poorest country groups.

In contrast, declining fertility was strongly and consistently associated with increasing use of modern contraceptives. Over the 45-year period, all three country groups in Figure 4 have an approximately linear relationship between TFR and CPR. The strong association is encouraging: for individual women, use of contraceptives can prevent undesired pregnancies and births, and for populations and countries it can reduce unsustainably high fertility and growth. But modern contraceptives are still unavailable for hundreds of millions of women, many of which face undesired pregnancy and child birth (see below).

4.1 | Fertility and economic growth

To test whether TFR decline was caused by economic growth we used four groups of developing countries, ranging from Very low to Relatively high GDP per capita (three groups for consumption per capita). Remarkably, the four groups showed similar TFR trends 1970–1999 (Figure 1). Moreover, TFR decreased markedly in all groups also during periods when GDP decreased (Figure 1). The widespread influential view that "development is the best contraceptive" therefore does not hold as regards economic development at country level. Access to and use of modern contraceptives instead offer direct, instant means for avoiding unwanted pregnancy and reducing unsustainably high population fertility.

TFR is related to multiple factors (Bongaarts, 2016; Colleran et al., 2014; de Silva & Tenreyro, 2017; Götmark & Andersson, 2020; KC & Lutz, 2017; Lee, 2020; Skirbekk, 2022), and studies focused at the individual level show that e.g. increased female schooling and economy bring about lower fertility (Ali & Gurmu, 2018; Balbo et al., 2013; Colleran et al., 2014; Keats, 2018; Pande et al., 2020; Shenk et al., 2013; van den Broeck & Maertens, 2015). At country level, however, our results show that economic growth does not explain the fertility drop that took place between 1970 and 2014, particularly 1970–1999, when fertility fell the most in poor countries. Instead, fertility decline usually preceded substantial economic growth, which may even be a consequence of lowered fertility (Canning & Schultz, 2012; Finlay & Lee, 2018; O'Sullivan, 2013) and "demographic dividends" (Bloom et al., 2003; Kotschy et al., 2020). Economic growth can be enhanced when the working part of the population increases relative to the part outside working age.

TFR decreases with increasing number of school years for females (e.g., Ali & Gurmu, 2018; Götmark & Andersson, 2020; KC & Lutz, 2017; Keats, 2018; Skirbekk, 2022), and the duration of girls' education increased globally after 1970 (McClendon et al., 2018). But evidence from low- and medium-income countries suggests that increased education may have small effects on TFR, and evidence linking fertility to education was inconsistent in a meta-analysis (Psaki et al., 2019). More work on this topic is needed. Cultural aspects and social desires and norms, including gender roles and religiosity, can also influence fertility and family size (Assaf & Davis, 2021; Upadhyay et al., 2014; Westoff & Bietsch, 2015). The influence of expanding religions and religious education on fertility and population growth in developing countries need more study.

We also analyzed TFR in relation to household consumption, a measure closely related to spending by individuals. Declining family size in the two poorest groups of countries was unrelated to household consumption. The negative association of TFR with consumption rate in the Relatively high group (Figure 3) accords with an influence of economic growth on fertility in more developed countries. But the relationship can be bi-directional, and there is evidence that lowered TFR can help improve the economy of developing countries (Bloom et al., 2003; Bongaarts & Hodgson, 2022; Canning & Schultz, 2012; Finlay & Lee, 2018; Kotschy et al., 2020; O'Sullivan, 2013).

4.2 | Fertility and modern contraception

The contraceptive prevalence rate (CPR) was relatively independent of GDP per capita (Figure 5), at least for the period 1970–1999. Clearly, other factors than economic growth led to increased use of modern contraceptives and reduced fertility rates. From about 1960, international family planning (FP) programs in developing countries (World Bank, 2007) have contributed to reducing fertility and family size, by information, counseling and media attention (de Silva & Tenreyro, 2017; Bongaarts & Hodgson, 2022), and by increasing access to and use of modern contraceptives by women and couples (Rana & Goli, 2018).

In Sub-Saharan Africa, the region with highest TFR (UN, United Nations, 2022a), FP programs have generally been weak (May, 2017) and in many countries remain so (Götmark & Andersson, 2020). But for 24 Sub-Saharan countries, FP programs and increased female schooling were positively correlated with contraceptive prevalence rate 1990–2015 (Bongaarts & Hardee, 2019). Without FP programs, CPR remained low there even where education levels rose substantially. Improved education and health in poor countries is of course highly desirable, but for lowering fertility they may have less immediate effect than FP programs that increase the use of modern contraceptives (Rana & Goli, 2018; World Bank, 2007).

Although natural (traditional) contraception is also involved in family planning, it is often unreliable compared to modern methods (Cleland, 2020), which have greatly reduced TFR in several countries. In the United States, the contraceptive revolution led to a sharp drop in fertility during the 1960s (Bailey, 2010), and contraceptive pills are considered a main cause of fertility decline in the United Kingdom (Murphy, 1993). Use of modern contraceptives has also contributed to strongly reduced fertility in for example Iran and some other developing countries (Abbasi-Shavazi & McDonald, 2006; World Bank, 2007).

Our results agree with and strengthen the evidence that use of modern contraceptives are crucial for reducing TFR, as it dropped

almost linearly with increasing CPR in developing countries (Figure 4). In the group Very low/Low, 9 of 16 countries are African, still with comparatively high TFR that decreases more slowly than it did in Latin America and parts of Asia (UN, United Nations, 2022a). But also in Africa, declining TFR is associated with increasing use of modern contraceptives (cf. figure 3.4 in Bongaarts & Hodgson, 2022).

The importance of contraceptive prevalence rate for TFR decline is further supported by differences among countries in group Very low in the GDP analysis (Figure 2). Whereas most of the 28 countries in this group had strongly declining TFR 1970–2014 (mean decline 2.02), TFR changed little or not at all in 5 African countries (mean decline 0.56). These 5 countries (not in Figure 4 because early data are lacking) in 2010–2015 all had much lower contraceptive use (mean CPR 15%) than six comparable African countries with strongly declining TFR (mean decline 2.82, mean CPR 45%, see Supplementary Table D in Data S1). This difference also points to the importance of modern contraceptives for fertility decline.

The TFR drop in developing countries 1970–2014 is also related to other factors such as reduced child mortality, increased education, family planning programs, urbanization (Lerch, 2019; Schoumaker & Sanchez-Paez, 2020) and media exposure (de Silva & Tenreyro, 2017; Manon, 2013). Among proximate factors influencing TFR, age of marriage and especially age of sex debut are important (Ariho & Kabagenyi, 2020), as is abortion (Cleland, 2020) and postpartum infecundability (Singh et al., 2022). More detailed country studies (Ariho & Kabagenyi, 2020; Shenk et al., 2013; van den Broeck & Maertens, 2015) and field and "natural" experiments (Ali & Gurmu, 2018; Bongaarts, 2016; Bongaarts & O'Neill, 2018; Khan & Wang, 2021) are needed to assess the relative role of each factor.

4.3 | Sustainability consequences

Continued decrease of TFR in many countries, as assumed by the UN, United Nations (2022a) in its medium population projection and in other projections (Abel et al., 2016; Bradshaw & Brook, 2014), is required for stabilizing the rapidly growing human population at sustainable level. The UN, United Nations (2022a) "medium variant" projection is 10.4 billion people in 2100, whereas its "constant fertility" projection instead would lead to 19 billion. In contrast, assuming UN, United Nations (2022b) Sustainable Development Goals (SDGs) with a strong fertility reduction, the population could be 8.5 billion by 2100 (Abel et al., 2016). At present, populations decline in about 30 countries (mainly developed) of 200 countries, due to age structure ("aging"), low fertility and/or emigration. Reduced population size can benefit both environment and people by, for instance, less crowding, lower consumption, and reduced pressure on resources and wildlife (Götmark et al., 2018; Skirbekk, 2022). In our country group Relatively high GDP, ultra-low fertility occurs in South Korea (1.1), and although its dense population has not yet started to decline, policies for declining aging populations are needed (see Park, 2020).

Unintended pregnancies and abortions are major problems for women in poor countries, and elsewhere. As many as 121 million such pregnancies per year occurred 2015–2019, 61% ending in abortions, many illegal and dangerous (Bearak et al., 2019). Such hazards are reduced if women and couples have means to choose their family size. In addition to empowerment of women and education of men and women, free or inexpensive modern contraceptives can greatly aid countries with unsustainably high birth rates. There, lower family size norms and wishes (see Assaf & Davis, 2021; Cleland et al., 2019) are also needed, which can be promoted by information about benefits of smaller families. Programs for voluntary family planning, successful in many countries in the past (Bongaarts & Hodgson, 2022; World Bank, 2007), can reduce fertility where it remains unsustainably high. Such programs should also include grassroots participation and education, raising awareness of the benefits of smaller families, also for environmental management (Haq, 2013).

Fertility reduction is likely to benefit the economy of poor developing countries, and increased aid for such measures is cost-effective in societies that strive to lower fertility and population growth (Bongaarts, 2016; UN, United nations, 2017; Zakiyah et al., 2016). Reduced fertility and population size will not only improve economies, but can lower our impact on the environment in many ways, for example as regards climate (Wolf et al., 2021) and biodiversity (Cafaro et al., 2022; Crist et al., 2017). Reducing fertility through family planning programs is likely key to achieving the Sustainable Development Goals (Starbird et al., 2016).

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

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