Socioeconomic development predicts a weaker contraceptive effect of breastfeeding

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Introduction

Future world population growth and the many challenges it brings are expected to primarily depend on fertility trends (1). Fertility is itself determined by both behavioral factors, such as contraceptive use, and physiological factors. In particular, it has long been established that lactation delays the resumption of ovarian function following birth (2-4). When contraception remains uncommon, as is still the case in many developing countries, postpartum suppression of ovarian activity by breastfeeding remains critical to control fertility (5).

Using published estimates on 48 pre-1980 populations, John Bongaarts and Robert Potter found a tight link between mean (or median) durations of breastfeeding and amenorrhea (6), best summarized by the "Bongaarts-Potter function" (BPF thereafter):

$$PPA = 1.753 \exp(0.1396\, BF - 0.001872\, BF^2)$$

Where *PPA* and *BF* are the mean (or median) durations of postpartum amenorrhea and breastfeeding, both in months. Specifically, this function explained 96% of the sample's variance on the log scale. This function enabled imputation of amenorrhea duration when missing (6-8), and has been considered strong evidence that breastfeeding duration alone largely outweighs any other determinant of postpartum amenorrhea (9-11).

Since the BPF was proposed in the early 1980s, physiological studies of the link between energy homeostasis and reproduction have accumulated (12). Several hormones signaling nutritional status, such as leptin and ghrelin, have been shown to modulate the activity of the hypothalamic neurons that control the reproductive axis (13). Direct action of insulin on follicular growth has also been suggested to be an important link between maternal metabolism and reproduction (14). In rats, resumption of ovarian activity is significantly delayed by chronic food restriction during lactation: time to first postpartum proestrus moved from 17 to 29 days when food intake was reduced to 50% the amount consumed *ad libitum* (15). While most investigations in humans focused on smaller variations in food intake, a seminal intervention study in rural Gambia found that high energy supplement during pregnancy and lactation induced significantly faster resumption of ovarian activity, with e.g. a 2-fold increase in estradiol plasma concentration at postpartum weeks 19-30 (16, 17).

Many low- and middle-income countries (LMICs) have experienced rapid economic growth and health improvements since the 1980s (18). These changes are expected to improve maternal energetic status in the postpartum period: increased real wages improve food intake, the implementation of labor-saving technologies decreases energy expenditure in agricultural work and household chores, and improved sanitation reduces the prevalence of diarrheal diseases. The few recent studies of specific communities have indeed found unexpectedly short durations of postpartum amenorrhea (19-21), suggesting that the breastfeeding – postpartum amenorrhea relationship might not be captured by a single function such as the BPF.

Using data on 2.7 million births from 301 demographic surveys conducted in 84 LMICS since 1975 (Fig. S1), we test two predictions derived from the 'maternal energetic status' hypothesis: first, that the breastfeeding - postpartum amenorrhea relationship has weakened over time in LMICs, then that this relationship is statistically modulated by measures of social and economic development such as the Human Development Index (HDI). These patterns are not incompatible with two other competing explanations, namely swifter transition to residual breastfeeding and changes in "nursing intensity", since high nursing frequency might help maintain ovarian function suppressed throughout lactation (22, 23). We therefore additionally test whether the association between *exclusive* breastfeeding and postpartum amenorrhea has weakened over time. Since cities are known to be forerunners of demographic and social change (7, 24), we assume any hidden changes in breastfeeding practice would diffuse more slowly in rural than in urban populations and inspect the evolution of the exclusive breastfeeding – postpartum amenorrhea relationship in rural regions.

Results

Accuracy of BPF prediction and country trajectories across time.

The BPF systematically overestimates the duration of postpartum amenorrhea except in Sub-Saharan Africa (SSA) (Fig. 1). The median deviation from the BPF (BPF prediction - observed duration of amenorrhea) is 1.6 months (IQR 0.1–3.5) overall. In SSA surveys, the median deviation is 0.4 months (IQR -0.5–1.7). By contrast, in Asian surveys, the median deviation is 7.0 months (IQR 3.8–10.0). The same pattern is observed in all sensitivity analyses (Fig. S2).

Figure 1 also shows the trajectory of selected countries across successive surveys. For instance, in Bangladesh, while breastfeeding duration has remained stable, mean duration of amenorrhea has steadily declined, moving from 15.2 months (95% CI 14.6–15.8) in 1975 to 7.7 months (95% CI 7.3–8.0) in 2017. In some other countries such as the Philippines, duration of breastfeeding has increased, without notable changes in postpartum amenorrhea duration (see Fig. S3 and S4 for detailed breastfeeding and amenorrhea schedules).

Breastfeeding – development – postpartum amenorrhea relationship

We assess the role played by development in these deviations from the BPF by estimating a meta-regression of mean duration of postpartum amenorrhea. Given the patterns revealed by Figure 1, we analyze separately Asia-Pacific, Sub-Saharan Africa and the rest of the world. The breastfeeding – postpartum amenorrhea relationship is found statistically modulated by the Human Development Index (Table S1 and Fig. S5), e.g. in Sub-Saharan Africa, where each 0.1 increase in HDI value is associated with a 0.07 $month^{-1}$ (0.02 0.13) reduction in the slope of the breastfeeding – postpartum amenorrhea relationship (baseline slope at HDI=0.2: 0.56 $month^{-1}$ (95%CI 0.39 0.74)).

To further investigate the role of development, we focus on groups of births defined by characteristics hypothesized as relevant for maternal energetic status (e.g., access to electricity; see *Methods* and Fig. S6). Adding these 'standard of livings' characteristics to the meta-regression's predictor, we again find a strong negative modulation of the breastfeeding – postpartum amenorrhea relationship (Table 1). For example, in energetic status groups from the Asia-Pacific region, each 0.1 increase in HDI reduces the slope of the breastfeeding – postpartum amenorrhea relationship by 0.06 $month^{-1}$ (0.03-0.09); access to electricity is everywhere found significantly associated with a reduced slope and/or intercept. Interestingly, the model leaves unexplained a clear SSA – Asia-Pacific difference in duration of postpartum amenorrhea: *ceteris paribus*, amenorrhea duration is longer in Sub-Saharan Africa (see intercept values in Table 1, see Fig. 2, left panels for an illustration).

Consistent with the maternal depletion hypothesis, higher parity is also found associated with longer postpartum amenorrhea. For instance, for a breastfeeding duration of 20 months, a birth of order 4 or above is expected to increase amenorrhea duration by similar amounts in Asia (1.0 month (95%CI 0.7–1.3)) Sub-Sahara Africa (1.2 months (95%CI 1.0–1.4)) and the 'other' regions (0.9 months (95%CI 0.5–1.2)), compared to a birth of order 2 or 3.

Breastfeeding – development – Total Fertility Rate (TFR) relationship

To explore the demographic significance of these findings, we simulate the postpartum infecundability index C_i for different values of our standard of livings variables and fixed realistic values for the other predictors. In all regions we find a large effect of development on C_i (Figure 2, right panels). For example, in Asia, an HDI of 0.3, rural residence, maternal absence of education, no electricity and distant water source predict a C_i value of 0.65 (95% CI 0.63–0.68) for a breastfeeding duration of 30 months. By contrast, an HDI of 0.5 combined with urban residence, maternal education, electricity and nearby water source corresponds to a C_i value 0.73 (95% CI 0.70–0.75). This change in C_i in turn leads to a 12% TFR increase (95% CI 9–15). For Sub-Saharan Africa the corresponding model prediction is a 24% (95% CI 20–27) TFR increase.

Exclusive breastfeeding – postpartum amenorrhea relationship. Studying the same groups of countries across surveys (Tables S2 and S3), we find a rapid weakening of the association between exclusive breastfeeding and early postpartum maintenance of amenorrhea (Fig. 3). In Asian countries, an exclusively breastfeeding woman on average spent 157 days (95% CI 153 160) amenorrheic in the first 6 months after childbirth in the early 1990s, but only 129 days (95% CI 127 130) in the latest period (p-value=3.3×10^{-54}). We find a more modest, albeit distinct, decline in SSA countries: time spent amenorrheic was 159 days (95% CI 157 161) in the latest period vs. 172 days (95% CI 169 175) in the early 1990s (p-value= 4.5×10^{-13}). The same result is found when the analysis is restricted to rural regions (Fig. S8) or when India is removed from the set of countries analyzed (Fig. S9).

Taken together, our results therefore favor improved maternal energetic status as the most likely of the competing hypotheses explaining the weakening of the breastfeeding - postpartum amenorrhea relationship observed in the past four decades.

Discussion

The energy demands of milk production, about 500 kilocalories a day for exclusive breastfeeding, are high enough to require a major shift in energy homeostasis (25, 26). Pregnancy is yet another energetically demanding period of a woman's life. Suppression of ovarian function during lactation thus prevents a situation that would compromise both mother's and offspring's survival and is therefore considered adaptive (27-29). Since meeting the metabolic cost of reproduction is more challenging under harsh environmental conditions, life history theory also helps explain why ovarian function appears so sensitive to energetic constraints, as repeatedly found by reproductive ecology studies (30, 31), clinically with functional hypothalamic amenorrhea (32) and historically in famines (33).

Accordingly, energetics has been suggested by anthropologists as key to explain low fertility in contemporary foraging societies (34, 35) or an event such as the Neolithic demographic transition (36). By contrast, most demographers have long assumed that only "a difference in fertility of more than a few percent [can] be expected between poorly and well-nourished women in developing countries" (37). For a long time, intensive breastfeeding and poor energetic status were simply too correlated to disentangle their effects on ovarian function.

While the potential abandonment of breastfeeding in LMICs long remained a matter of concern (38), it became clear in the early 1990s that there was not much evidence for such a trend (39). Thanks to information campaigns on its health benefits, breastfeeding has even been increasing since then (40). At the same time, many LMICs have rapidly developed, thus creating situations of both extended breastfeeding and improved nutritional status. A pioneering study conducted in intensely breastfeeding, well-nourished women of an Argentinian indigenous group for instance found a mean duration of postpartum amenorrhea of only 10 months (19).

We showed here that the breastfeeding – postpartum amenorrhea relationship at the population level is much more sensitive to environmental conditions than previously thought. Our results therefore resolve the longstanding apparent contradiction between demographic evidence and reproductive ecology findings (41). To the best of our knowledge, all previously published cases of mean durations of postpartum amenorrhea above 20 months either suffered from methodological limitations (e.g., relying on implausible reports) or pertained to deprived populations where prolonged lactation combines with other severe energetic constraints.

Perhaps the most puzzling finding of the study is the unexplained difference between Sub-Saharan Africa and Asia. The Human Development Index is not specifically centered on energetics but rather a summary measure of socioeconomic development. Defining energetic status groups aimed at moving closer to energetics, but some potentially relevant variables (e.g. the level of mechanization) remain elusive and might drive the unexplained difference. Another, speculative, explanation relates to social organization. Women of Sub-Saharan Africa have traditionally been economically independent and have assumed an unusually high share of agricultural work, while by contrast many South Asian communities have long been characterized by customary female seclusion and limited labor force participation (42-44) .

The data we use have exceptional geographic coverage, enable the regular follow-up of the same populations across decades and offer the possibility of methodological standardization, thus removing important barriers faced by previous research. They nevertheless suffer from several limitations. Light, sporadic bleeding can occur in the early postpartum and may be confused with the return of menses. Babies given only minimal amounts of supplementary food are not considered exclusively breastfed. Uncertainty on date of birth translates into uncertainty on age. Yet we have no reason to believe these limitations could explain our results, simultaneously observed in countries that differ in many important respects (e.g. start date of the demographic transition, current fertility level, type of contraceptives used, degree of urbanization, ethnicity, religious beliefs). Another limitation, the lack of detailed information on women's nutritional history and physical workload, prevented us from testing further our hypothesis on the aforementioned Asia – Sub-Saharan Africa difference.

To conclude, the most important prediction resulting from this work is an accelerated weakening of the breastfeeding - postpartum amenorrhea relationship in Sub-Saharan Africa with further advances in development. While the slower pace of the African fertility decline has had other causes (45, 46), our results assuredly call for continued diffusion of contraception.

Methods

Data. The Demographic and Health Surveys (DHS) are nationally representative household surveys conducted in LMICs that include a questionnaire for (married) women aged 15-49. The DHS are intended to be regularly rerun on the same countries, typically every 5 years. A section of the questionnaire contains detailed questions on the births within the last 5 or, for few DHS, 3 years. The mother is asked whether she still breastfeeds the child and whether her menstrual period has returned. The World Fertility Surveys (WFS) program, the forerunner to the DHS program, conducted about 40 surveys in developing countries between 1974 and 1982, a fraction of which investigated postpartum amenorrhea (9).

We pool together 284 DHS and 17 WFS covering the period 1975-2019 for 84 LMICs (Fig. S1). In order to exploit the large sample size of the 4 Indian DHS, the 6 standard zones of India were analyzed separately, yielding 321 'pseudo-surveys'.

The interview of 1,816,174 women provided information on breastfeeding and postpartum amenorrhea for 2,663,496 children born in the 5 years preceding survey. We excluded from the main analysis all births to women taking hormonal contraception at the time of interview, since this may have interfered with the normal pattern of menses resumption.

Amenorrhea status. Though implausible, some women interviewed shortly after childbirth declare menstruation has already resumed. For all computations, we assume all women less than 1 month postpartum are still amenorrheic. If the mother reported being pregnant at the time of interview, the last period of postpartum amenorrhea is considered over whatever the answer to the question 'has your menstrual period returned?'.

Exclusive breastfeeding status. Individual questions relate to the foods given to each child in the 24 hours preceding the interview ("Was the child given food *X*?"). When the answer is no to all of these questions, the child is considered exclusively breastfed. We reconstruct individual-level exclusive breastfeeding status, then recompute median durations of exclusive breastfeeding following the DHS program's methodology (47) and check they match routine estimates given by the DHS program (Fig. S10).

Energetic status groups. We define groups of births based on parity (1; 2 or 3; 4 or more), residence (urban/rural), maternal access to electricity (yes/no), maternal access to water (source for water 30 minutes or less away round trip: yes/no) and maternal education (no education/primary or more). Defining such energetic status groups is possible for 254 of our 321 surveys. We restrict the analysis to the 4,031 groups with an (unweighted) sample size of 70 individuals or more. We estimate mean durations of amenorrhea, breastfeeding and exclusive breastfeeding for each of these groups as described below.

Statistical analysis.

Estimation of mean durations. Retrospectively reported durations are known to be unreliable in the WFS and DHS because of recall bias and because of heaping on multiples of three months. For the estimation of mean durations, we therefore predict current status data (e.g., answer to the question: "are you still amenorrheic?") using a spline function of child's age. Writing $\pi(a)$ the probability of still being amenorrheic *a* months after childbirth, we fit the logistic regression $log(\frac{\pi(a)}{1-\pi(a)}) = s(a)$ with *s* a monotonically decreasing spline. Mean duration of amenorrhea is then estimated as $\int \pi(a)da = \int \frac{da}{1+exp(-s(a))}$.

To get unbiased estimates of population means, normalized sampling weights are introduced in the model's log-likelihood. We estimate standard errors using bootstrap resampling.

Breastfeeding - Postpartum Amenorrhea relationship. We estimate a Bayesian hierarchical meta-regression model to assess the breastfeeding (*BF*) – postpartum amenorrhea (*PPA*) relationship while accounting for measurement error on breastfeeding and exclusive breastfeeding (*EXC*) durations. Writing $\widehat{PPA}_s$, $\widehat{BF}_s$ and $\widehat{EXC}_s$ our estimates for survey *s* and $\sigma_{PPA,s}, \sigma_{BF,s}$ and $\sigma_{EXC,s}$ their (estimated) standard errors, we assume the measurement error models: $\widehat{PPA}_s \sim N(PPA_s, {\sigma_{PPA,s}}^2)$; $\widehat{BF}_s \sim N(BF_s, {\sigma_{BF,s}}^2)$; $\widehat{EXC}_s \sim N(EXC_s, {\sigma_{EXC,s}}^2)$ and a standard linear model linking true durations:

$$PPA_s \sim N(\, (\alpha_{BF} + \alpha_{HDI^*:BF}\, HDI^*)\, BF_s + \alpha_{HDI^*}\, HDI^* + X_s\beta,\ \sigma^2\,).$$

We define HDI* is $10 \times$ (HDI-0.2) for interpretability of regression coefficients. α_{BF} (respectively α_{EXC}) is the effect of an additional month of breastfeeding (resp. exclusive breastfeeding) on amenorrhea duration at HDI=0.20 and $\alpha_{BF:HDI^*}$ is the coefficient for the HDI* – breastfeeding interaction. X_s is a vector of covariates, β is a vector of coefficients and σ is the standard error of the true relationship's noise. X_s includes *EXC*, mean parity in the sample and a spline function of calendar time (with 6 uniformly spaced knots) controlling for unobserved smoothly-varying factors. The prior distributions for *PPA*, *BF* and *EXC* are chosen so as to approximately match the observed distributions of $\widehat{PPA}$, $\widehat{BF}$ and $\widehat{EXC}$. Weakly informative priors are set on the other coefficients.

The same analysis is then repeated on energetic status groups. Group characteristics are added to the linear predictor of *PPA*. The total effect of development (defined here as: moving from rural to urban residence + maternal education + access to electricity and easier access to water + a 0.1 increase in HDI) on the breastfeeding – postpartum amenorrhea relationship can thus summarized by both $\alpha_{resid:BF} + \alpha_{elec:BF} + \alpha_{water:BF} + \alpha_{educ:BF} + \alpha_{HDI^*:BF}$ (slope change) and $\alpha_{resid} + \alpha_{elec} + \alpha_{water} + \alpha_{educ} + \alpha_{HDI^*}$ (intercept change).

Effect on the Total Fertility Rate (TFR). We assess the effect of development on the TFR by translating our results on *PPA* in terms of postpartum infecundability index C_i, that in its simplest form (neglecting age structure and postpartum abstinence) is equal to 20/(18.5 + *PPA*) (6). We set the following values for the other predictors: EXC=2.5 months; survey year = 1985; mean parity = 2.5. We generate breastfeeding – postpartum amenorrhea relationships from the posterior distribution of the previous model, then translate them into breastfeeding – C_i relationships. We repeat the same exercise for the energetic status groups analysis (same EXC and survey year values, parity set to "2-3").

Time spent amenorrheic by exclusively breastfeeding women. For each group of surveys listed in Tables S2 and S3, we adjust a logistic regression of current amenorrhea status on a spline function of child's age, restricted to women exclusively breastfeeding and not taking hormonal contraception. We then compute mean time spent amenorrheic in the first 6 months postpartum as $\int_0^6 \pi(a)da$ and use bootstrap resampling for standard error estimation.

Extraction of WFS data used the *wfs* Stata command (48). The meta-regression model was written in Stan (49). All other analyses were performed in R (50), using package *rdhs* for extraction of DHS data (51), package *scam* for estimation of shape constrained additive models (52) and package *survey* for bootstrap resampling (53). All computer codes needed to replicate the analysis are available at <link to GitHub repo>.

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Figures

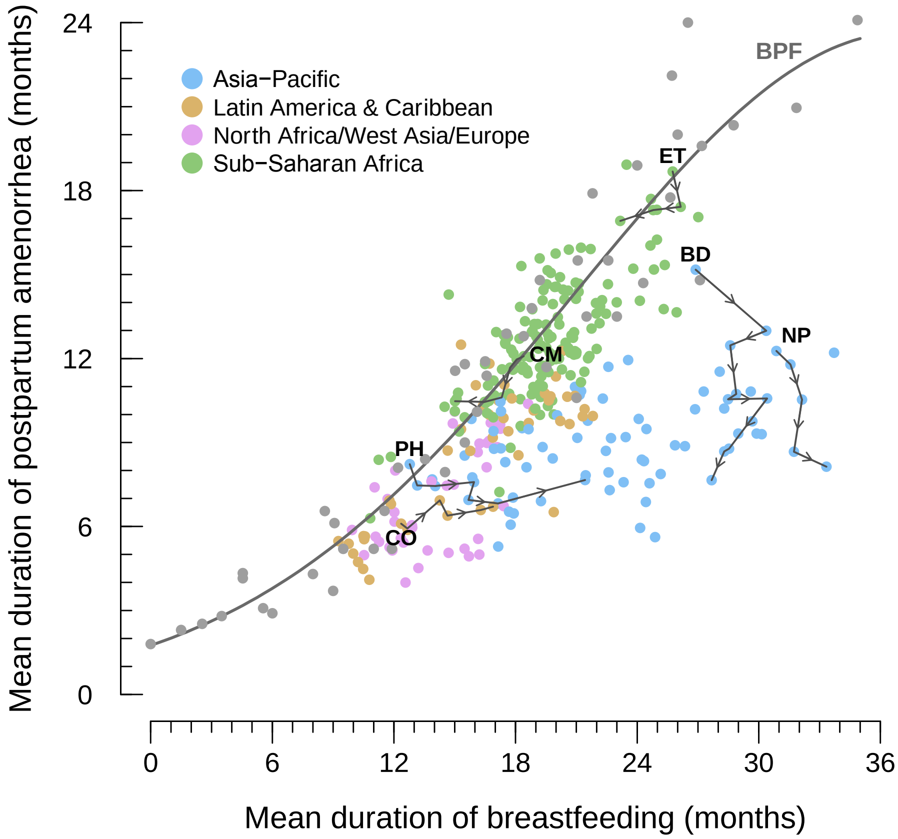

Figure 1. Mean duration of postpartum amenorrhea as a function of mean duration of breastfeeding.

The original points used by Bongaarts and Potter in ref (6) for the estimation of the breastfeeding – postpartum amenorrhea relationship are superimposed in gray, as well the Bongaarts-Potter function (BPF). For selected countries, lines link values for successive surveys, with country identifier located at first survey. BD: Bangladesh (first survey: 1975, most recent survey: 2017). CM: Cameroon (1978-2018). CO: Colombia (1986-2010). ET: Ethiopia (2000-2016). NP: Nepal (1996-2016). PH: Philippines (1978-2017).

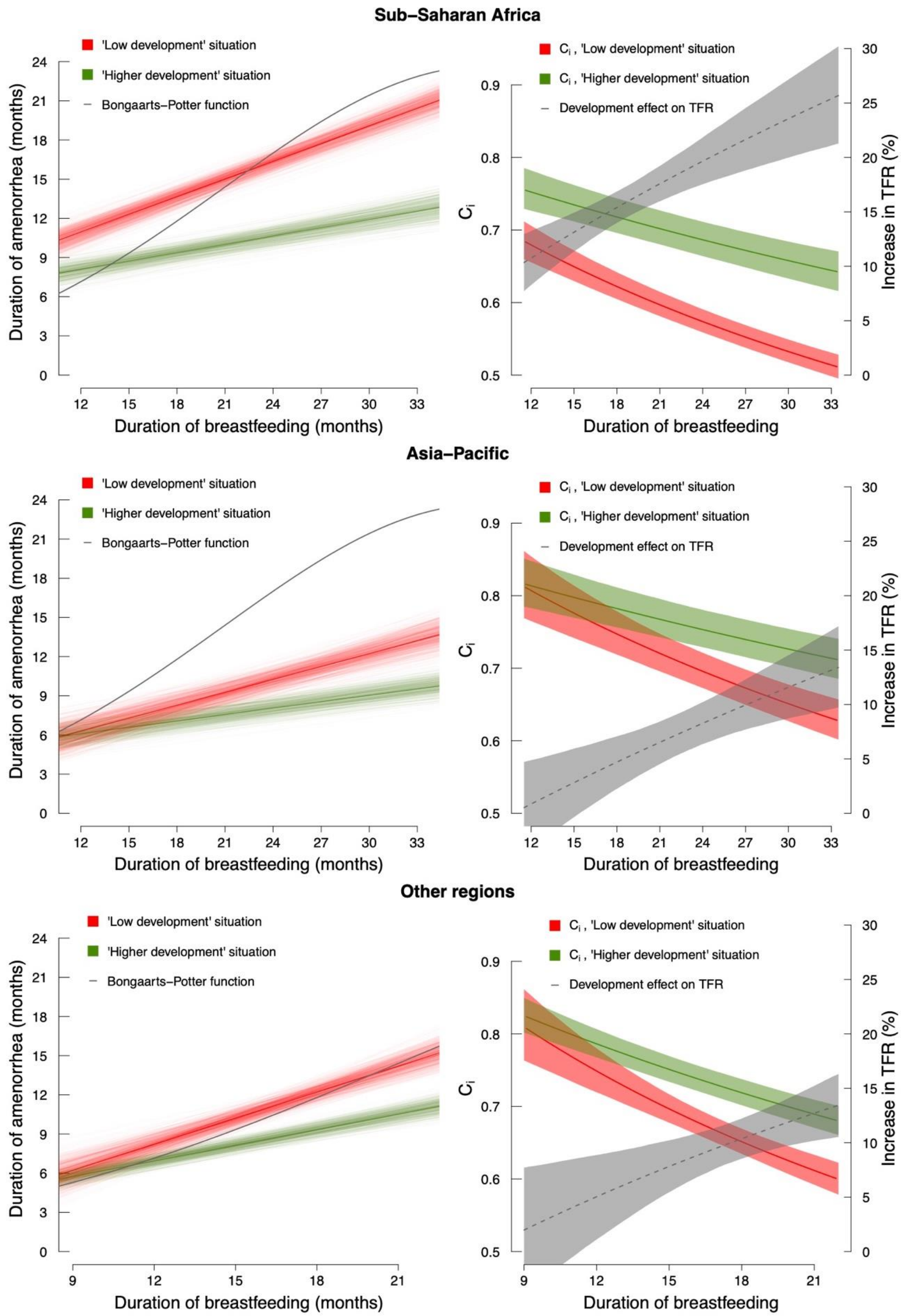
Sub–Saharan Africa
'Low development' situation
'Higher development' situation
Bongaarts–Potter function
Duration of amenorrhea (months)
Duration of breastfeeding (months)
C_i, 'Low development' situation
C_i, 'Higher development' situation
Development effect on TFR
C_i
Increase in TFR (%)
Duration of breastfeeding
Asia–Pacific
'Low development' situation
'Higher development' situation
Bongaarts–Potter function
Duration of amenorrhea (months)
Duration of breastfeeding (months)
C_i, 'Low development' situation
C_i, 'Higher development' situation
Development effect on TFR
C_i
Increase in TFR (%)
Duration of breastfeeding
Other regions
'Low development' situation
'Higher development' situation
Bongaarts–Potter function
Duration of amenorrhea (months)
Duration of breastfeeding (months)
C_i, 'Low development' situation
C_i, 'Higher development' situation
Development effect on TFR
C_i
Increase in TFR (%)
Duration of breastfeeding

Figure 2. Socioeconomic development predicts a weaker effect of breastfeeding on postpartum amenorrhea.

'Low development' is defined here as: HDI=0.3, rural residence, no electricity, source of water 30 minutes or more away, no maternal education. 'Higher development': HDI=0.5, and the reverse of their low development values for the other variables. *Left*: breastfeeding – postpartum amenorrhea relationship in low and higher development situations (posterior mean and 500 replicates shown), based on a meta-regression of mean postpartum amenorrhea duration (see *Methods*). *Right*: relationship between breastfeeding and postpartum infecundability index (C_i) in low and higher development situations (posterior mean and 95% CI). The theoretical increase in Total Fertility Rate (TFR) that follows the low -> higher development change is simply the ratio of C_i values (right y-axis; posterior mean and 95% CI).

NB: the different range of breastfeeding durations chosen for the 'Other regions' group reflects the range effectively observed, as shown on Fig. 1.

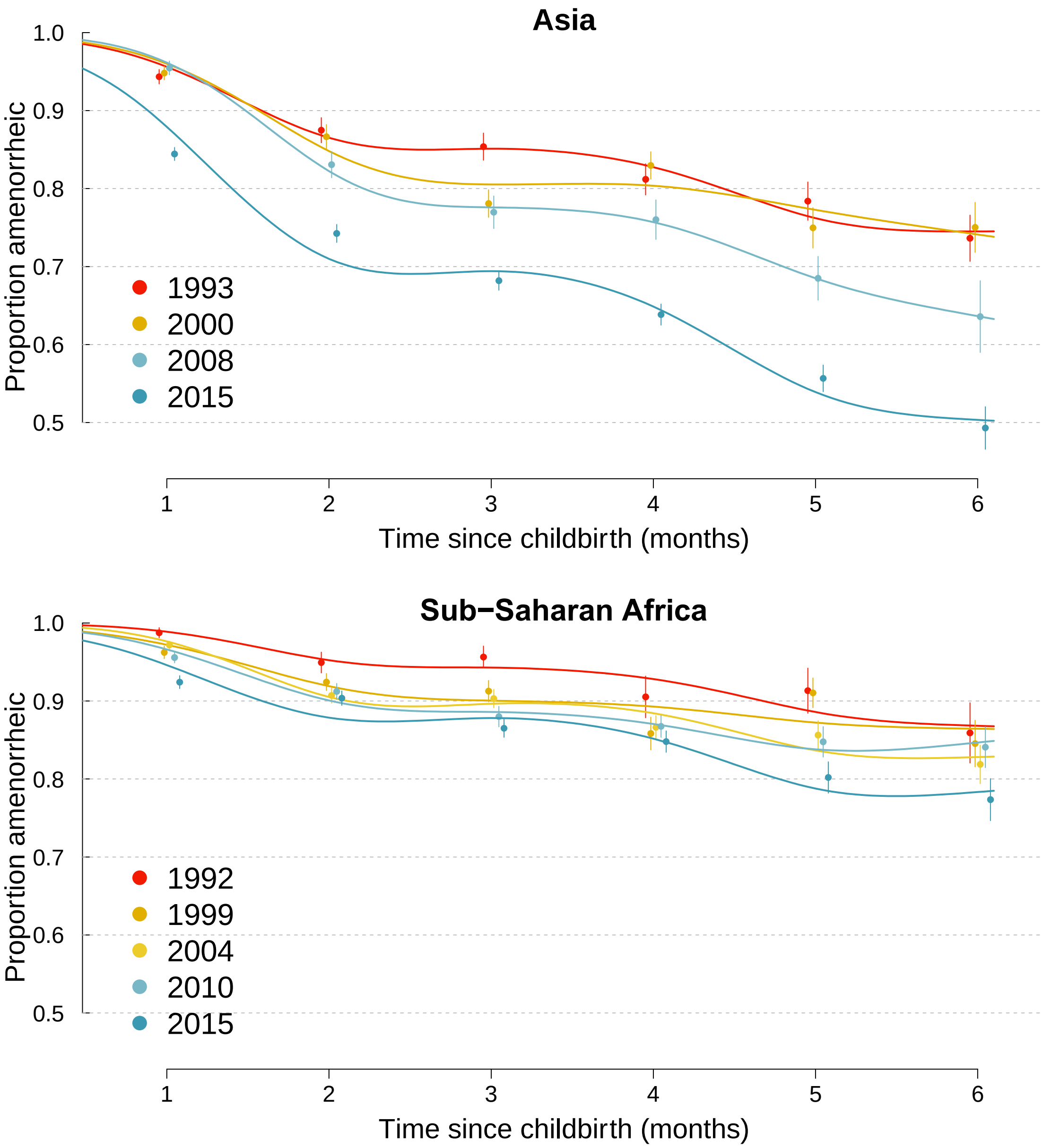

Figure 3. Proportion amenorrheic among women still exclusively breastfeeding, by time elapsed since childbirth survey wave.

DHS that were approximately contemporary are grouped for 7 Asian countries (Tables S2). Similarly, DHS for 16 Sub-Saharan African countries are grouped (Tables S3). Points are proportions ± standard error (SE). Lines are predictions from a logistic regression of current status on a spline function of time elapsed since childbirth.

Table 1. Meta-regression of mean duration of postpartum amenorrhea.

	Sub-Saharan Africa	Asia-Pacific	Other regions
Duration of breastfeeding	**0.50 (0.42 0.57)**	**0.39 (0.28 0.50)**	**0.70 (0.51 0.89)**
Living standards variables – interaction with breastfeeding			
Standardized Human Development Index *	-0.05 (-0.07 -0.02)	-0.06 (-0.09 -0.03)	-0.03 (-0.07 0.00)
Urban residence	-0.08 (-0.15 -0.02)	0.04 (0.00 0.08)	-0.10 (-0.16 -0.04)
Household has electricity	-0.06 (-0.13 0.00)	-0.01 (-0.06 0.03)	-0.01 (-0.08 0.06)
Water source 30 minutes away or less	-0.04 (-0.09 0.00)	-0.02 (-0.08 0.04)	0.00 (-0.13 0.12)
Maternal education	0.05 (-0.01 0.10)	-0.05 (-0.10 0.00)	-0.09 (-0.18 -0.01)
**Combined modulation effect ** **	**-0.19 (-0.27 -0.12)**	**-0.10 (-0.17 -0.03)**	**-0.24 (-0.38 -0.09)**
Parity – interaction with breastfeeding			
1	-0.05 (-0.11 0.01)	-0.04 (-0.08 0.00)	-0.07 (-0.13 -0.01)
2 or 3	Ref	Ref	Ref
4 or more	-0.04 (-0.09 0.01)	0.06 (0.01 0.11)	0.04 (-0.03 0.11)
Living standards variables – main effects			
Standardized Human Development Index *	0.54 (0.09 0.99)	1.61 (0.95 2.27)	0.00 (-0.55 0.55)
Urban residence	0.65 (-0.49 1.82)	-1.36 (-2.31 -0.43)	1.32 (0.32 2.31)
Household has electricity	-0.18 (-1.43 1.07)	-0.96 (-2.01 0.10)	-1.04 (-2.28 0.19)
Water 30 minutes away or less	0.55 (-0.39 1.52)	-0.01 (-1.35 1.36)	0.02 (-2.24 2.39)
Maternal education	-2.09 (-3.21 -0.96)	0.88 (-0.19 2.02)	1.64 (0.07 3.28)
Combined main effect **	-0.53 (-2.01 0.94)	0.16 (-1.54 1.84)	1.93 (-0.73 4.67)
Parity – main effects			
1	-0.69 (-1.81 0.44)	-1.06 (-1.99 -0.13)	-0.32 (-1.29 0.64)
2 or 3	Ref	Ref	Ref
4 or more	2.05 (1.02 3.09)	-0.16 (-1.31 0.97)	0.01 (-1.21 1.27)
Exclusive breastfeeding	-0.05 (-0.12 0.01)	0.28 (0.17 0.38)	0.33 (0.20 0.45)
Intercept	4.81 (1.83 7.30)	0.54 (-3.14 4.11)	-0.36 (-3.89 3.40)

Posterior mean (95% CI). See Fig. S7 for the spline functions of calendar time.

Reading: in Sub-Saharan Africa (SSA), easier access to water is associated with a 0.04 (95% CI 0.00 0.09) reduction in slope and a 0.55 (95%CI -0.39 1.52) increase in intercept of the breastfeeding–postpartum amenorrhea relationship. On the range of breastfeeding durations effectively found in SSA (mostly > 15 months), easier access to water is therefore associated with a shorter duration of postpartum amenorrhea (since 15x0.04> 0.55).

* Defined as 10 x (HDI-0.2).

** Assuming a 0.1 change in absolute value of HDI, the posterior mean for the combined modulation effect is simply the sum of the coefficients for individual living standards variables.