Contraceptive Use and Fertility Transitions: The Distinctive Experience of Sub-Saharan Africa
A — METHODOLOGICAL APPENDIX and SUPPLEMENTARY ANALYSES

Aisha N. Z. Dasgupta[1], Mark C. Wheldon[1], Vladimíra Kantorová*[1], and Philipp Ueffing[1]

[1]United Nations, Department of Economic and Social Affairs, Population Division, New York, NY, United States of America†

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*Corresponding author. Vladimíra Kantorová, Population Division, Department of Economic and Social Affairs, United Nations, kantorova@un.org

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Contents

List of Tables

List of Figures

This appendix provides additional information on data and methods (Section A 1) that complements that in the main manuscript. It also provides some supplementary results, including extra figures and an expanded analysis of parameter associations by region and subregion (Section A 2). A short discussion focusing on the additional analyses is also included (Section A 3).

A 1 Methods

Section A 1.1 provides additional information on the data used to fit the contraceptive transition model. Sections A 1.2– A 1.4 provide more details on the derivation of the model parameters. Section A 1.5 describes the methods used to analyze the associations between pairs of model parameters, including additional analyses that appear only in this appendix.

A 1.1 Data Availability

The data used to fit the contraceptive prevalence transition model are publicly available from *World Contraceptive Use 2020* (United Nations, Department of Economic and Social Affairs, Population Division, 2020b) and are summarized by region and time period in Figure A1.

A 1.2 Transition Model Parameters

The parameters from the contraceptive prevalence and fertility transition models used in this analysis are summarized in Table A1. In this section we give technical details on how these parameters were derived from the respective models and any additional notes relevant to their interpretation.

Table A1. Fertility and contraceptive transition model parameters with units.

	Fertility transition model		Contraceptive use transition model	
Concept	Parameter	Units	Parameter	Units
Timing	Y_c	years	Ω_c	years
Pace	d_c	children / women	ω_c	prevalence proportion per year
Asymptote	U_c	children / women	$\tilde{P}_c$	prevalence proportion

A 1.3 Derivation of the Fertility Transition Model Parameters

The fertility transition model was fitted to data observed between 1950 and 2014. This model operated at the resolution of the 5-year period so the start and end periods were 1950–1954 and 2010–2014.

In the explanations below, in addition to the parameters described in Table A1 and the main manuscript, we make use of those listed in Table A2. They are described in detail in Alkema et al. (2011) and Ševčíková et al. (2011).

Table A2. Additional parameters of the fertility transition model used in this appendix.

Parameter	Description
τ_c	Start period of Phase II (year range). Determined deterministically.
λ_c	Start period of Phase III (year range). Determined deterministically.

A 1.3.1 Pace: Maximum Possible Decrement

The pace parameter, d_c, was estimated for all countries.

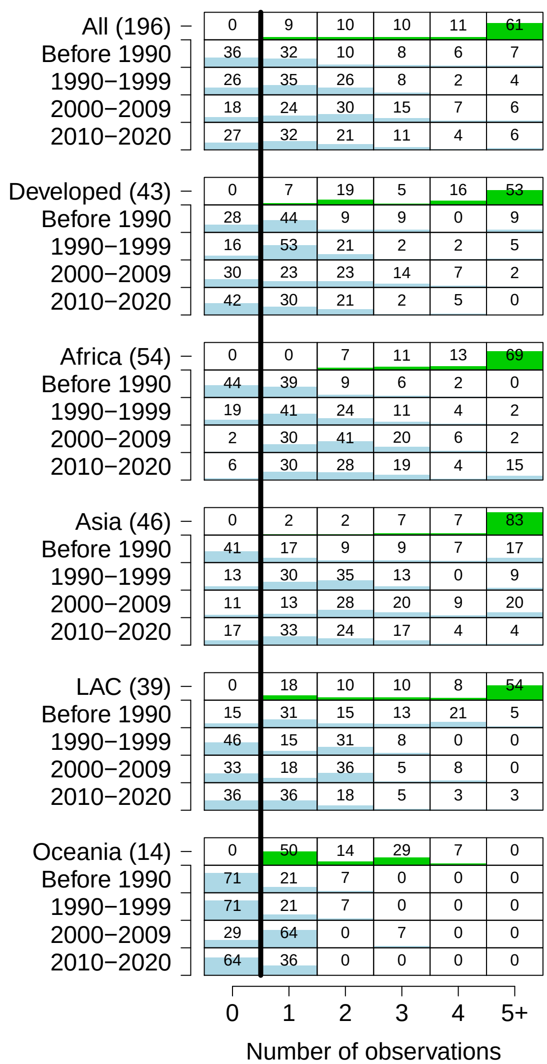

Figure A1. Data availability by region, time-period, and indicator. Proportion of countries by number of observations of contraceptive prevalence (any method) by region and time period among married women aged 15–49. The cells give the percentage of all countries for the given region and time period with the number of observations according to column. The cells sum to 100 (within rounding) across each row. The numbers in parentheses next to the region names are the number of countries in that region with at least one observation. The "Developed" group comprises all regions of Europe plus Northern America, Australia/New Zealand and Japan.

A 1.3.2 Level: TFR at the Start of Phase II

The level parameter, U_c, was not available for countries that entered Phase II in the observation period because it was not estimated by the fertility transition model in those cases. To obtain estimates we fixed it at the observed total fertility rate (TFR) at τ_c, i.e., $U_c := f_{c,\tau_c}$. Since τ_c was estimated deterministically, the estimate of U_c in these cases was also deterministic. For a small number of cases no estimate of U_c was available (see Tables A3 and B1 in Appendix B).

Table A3. Frequency table of countries by region and availability of U_c.

	U_c		
Region	Available	Unavailable	Total
Africa	54	0	54
Asia	48	0	48
Europe	37	0	37
Latin America and the Caribbean	35	4	39
Northern America	2	0	2
Oceania	10	5	15
Total	186	9	195

A 1.3.3 Timing: Year of Greatest Decrement

The fertility model did not have a parameter specifically for the year at which TFR experiences its greatest decrement because the declines were defined in terms of TFR, not the time at which they occur. To estimate Y_c, the year of greatest decrement, the year in which the Phase II TFR reached

$$f_c^* := U_c - \Delta_{c1} - \Delta_{c2}/2 \tag{1}$$

was found according to the following process.

The *bayesTFR* package generated a set of trajectories from the posterior distribution of the Phase II and Phase III model parameters (see Ševčíková et al., 2011). For each trajectory, k, in this set the TFR at the maximum decrement, $f_c^{*(k)}$, was computed according to (1). The TFR projections themselves, $f_{c,t}^{(k)}$, were for five year periods $[t-2.5, t+2.5)$. Therefore, they were linearly interpolated to single-year values. Call the interpolated values $f_{c,y}^{(k)}$, where y indexes the year. Then $Y_c^{(k)}$ was defined for each trajectory as the year in which the TFR was closest to $f_c^{*(k)}$ in the absolute sense:

$$Y_c^{(k)} := \{y \ : \ f_{c,y}^{(k)} = \arg\min_{f'} |f' - f_c^{*(k)}|\} \tag{2}$$

where f' ranged over the annually interpolated TFRs in trajectory k, i.e., $f_{c,y_1}^{(k)}, f_{c,y_2}^{(k)}, \dots, f_{c,y_{\text{end}}}^{(k)}$, y_1 was the most recent year TFR was equal to TFR at start of Phase II, and $y_{\text{end}} := 2098$. Quantiles of the trajectories $Y_c^{(k)}$ were used as posterior summaries of the time at which the maximum decrement in TFR occurred.

The TFR projections used in *WPP 2019* (United Nations, 2019) began in period 2015.5–2020.5. These were indexed to the midpoint, 2018, so the first value in each trajectory was $f_{c,2018}^{(k)}$. To accommodate trajectories in which $f_c^{*(k)}$ occurred earlier, the observed TFR values used to fit the projection model were prepended to the trajectories $f_{c,t}^{(k)}$ for all k, prior to interpolation. There was no uncertainty associated with these values so any Y_c prior to 2018 were similarly without uncertainty. The observed TFR values dated back only the period 1950.5–1955.5. For countries that underwent their fertility transitions before this period Y_c could not be estimated (see Tables A4 and B1 in Appendix B).

Table A4. Frequency table of countries by region and availability of Y_c.

	Y_c		
Region	Available	Unavailable	Total
Africa	54	0	54
Asia	43	5	48
Europe	2	35	37
Latin America and the Caribbean	27	12	39
Northern America	0	2	2
Oceania	8	7	15
Total	134	61	195

A 1.4 Derivation of the Contraceptive Use Transition Model Parameters

A summary of parameters from the contraceptive use model used to construct the outputs in the main manuscript is in Table A5. For full details see the appendices of Cahill et al. (2017) and Kantorová et al. (2020).

Table A5. Additional parameters of the contraceptive transition model used in this appendix.

Parameter	Description
$P^*_{c,t}$	Contraceptive prevalence (any method) in country c in year t.
$\epsilon_{c,t}$	Auto-correlated distortion terms added to first differences of $P^*_{c,t}$.
$P_{c,t}$	$P^*_{c,t} + \epsilon_{c,t}$.
S_c	Defined as logit($P_{c,1990}$), i.e., the log odds of using contraception (any method, incl. distortion) in country c in 1990. "S" for "set level".

A 1.4.1 Timing: Year of Maximum Rate of Increase

The timing parameter, Ω_c, was not explicitly modelled. Therefore, it was obtained from the model output trajectories via the formula in (3) supplied by N. Cahill (pers comm., 2019).

$$\Omega_c = 1990 + \frac{1}{\omega_c} \log\left(\frac{\tilde{P}_c}{\exp(S^*_c)} - 1 + \tilde{P}_c\right) \tag{3}$$

where

$$S^*_c := S_c - \epsilon_{c,1990}$$

Ω_c was undefined for trajectories at the asymptote ($\tilde{P}_c$) because the model operated under a different regime in those cases. Contraceptive prevalence in those trajectories was estimated not as a parametric logistic curve plus distortion, but as a random walk determined by the distortion terms alone. The proportion of trajectories within each country for which Ω_c was undefined ranged from 0 to 1; some countries had no undefined trajectories, others had no defined trajectories. Moreover, the proportion of trajectories with undefined Ω_c was strongly associated with estimated prevalence ($P_{c,t}$), with high $P_{c,t}$ associated with greater proportions of undefined Ω_c. Countries where Ω_c was undefined for more than 10 percent of the trajectories were not included in the analysis (see Tables A6 and B3 in Appendix B). The only countries in sub-Saharan Africa that had less than 90 percent valid trajectories were Réunion, and Mauritius.

Table A6. Frequency table of countries by region and availability of Ω_c.

	Ω_c		
Region	Available	Unavailable	Total
Africa	52	2	54
Asia	33	15	48
Europe	0	37	37
Latin America and the Caribbean	28	11	39
Northern America	0	2	2
Oceania	12	3	15
Total	125	70	195

A 1.5 Analysis of Parameter Associations by Region and Subregion

Here and in the main manuscript we used locally estimated scatterplot smoothing (loess) (Cleveland et al., 1992) to visualize associations between posterior medians for each pair of model parameters (timing, pace, level) for all countries together and separately by region. In the supplementary analyses below, we used ordinary least squares (OLS) to screen associations at the subregional level. For each subregion, we performed a t-test of the null hypothesis that the slope coefficient was zero. We reported only those subregions where the associated p-value was less than 0.05. Subregions where a significant result was driven by a single high-leverage observation were not reported. We used linear regression instead of loess at this level because nonparametric smoothers become unstable when the number of observations is small and this technique is simple to perform and interpret. In the regression models we set the contraceptive prevalence parameters as the explanatory variables because it seemed reasonable that any causal link would flow from contraceptive use to fertility. This was an assumption; we do not claim that the results or analysis presented here are evidence in support of it.

In the analysis of the timing parameters we looked separately, in some cases, at countries where the posterior median estimate of the mid-point of the contraceptive transition (Ω_c) was 2020 or earlier. Estimates of Ω_c greater than 2020 were necessarily model-based projections and were more variable than estimates pre-2020. There remains considerable uncertainty about the timing of these countries' contraceptive transitions, and any relationship to the timing of their fertility transitions.

We wish to stress that these analyses were intended to be exploratory, and to be most useful for suggesting avenues for further research rather than testing particular hypotheses. See the Discussion (Section A 3) for important limitations.

A 2 Results

Subsection A 2.1 presents results supplementary to Subsection "Relationship between contraceptive use and fertility" in the main article. Subsections A 2.2–A 2.4 present results supplementary to those presented in Subsection "Evidence from fertility and contraceptive prevalence model parameters" in the main article. They contain more detailed analyses of parameter associations at the regional and subregional levels.

A 2.1 Relationship Between Contraceptive Use and Fertility Among Married/In-Union Women

In contrast to Figure 6 presented in the main article for all women, Figure A2 shows total fertility against the prevalence of contraception among married/in-union women in 1990 and 2020.

Figure A3 shows the trend in TFR for countries in sub-Saharan Africa by subregion. It complements Figure 7 in the main article.

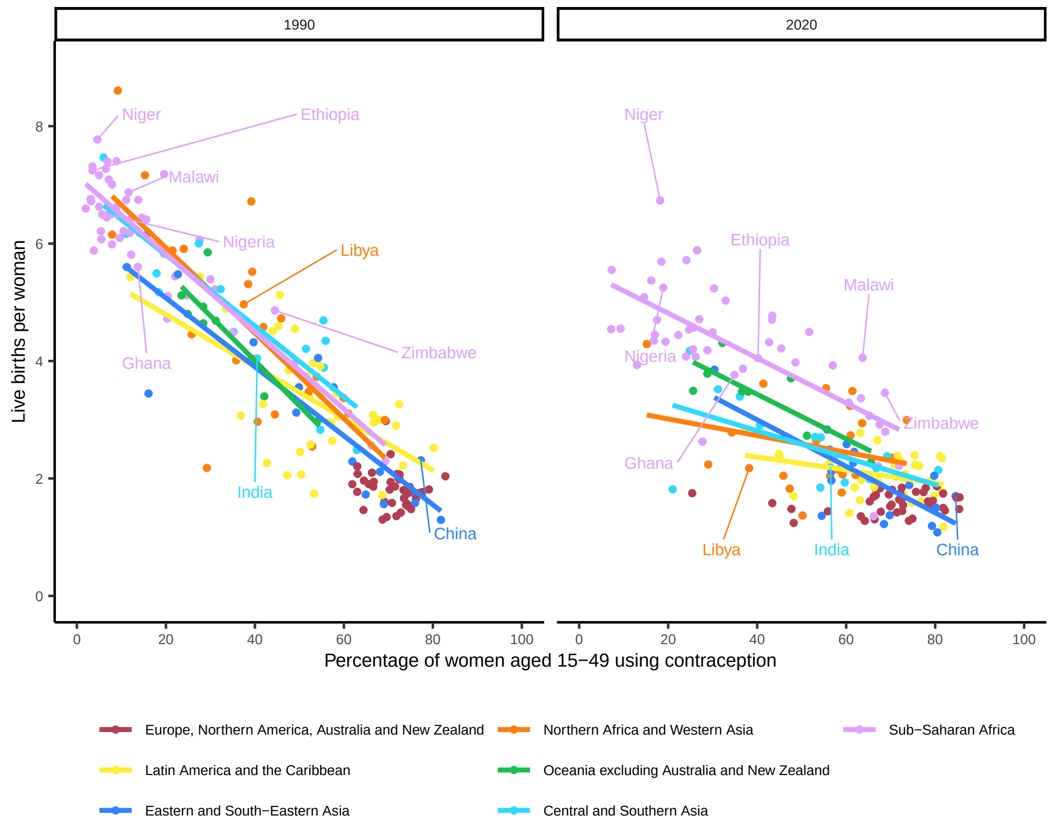

Figure A2. Total fertility rate in 1970 and 2020 by prevalence of contraceptive use among married/in-union women aged 15–49, 186 countries or areas presented by region. This figure shows the same variables as Figure 6 in the main article but only for married/in-union women aged 15–49.

Notes: All regression lines were estimated using ordinary least squares (OLS). In 2020, slopes of the regression lines were smaller in magnitude compared to 1990, and a lower proportion of the variation was explained (R^2). Regression lines are not included for Europe and Northern America, or for Australia and New Zealand.

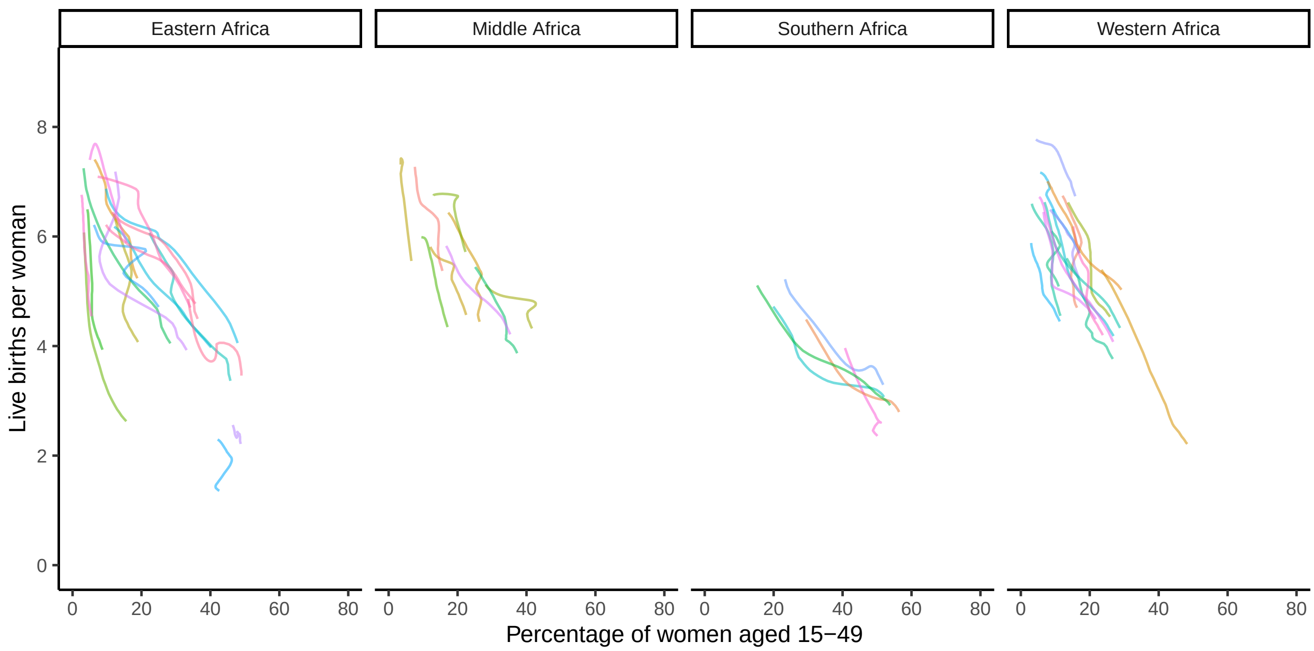

Figure A3. Country-specific trajectories of the total fertility rate versus the prevalence of contraceptive use (any method) among married or in-union women aged 15-49 during 1970–2020 in sub-Saharan Africa, by subregion. Different colours are used to allow individual country trajectories to be distinguished.

A 2.2 Pace Parameter Associations by Region and Subregion

Posterior median estimates of ω_c and d_c were plotted against each other for all countries studied in Figure 10 in the main article. The same estimates are plotted by region in Figure A4 in this appendix. The ranges of both parameters' posterior medians were similar in Africa and Latin America and the Caribbean; in Asia they were somewhat larger. Loess smooths indicated a complex association, if any, between the two parameters at the regional level.

The contraceptive transition model had a hierarchical structure in which ω_c was clustered by subregion, within region. This clustering was reflected in the results, particularly within Asia and Latin America and the Caribbean, where there was little overlap among the ranges of the ω_c for several of the subregions. The Caribbean and Eastern Asia subregions were particularly marked examples. The larger range of the ω_c medians in Asia was entirely due to Eastern and South-Eastern Asian countries.

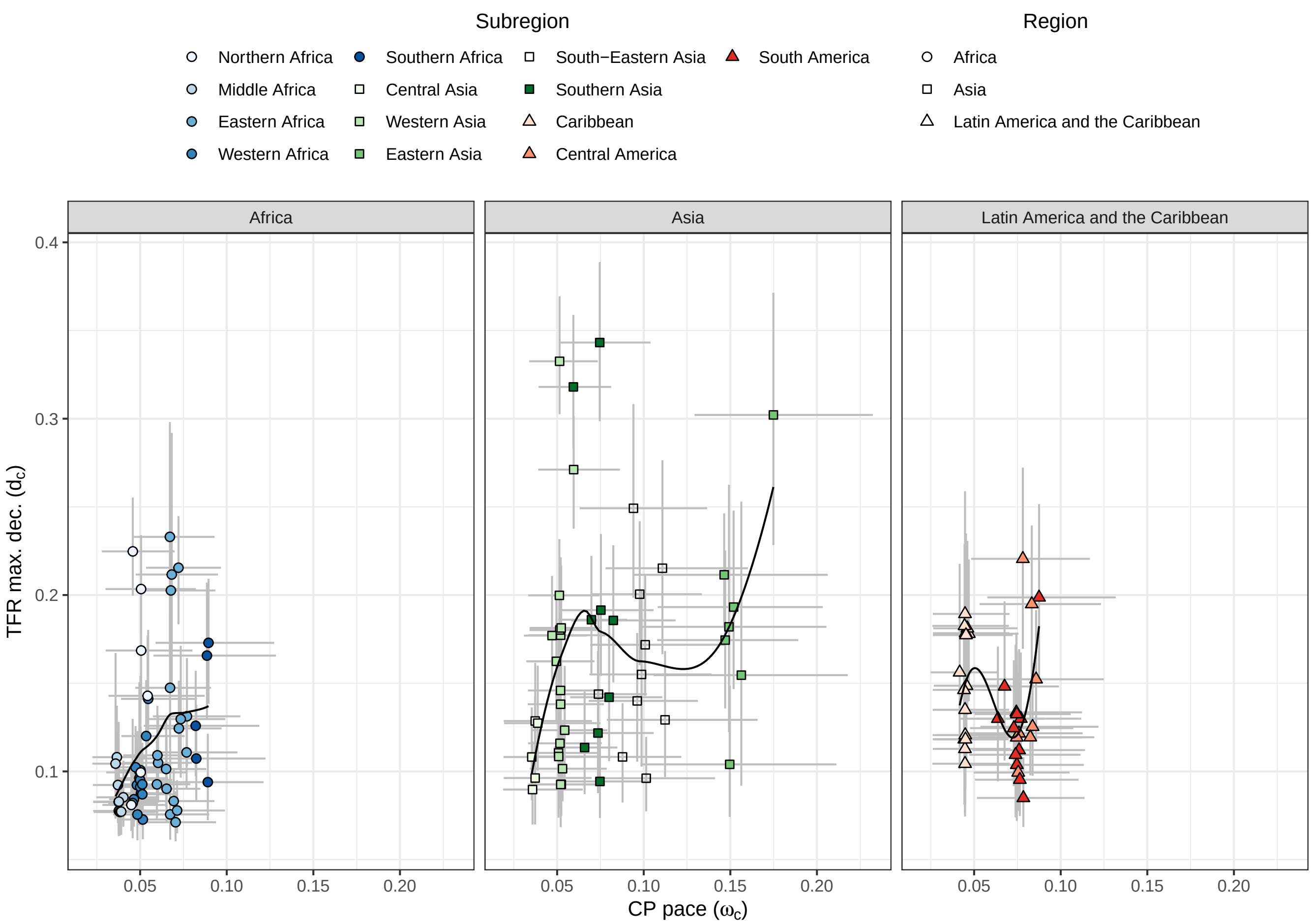

Figure A4. Posterior median estimates of pace parameters ω_c and d_c, by region, for Africa, Asia, Latin America and the Caribbean. Central 80 percent uncertainty intervals are shown by grey cross-hairs. Loess smooths are overlaid to indicate any bivariate associations. Loess was fitted only to the medians; posterior uncertainty in the parameter estimates was not accounted for.

The OLS screening procedure identified possibly significant associations in Middle Africa and Western Africa. The relationship between the pace of contraceptive prevalence and fertility change was positive for Western Africa, but negative for Middle Africa. However, the posterior uncertainty in the parameter estimates for these subregions was very high. Due to extreme doubt as to whether the associations identified would survive a more rigorous analysis, the results are not shown.

A 2.3 Timing Parameter Associations by Region and Subregion

A 2.3.1 All Countries

The association between the posterior medians of the timing parameters was approximately linear among countries in the three regions of interest. A similar relationship held when restricted only to countries with Ω_c (and Y_c) 2020 or earlier (Figure 9 in the main article and Figure A5 in this appendix). We quantified these relationships by fitting OLS regressions with Y_c as the response variable and Ω_c as the explanatory variable (Table A8). The results using the restricted set suggested that an increase of 1 year in the timing of the contraceptive use transition was associated with an increase of about 0.39 (95% CI: 0.26, 0.51) years in the fertility rate transition for these countries during the period of observation (the confidence interval is from the regression and does not account for posterior uncertainty in the estimates of Y_c and Ω_c). Countries with posterior median estimates of $\Omega_c > 2020$ were mostly from Western, Middle, and Eastern Africa (Tables A9 and B3 in Appendix B).

Table A7. Frequency table of countries by region and value of Ω_c.

	Ω_c		
Region	≤ 2020	> 2020	Total
Africa	23	29	52
Asia	31	2	33
Latin America and the Caribbean	27	1	28
Total	81	32	113

Table A8. Ordinary least squares (OLS) regression of posterior medians of timing parameter Ω_c on posterior medians of Y_c for all countries in Africa, Asia, and Latin America and the Caribbean ("unrestricted set") and for countries in those regions with $\Omega_c \leq 2020$ ("restricted set"). See also Figure A5.

	Unrestricted set	Restricted set
(Intercept)	1986.27 [1984.35; 1988.19]	1980.62 [1978.73; 1982.50]
(Slope coef.) Ω_c	0.44 [0.37; 0.52]	0.39 [0.26; 0.51]
R^2	0.53	0.33
Adj. R^2	0.53	0.32
Num. obs.	112	79

Table A9. Frequency table of countries in Africa by subregion and value of Ω_c.

	Ω_c		
Region	≤ 2020	> 2020	Total
Eastern Africa	9	7	16
Middle Africa	3	6	9
Northern Africa	5	1	6
Southern Africa	5	0	5
Western Africa	1	15	16
Total	23	29	52

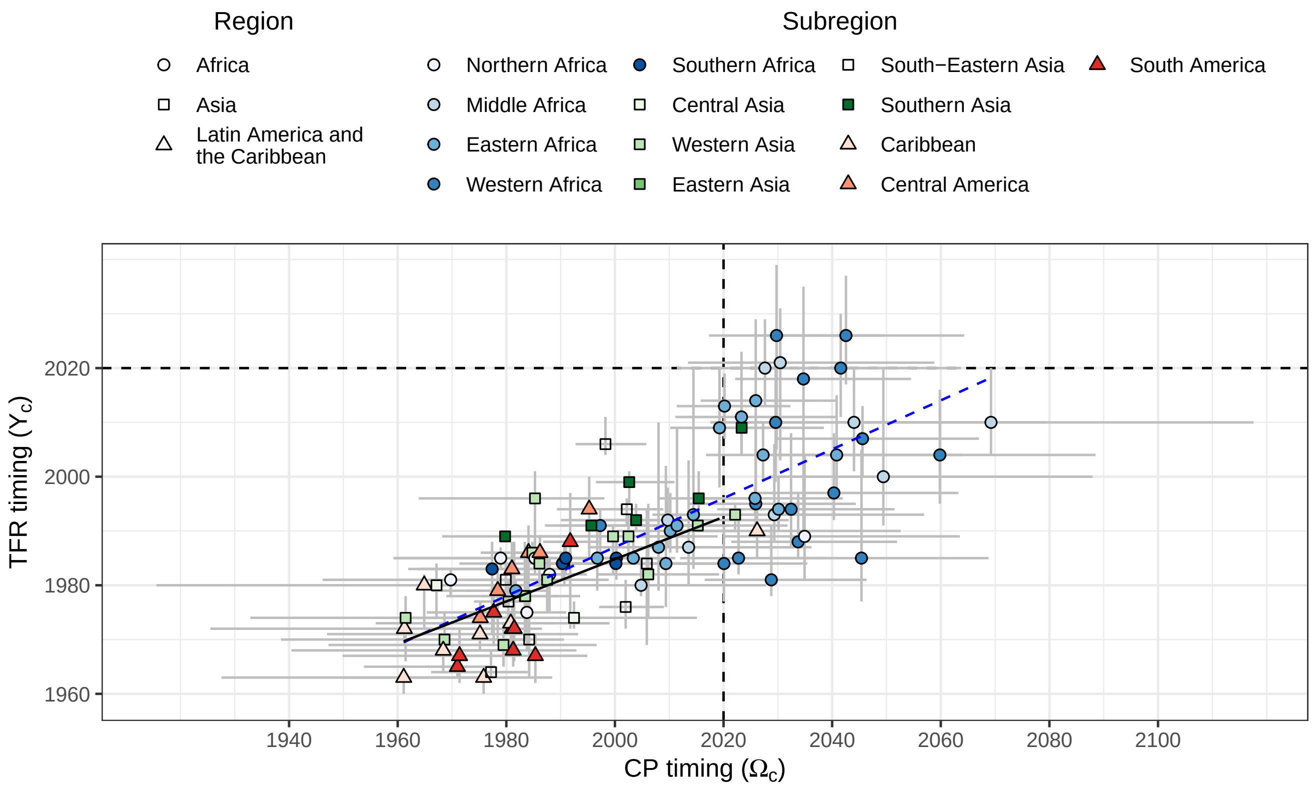

Figure A5. Posterior median estimates of timing parameters Y_c and Ω_c for Africa, Asia, and Latin America and the Caribbean. Central 80 percent uncertainty intervals are shown by grey cross-hairs. Ordinary least squares (OLS) regression lines are overlaid. The solid black line is the regression line fitted only to countries for which $\Omega_c \leq 2020$; the dashed blue line is the regression line fitted to all observations. The regressions are fitted only to the posterior medians; posterior uncertainty in the parameter estimates was not accounted for. Reference lines at 2020 on both axes are added. This is the same as Figure 9 in the main article but with the loess smooth replaced with the linear regression lines.

A 2.3.2 Analysis by Region and Subregion

Posterior median estimates of Ω_c and Y_c are plotted by region in Figure A6. The contraceptive prevalence model did not have a geographic hierarchy for timing parameter Ω_c as it did for pace parameter ω_c. Nevertheless there were some geographic patterns. The medians of both parameters were generally lowest among Latin America and the Caribbean countries and highest among African countries.

Almost all of the Ω_c medians in Latin America and the Caribbean and Asia were 2020 or earlier compared with only about half of those in Africa (Table A7). As noted above, values after 2020 were model-based projections and there was little in the way of a relationship among the parameter estimates in those years. This was evident in the flattening off after 2020 of the loess smooth in the African countries. In the period prior to 2020, however, there was a clear increasing relationship in each of the regions, mirroring that shown in Figure A5 for all regions combined.

Repeating the screening procedure by subregion identified four subregions of potential interest: Eastern Africa, Western and Southern Asia, and Central America (Table A10, Figure A7). In all cases the suggested

Table A10. Ordinary least squares (OLS) regression of posterior medians of timing parameter Ω_c on posterior medians of Y_c for the subregions where the linear association was significant at the 0.05 level. Ninety-five percent confidence intervals are in square brackets. The Ω_c were centered so that the intercepts estimate Y_c at the mean of Ω_c. See also Figure A7.

	Central America	Eastern Africa
(Intercept)	1983.67 [1981.89; 1985.45]	1996.19 [1991.88; 2000.49]
(Slope coef.) Ω_c	0.95 [0.67; 1.23]	0.59 [0.28; 0.90]
R^2	0.96	0.54
Adj. R^2	0.95	0.51
Num. obs.	6	16

	Western Asia	Southern Asia
(Intercept)	1982.78 [1978.89; 1986.68]	1992.25 [1987.65; 1996.85]
(Slope coef.) Ω_c	0.35 [0.12; 0.58]	0.53 [0.21; 0.86]
R^2	0.50	0.73
Adj. R^2	0.45	0.68
Num. obs.	13	8

linear associations were positive. The ninety-five percent confidence intervals for the slope coefficient estimates overlapped the corresponding confidence interval of the all-country analysis (Section A 2.3.1) for all subregions except Central America, which had a larger estimate.

A 2.3.3 Difference Between Fertility and Contraceptive Use Transition Timings

A consequence of the apparent relationship between Ω_c and Y_c, and the clustering of countries by subregion, is that the difference between the timing parameters of the two transitions was much smaller, on average, in Asia and Latin America and the Caribbean than it was for Africa. The midpoint of the fertility transition in countries where Ω_c was estimated to be less than 2020 in Latin America and the Caribbean occurred, on average, 3 years before the midpoint of the contraceptive use transition; the same difference was 6.8 years in Asia. In Africa the gap was estimated to be 11 years (Table A11). Analysis by subregion revealed substantial heterogeneity within regions. The large gap in Africa was driven primarily by the Eastern and Middle Africa subregions (among countries with estimated $\Omega_c \leq 2020$). Central Asia, the Caribbean, and Central America had small and small-and-negative gaps, respectively (Table A12).

Table A11. Mean difference between posterior medians of Ω_c and Y_c by region.

	Difference ($\Omega_c - Y_c$)	
Region	$\Omega_c \leq 2020$	All
Africa	11.4	22.6
Asia	6.8	7.8
Latin America and the Caribbean	3.0	4.5

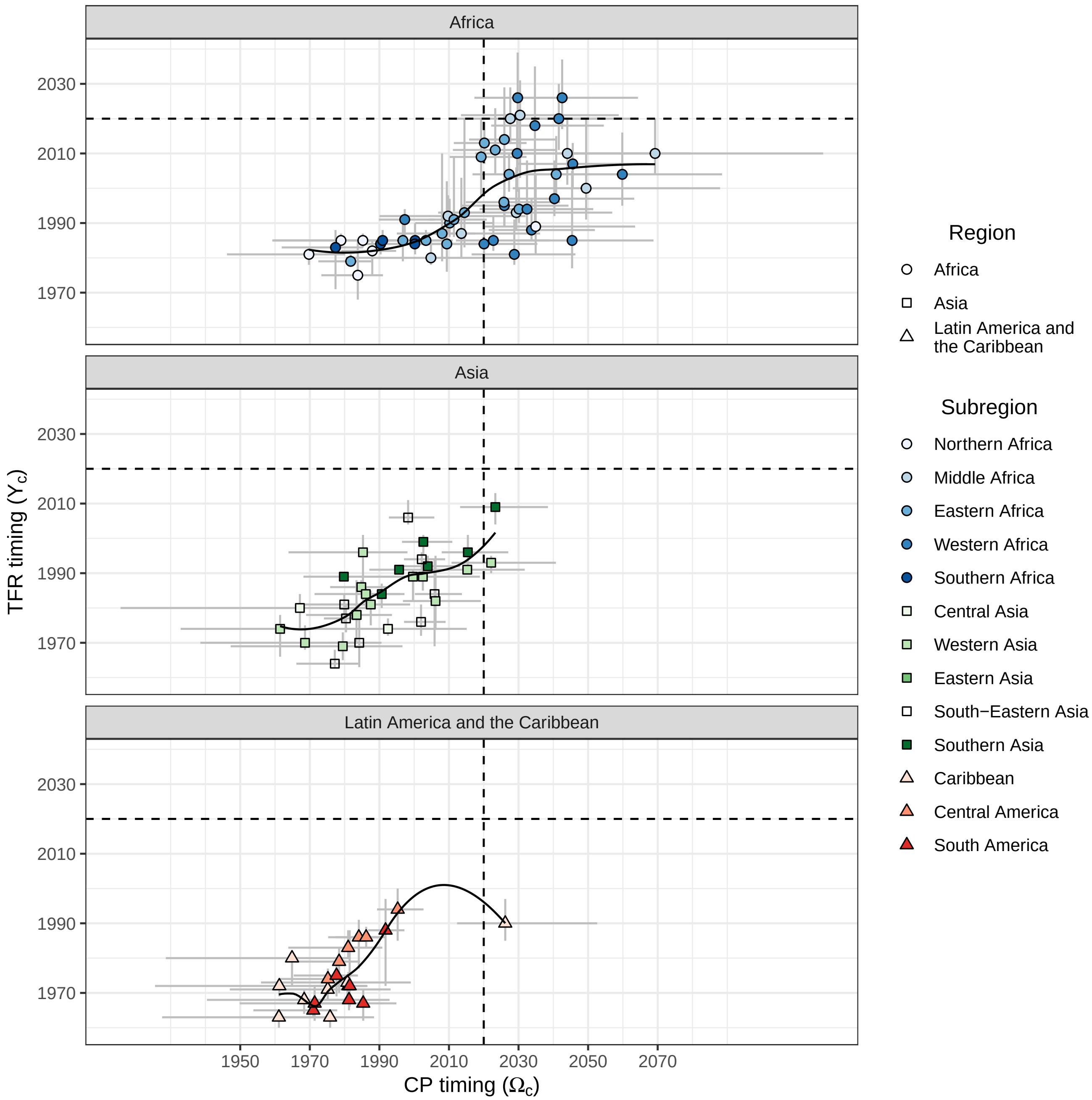

Figure A6. Posterior median estimates of timing parameters Ω_c and Y_c, by region, for Africa, Asia, Latin America and the Caribbean. Central 80 percent uncertainty intervals are shown by grey cross-hairs. Loess smooths are overlaid to indicate any bivariate associations. Loess was fitted only to the medians; posterior uncertainty in the parameter estimates was not accounted for.

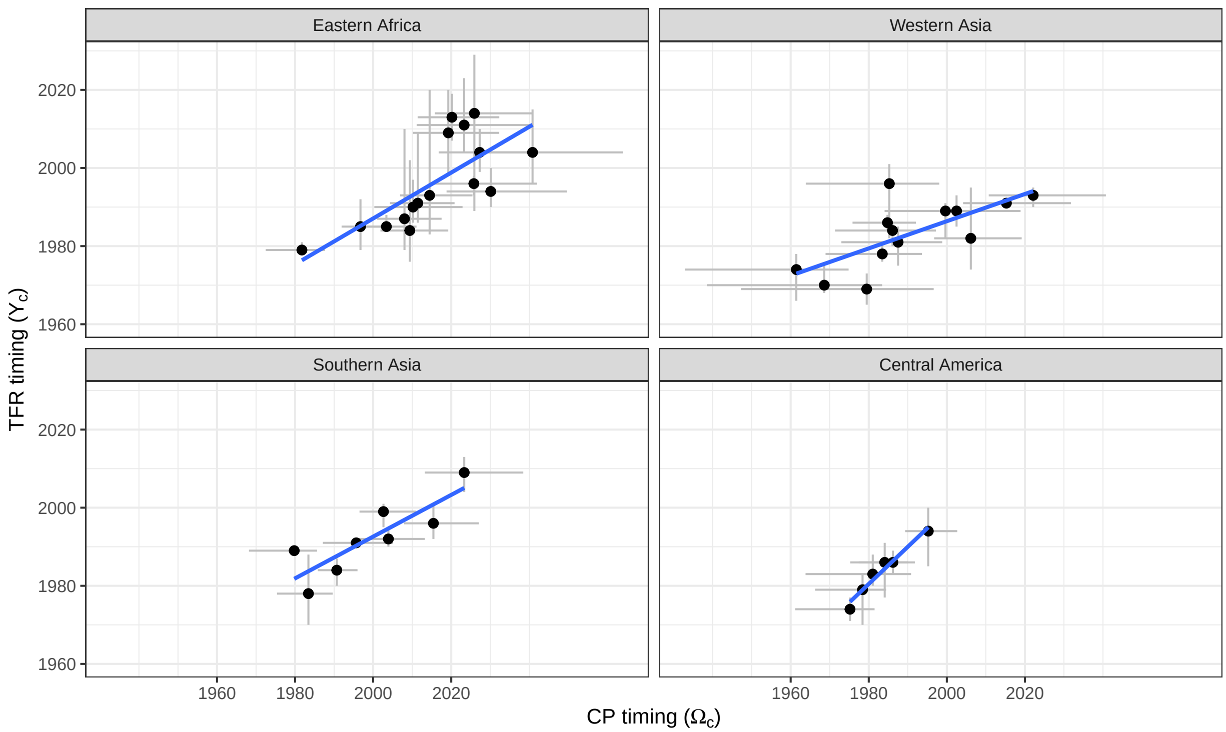

Figure A7. Posterior median estimates of timing parameters Ω_c and Y_c, by subregion, for the subregions where the linear association was significant at the 0.05 level. Central 80 percent uncertainty intervals are shown by grey cross-hairs. Ordinary least squares (OLS) regression lines are overlaid. The regressions were fitted only to the medians; posterior uncertainty in the parameter estimates was not accounted for. See also Table A10.

Table A12. Mean difference between posterior medians of Ω_c and Y_c by subregion.
Note: No estimates of Ω_c were available for Eastern Asia.

		Difference ($\Omega_c - Y_c$)	
Region	Subregion	$\Omega_c \leq 2020$	All
Africa	Eastern Africa	16.8	19.3
	Middle Africa	23.0	29.5
	Northern Africa	-0.5	7.3
	Southern Africa	7.6	7.6
	Western Africa	6.3	32.5
Asia	Central Asia	2.8	2.8
	South-Eastern Asia	9.7	9.7
	Southern Asia	6.1	7.1
	Western Asia	5.9	7.7
Latin America and the Caribbean	Caribbean	-0.4	4.2
	Central America	-0.3	-0.3
	South America	8.4	8.4

A 2.4 Level Parameter Associations by Region and Subregion

No relationship was evident between the posterior medians of the contraceptive prevalence asymptote ($\tilde{P}_c$) and the starting level of the fertility transition (U_c) (Figure A8). Posterior uncertainties about these parameters, especially about $\tilde{P}_c$, are very large because they concern the end of a transition which remains, for many countries, several years in the future.

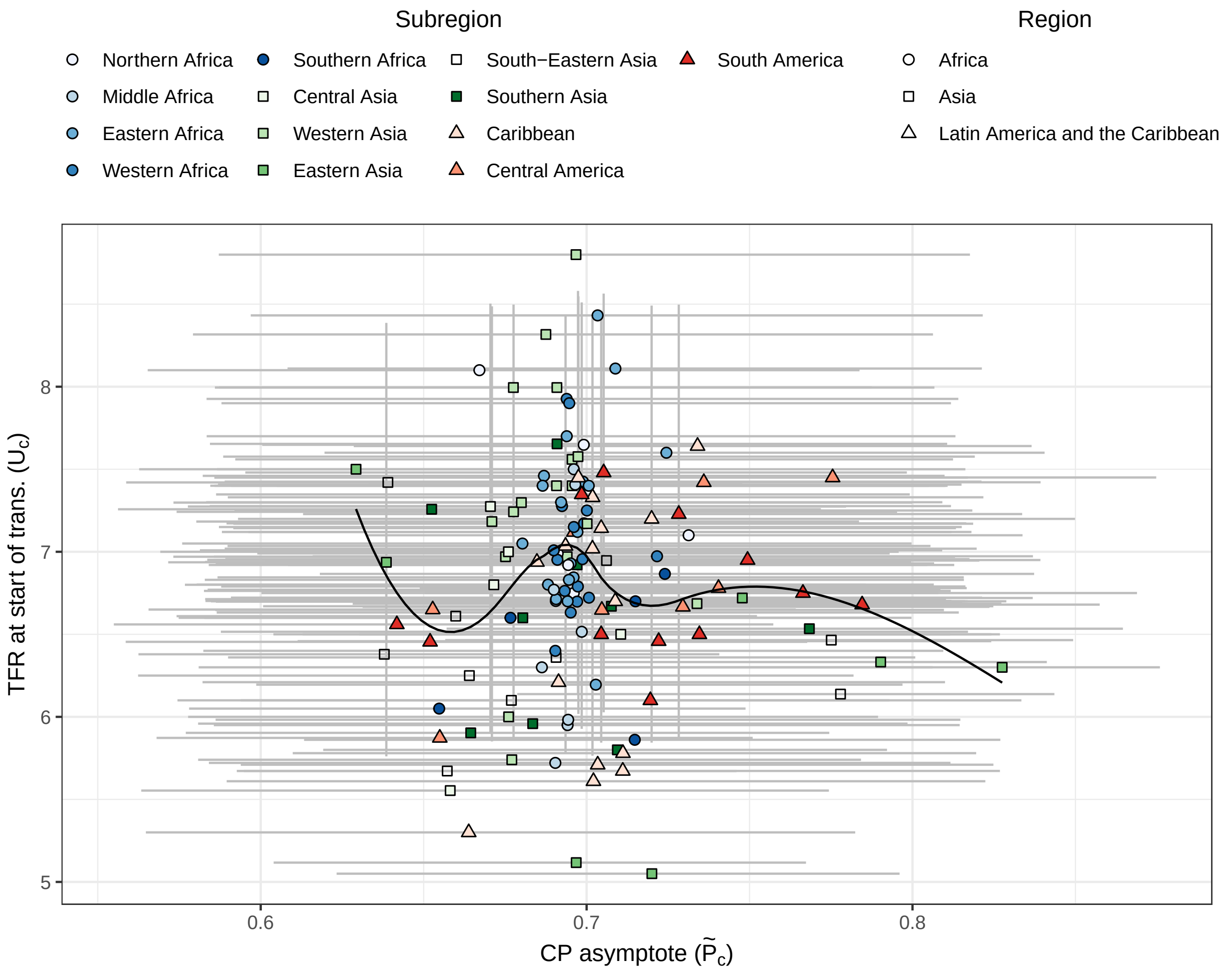

Figure A8. Posterior median estimates of level parameters $\tilde{P}_c$ and U_c for Africa, Asia, Latin America and the Caribbean. Central 80 percent uncertainty intervals are shown by grey cross-hairs. Loess smooths are overlaid to indicate any bivariate associations. Loess was fitted only to the medians; posterior uncertainty in the parameter estimates was not accounted for.

A 3 Discussion of Parameter Association Analyses

Scatterplots, loess smoothers, and OLS regressions were used to further explore the associations between posterior median estimates of the transition model parameters for countries in Africa, Asia, and Latin America and the Caribbean. Associations among the pace parameters overall, and at the regional level were complex, with strong subregional variation. Two subregions were identified as having potentially significant associations by the screening procedure but, due to extreme doubt as to whether they would endure under a more rigorous analysis taking proper account of uncertainty, we did not present the results.

A particular feature of the pace parameters that could have affected the detection of any potential associations is that they are time-localized measures of the transition speeds. In the contraceptive transition model, ω_c is the instantaneous rate of change at the midpoint Ω_c. In the fertility model, d_c is the upper bound of the single largest 5-year decrement in TFR, whenever it happens to occur. It is possible that using parameters that summarize pace over a longer time period could yield different results.

More convincing evidence of substantive associations was found between the timing parameters. There were consistent, positive associations between the estimated midpoints of the contraceptive use and fertility transitions at the overall, regional, and subregional levels. Moreover, this appeared to be well approximated by a linear function at the overall level. We also found that the difference between the midpoints of the two transitions was noticeably greater in Africa, particularly Eastern and Middle Africa, and Western Africa based on projections, relative to the differences in other subregions and regions.

The contraceptive prevalence and fertility models were not conceptually linked and were fitted independently to different source data. A consequence is that identified associations between their respective parameters were not simply a case of “re-discovering” associations already encoded in the models. Nevertheless, a more formal analysis would require the construction of a model that includes both contraceptive prevalence and fertility.

We wish to stress that these analyses were intended to be exploratory, and to be most useful for suggesting avenues for further research rather than testing particular hypotheses. They used only the posterior median estimates of model parameters and did not account for estimation uncertainty. Uncertainty at the subregional level was particularly high. Moreover, the model parameters analyzed pertain only to the systematic, or parametric, components of the contraceptive prevalence and fertility transition models. Both models also include non-systematic (distortion term) components that were not included in any of the analyses done here.

References

Alkema, L., Raftery, A. E., Gerland, P., Clark, S. J., Pelletier, F., Buettner, T. and Heilig, G. K. (2011). Probabilistic projections of the total fertility rate for all countries. *Demography* 48 (3), pp. 815–839. URL: http://dx.doi.org/10.1007/s13524-011-0040-5.

Cahill, N., Sonneveldt, E., Stover, J., Weinberger, M., Williamson, J., Wei, C., Brown, W. and Alkema, L. (2017). Modern contraceptive use, unmet need, and demand satisfied among women of reproductive age who are married or in a union in the focus countries of the family planning 2020 initiative: a systematic analysis using the family planning estimation tool. *The Lancet* 391 (10123), pp. 870–882. DOI: 10.1016/S0140-6736(17)33104-5.

Cleveland, W. S., Grosse, E. and Shyu, W. M. (1992). Local regression models. In: *Statistical Models in S*. Boca Raton: Routledge, pp. 309–376. DOI: 10.1201/9780203738535-8.

Kantorová, V., Wheldon, M. C., Ueffing, P. and Dasgupta, A. N. Z. (2020). Estimating progress towards meeting women's contraceptive needs in 185 countries: a Bayesian hierarchical modelling study. *PLOS Medicine* 17 (2), e1003026. DOI: 10/ggk3cf.

Ševčíková, H., Alkema, L. and Raftery, A. (2011). bayesTFR: an R package for probabilistic projections of the total fertility rate. *Journal of Statistical Software* 43 (1), pp. 1–29. DOI: 10/gf8ttd.

United Nations (2019). *World Population Prospects: The 2019 Revision*. Department of Economic and Social Affairs, Population Division. URL: https://population.un.org/wpp/ (visited on 25/02/2021).

United Nations, Department of Economic and Social Affairs, Population Division (2020a). *Estimates and Projections of Family Planning Indicators 2020*. New York: United Nations. URL: https://www.un.org/en/development/desa/population/theme/family-planning/cp_model.asp (visited on 25/02/2021).

United Nations, Department of Economic and Social Affairs, Population Division (2020b). *World Contraceptive Use 2020*. URL: https://www.un.org/development/desa/pd/data/world-contraceptive-use (visited on 25/02/2021).