Small area estimation of modern contraceptive use in Kenya using the Family Planning Estimation Tool

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Abstract

National-level estimates of family planning indicators such as contraceptive use and unmet need for family planning are produced on a regular basis by the United Nations Population Division and the FP2020 initiative, using the Family Planning Estimation Tool (FPET). While national level modeling can inform national discussions and focus international programs, subnational estimates for policy-relevant areas are needed to inform programming. To date, estimation efforts have focused on subnational estimation for large populations. We extend the FPET model to produce estimates for smaller populations, illustrated for counties in Kenya, by extending the hierarchical structure used and capturing spatial correlation among areas where appropriate. The model is fitted to contraceptive use data at the county-level data when available, and otherwise draws on data that are available at a coarser scale (i.e. national level prevalence).

1 Introduction

National-level estimates of family planning indicators such as contraceptive use and unmet need for family planning are produced on a regular basis by the United Nations Population Division[1] and the FP2020 initiative, using the Family Planning Estimation Tool (FPET).[2;3]. While national-level estimates are useful for monitoring overall progress and assessing average trends, such analyses can mask local disparities. Subnational estimates are needed to assess in-country heterogeneity and to inform local policy and programs in smaller administrative areas.

Prior studies in family planning estimation have focused on estimation for larger population groups, generally administrative level 1 areas, i.e. states in India[4], selected administrative level 1 areas in countries with PMA2020 surveys[5], and estimates for states in Nigeria[6]. In this application, we focus on producing estimates for smaller populations. We illustrate the approach for counties (approximately administrative level 2) in Kenya.

We extend FPET to estimate levels and trends in family planning indicators for small subnational population groups. The main challenges involved in constructing subnational estimates of levels and trends for smaller populations are data sparsity and uncertainty associated with available data: Data disaggregated to lower administrative levels are not necessarily available, especially for earlier years when geo-location of surveys clusters is not given, and moreover, there is generally greater uncertainty associated with those data due to larger sampling errors. Data uncertainty necessitates the use of statistical models to (i) combine information from multiple sources and varying levels of aggregation, and, as appropriate, (ii) to inform estimates for data-sparse population-periods with information from neighboring populations or preceding time periods. We extend the FPET model to produce estimates for smaller subnational populations by extending the hierarchical structure used and capturing spatial correlation where appropriate. The model is fitted to population-subgroup-specific data where available, and aggregated data, i.e. national-level prevalence, is incorporated when break-downs are not available.

In this extended abstract, we first summarize data availability and the FPET model set-up, focusing on contraceptive use only. We then introduce FPET-subnational, which is an extended version of FPET to enable estimation in smaller populations. We use FPET-subnational to estimate family planning indicators for counties in Kenya for women of reproductive age who are married or in a union.

2 Data

2.1 Contraceptive use data

The contraceptive prevalence rate (CPR) is defined as the percentage of women currently using any contraceptive method, and the modern contraceptive prevalence rate is the same but limited to women using modern contraceptive methods, including sterilisation, condoms, oral hormonal pills, intrauterine devices, injectables, implants, vaginal barrier methods, and emergency contraception.

We use data on contraceptive use from Demographic Health Surveys (DHSs) and PMA2020 (PMA) for Kenya, obtained from IPUMS.[7;8] Earlier DHSs are missing geolocations (see Table 1). We summarize data at the county level where possible, at the province or country-level otherwise.

Year	Survey	Geolocation available	Sample size
1989	DHS	No	7,150
1993	DHS	No	7,540
1998	DHS	No	7,881
2003	DHS	Yes	8,195
2008	DHS	Yes	8,444
2014	DHS	Yes	31,079

Table 1: Data sources and sample sizes for county-level contraceptive use prevalence in Kenya from DHS.

2.2 Subnational population estimates for married women of reproductive age

To construct estimates of contraceptive use for subnational areas, estimates of the number of women of reproductive age by marital status are needed to translate proportions into numbers, i.e. number of (additional) users. In addition, population information is needed for model fitting, to include aggregated data to inform estimates at lower levels.

For a country like Kenya, where information on recent admin2 areas is not readily available from earlier censuses (because the counties were more recently formed), county-level back projections are also generally not available. We used the model set-up proposed by Alexander and Alkema to obtain estimates for the current 47 counties.[9] The approach taken is to model the individual counties and fit the model to population data in its most disaggregated form. The model also includes a subnational migration component and incorporates census data to inform the migration estimates.

Information on marital status can be readily obtained from censuses with the same limitation as mentioned for population data: information for all censuses up to the year 2009 are for aggregated counties only. We used a simple approach to obtain the proportion married, which is to apply the rate from the district to the county.

3 Methods

3.1 Summary overview of FPET

In FPET total contraceptive use is modeled using a logistic growth curve and an ARIMA(1,1,0) time series process. In the global FPET, country-specific parameters of the logistic growth curves are estimated using hierarchical models, where countries are organized into subregions, regions and the world. A similar approach is used for estimating the ratio of modern to total use. Model projections depend on the current level of an indicator and past experience, as summarised in the country-specific model parameters. For example, changes in contraceptive prevalence occur according to an underlying trend that assumes growth rates are slow at low levels of the indicator, rates are fastest at intermediate levels, and will slow down again at high levels. Therefore, if a country currently has intermediate contraceptive prevalence then there is room for continued growth in the projection period. Conversely, if a country currently has high contraceptive prevalence, lower growth rates are expected in the projection period. Finally, in global FPET, a data model adjusts for differing data quality and for data that do not pertain to the base population of interest (eg, data for married women not aged 15- 49 years).

Global FPET produces estimates for all countries simultaneously. Fitting the global FPEM is computationally intensive which makes it cumbersome to use for monitoring on a country level; updating a country's estimates based on one new data point takes a long time. New et al. (2017) proposed a country-specific implementation of FPET, as an alternative to the global model estimation approach. The key features of the country-specific FPET is that all non-country-specific parameters are fixed based on the results from the global FPET fit rather than estimated. The country-specific FPET can be considered as a model with informative priors informed by the global FPET.

3.2 FPET model equations for estimating modern use

Let $p_{c,t,k}$ denote prevalence in population c, year t, and category k where $k = 1$ refers to traditional use, $k = 2$ to modern use and $k = 3$ is no use (in FPET, this is further broken down into unmet and no need categories). We estimate total prevalence $P_{c,t} = p_{c,t,1} + p_{c,t,2}$ and the ratio of modern to traditional prevalence $R_{c,t} = p_{c,t,2}/P_{c,t}$. The ratio is modeled as the sum of a logistic growth curve and a time series process (on the logit-transformed scale):

$$
\begin{aligned}
R_{c,t} &= \text{logit}^{-1}\left(\text{logit}(R^*_{c,t}) + \eta_{c,t}\right), \\
\eta_{c,t} &\sim N(\rho_\eta \cdot \eta_{c,t-1}, \tau^2_\eta), \\
R^*_{c,t} &= \frac{\tilde{R}_c}{1 + \exp(-\psi_c(t - \Psi_c))},
\end{aligned}
$$

where asymptote R_c, pace parameter ψ_c and timing parameter Ψ_c are estimated using hierarchical models. For example, for transformed pace parameter $\psi^*_c = \log\left(\frac{\psi_c - 0.01}{0.5 - \psi_c}\right)$ we assume

$$
\begin{aligned}
\psi^*_c &\sim N(\psi^{subregion}_{s[c]}, \kappa^{(c)}_\psi), \\
\psi^{subregion}_s &\sim N(\psi^{region}_{r[s]}, \kappa^{(s)}_\psi), \\
\psi^{region}_r &\sim N(\psi^{world}, \kappa^{(r)}_\psi),
\end{aligned}
$$

where $s[c]$ refers to the subregion of country c and $r[s]$ refers to the region of subregion s.

The model for total prevalence $P_{c,t}$ is also based on the combination of a logistic growth curve and a time series process but instead of summing logistic curve and time series process, the rate of change in $P_{c,t}$ is written as an expected rate of change (based on the current level and logistic growth curve) and a time series process. I.e. for $P_{c,t-1} < \tilde{P}_c$, with $\tilde{P}_c$ is the asymptote of the logistic growth curve, the expression for $P_{c,t}$ is obtained as follows:[2]

$$logit(P_{c,t}) = logit\left(\tilde{P}_c \times logit^{-1}\left(logit\left(\frac{P_{c,t-1}}{\tilde{P}_c}\right) + \omega_c\right)\right) + \epsilon_{c,t}, \quad (1)$$

where ω_c is the pace parameter of the logistic curve, and $\epsilon_{c,t}$ follows an AR(1) process.

3.3 Subnational-FPET

The country-specific FPET has been successfully used to produce subnational estimates in various larger countries, i.e. in India.[4] However, for smaller subnational populations, data are more sparse and uncertain, necessitating greater pooling of information across smaller populations. This motivates the need for an extended version of FPET, referred to as subnational-FPET.

The model for modern and traditional prevalence in subnational-FPET follows the same set-up as summarized in Section 3.2 for the global FPET model. The difference between subnational-FPET and FPET lies in how population-specific parameters are being estimated. In subnational-FPET, extra level(s) of hierarchy and spatial models are introduced to allow for greater pooling of information across smaller populations. For example, for estimating increases in total use (see Eq.(1)), candidate models for the pace parameter ω_c include hierarchical and spatial models, and the time series process for $\epsilon_{c,t}$ can be replaced by a spatio-temporal process.

The data model in subnational-FPET, which captures the relation between the truth and the observed values, also follows the same set-up as in the global FPET with two differences: (1) sampling errors are calculated for smaller subnational populations and tend to be larger, (2) some observations are for population aggregates only, as opposed to for the population of interest. For aggregated observations, we use the population estimates (Section 2.2) to match the aggregate-level observation with a population-weighted average of county-specific prevalences.

4 Preliminary findings

The subnational-FPET model was fitted to DHS and PMA observations from 2003-2016. Figure 1 shows preliminary model-based estimates of modern contraceptive use in 47 counties in Kenya in 2013 (left) and 2016 (right). The assessment in the final paper will be based on the complete dataset and provide details on the spatio-temporal smoothing used.

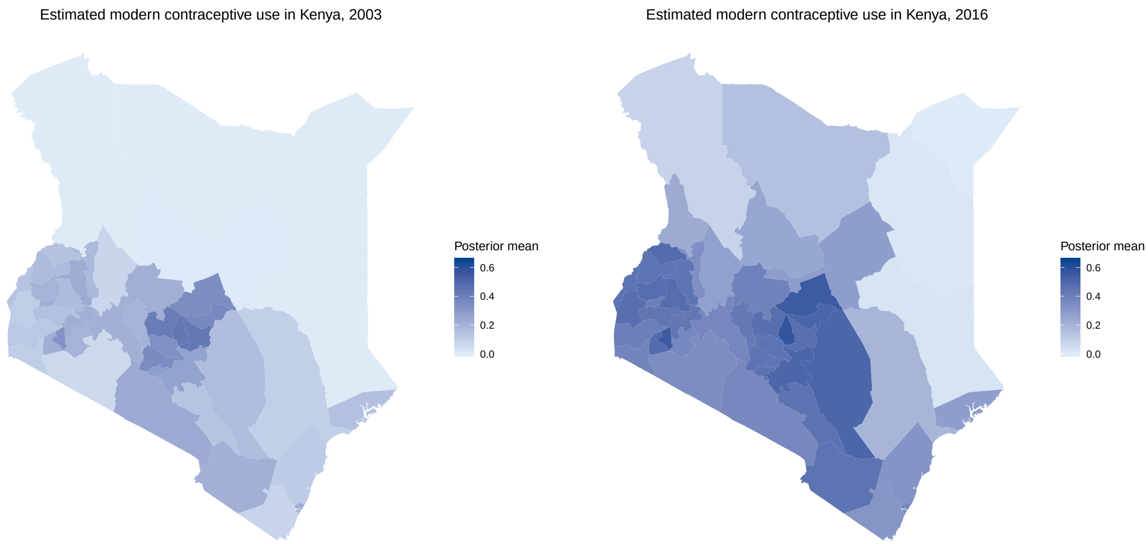

Figure 1: Preliminary model-based estimates of modern contraceptive use in 47 counties in Kenya in 2013 (left) and 2016 (right).

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