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Estimating and forecasting age-specific maternal mortality rates in Brazil

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Brazil has not fulfilled its international commitment to reduce 75% of maternal deaths by 2015 (United Nations, 2015a). In that year, the maternal mortality ratio was around 62 per 100,000 live births and it increased to 64.4 per 100,000 in 2016. This number hides deep regional inequalities, varying from 44.2 in the southern region to 84.5 per 100,000 in the northern region. In the state of Amapá, the ratio reaches 141.7 per 100,000 live births. In Brazil, maternal mortality studies are challenging due to limitations in vital statistics records, especially regarding the quality in data collection. These studies are relevant to help public health policy makers to track trends and prepare proper measures in order to achieve such goals. In this paper, we use maternal mortality estimated based on the Brazilian Mortality

Database to forecast maternal mortality by age groups to 2030. We consider estimates produced in a previous paper combining alternative demographic methods to adjust both death counts and live births to produce more robust estimates of maternal mortality. The goal in this paper is to provide public health policy makers an estimate to track recent trends in maternal mortality to help to elaborate better social and health policies to achieve Sustainable Development Goals (United Nations, 2015b).

Introduction

The Sustainable Development Goals are a series of goals to be achieved by 2030. Among them, ensure health lives and promote well-being for all ages are considered direct health-related factors. In relation to this goal, the World Health Organization (WHO) recently defined the importance of eliminating preventable maternal deaths and set as target that maternal mortality should be reduced to levels below 70 maternal deaths per 100,000 live births by 2030.

Obtaining mortality estimates in less developed countries is a challenge, since the quality of information is generally not satisfactory (Dorrington (2012a); Dorrington (2012b); Hill and Queiroz (2010); Hill et al. (2009); Hill et al. (2005)), which imposes several limitations on monitoring the evolution of maternal mortality. These problems affect the quality of the general registration of births and deaths and also the quality of information on the causes of death. Additionally, the available data presents high regional disparity in the information quality and significant structural changes along the time. Then, it is essential to develop appropriate methods to assess the quality of the records that enable to produce confident maternal mortality estimates. Based on proper estimates, the mortality trends may be projected to support the identification of countries and/or regions that progress at a slower pace and discuss policies and interventions that can assist in meeting the established goals.

Mortality data is organized using ICD-X Review codes. According to the ICD-X, maternal mortality is defined as the death of a woman during pregnancy or within 42 days after termination of pregnancy, regardless of the duration and location of the pregnancy, from any direct or indirect causes related or aggravated by the pregnancy, but not from intentional or accidental causes. Direct causes, according to the WHO, are those related to obstetric complications of the pregnancy, which can be related to the process of pregnancy, labor, or the puerperium. Indirect causes are the result of previous illnesses or illnesses developed during pregnancy that may

have been aggravated by physiologic effects of pregnancy. To measure maternal mortality, we consider the maternal mortality ratio, that refers to the number of maternal deaths in relation to the number of live births, usually multiplied by 100,000.

In Brazil and its regions, maternal mortality studies are further complicated due to limitations in vital statistic records, especially regarding the data quality and other adversities in data collection. These problems not only affect the quality of the general registration of births and deaths but also the accuracy of information on the causes of death. In addition, there are great regional variability in the quality of information and over time.

In this paper, we use maternal mortality estimates based on the Brazilian Mortality Database to forecast maternal mortality by age groups in Brazil and regions. We consider estimates of maternal mortality produced in a previous paper (Queiroz et al., 2021), that combined alternative demographic methods to adjust both death counts and live births to produce more robust estimates of maternal mortality. The goal in this paper is to provide public health policy makers an estimate to track recent trends in maternal mortality to help to elaborate better social and health policies to achieve Sustainable Development Goals.

1 Data and Methods

We use data from the Ministry of Health's Mortality information system. We consider the Mortality Information System (SIM) made available by DATASUS (`http://www2.datasus.gov.br`). It provides information on deaths and causes of deaths, by age and sex at the municipal level since 1979. Birth data is obtained from the Live Birth Information System (SINASC). The system aims to organize and better understand the characteristics of live births in Brazil and has information about the baby's sex, general health conditions and the mother's age. Thus, like mortality data, birth information is made available at the municipal level. The population by age and sex, at the local level, comes from the Brazilian Censuses (1991, 2000 and 2010) and

from the population estimates produced by the Brazilian Institute of Geography and Statistics (IBGE). All of this data is publicly available.

Estimating the maternal mortality rate requires two types of data: number of deaths of women related to pregnancy and number of births in the period covered by the deaths. As discussed earlier, data in countries like Brazil have a number of limitations and adjustments are needed. Thus, the estimation procedure considers the application of a variety of methods for assessing data quality, obtaining data correction factors that are essential to compute adequate estimates. In this paper, we use two measures of deaths related to pregnancy (maternal mortality). The first one is the data used to estimate maternal mortality ratios, available from 2009 to 2019, that considers the maternal mortality definition exactly according to the WHO - and it is subjected to the Ministry of Health evaluation program. The second one, available in a longer series, from 1979 to 2019, considers the ICD-X definition of maternal causes of deaths, those events can be considered a late maternal death since it is the death of a woman from direct or indirect obstetric causes, more than 42 days but less than one year after termination of pregnancy.

The first step of the study is to assess the quality of the death record in relation to the age structure of mortality and the age structure of deaths. This analysis is done using a series of traditional demographic methods, better known as Death Distribution Methods Hill et al. (2009). These methods were developed, based on population dynamics equations, to assess the coverage of deaths in relation to the population and the quality of the declaration of information on deaths and population. We also adjusted live births data using traditional demographic methods such as Brass P/F and Gompertz Lima et al. (2018). For more details see Queiroz et al. (2021).

To produce adequate estimates for the future maternal mortality rates, we aim to consider probabilistic forecasting models that account for the possible trend differentials between age groups or regions. The widely used Lee-Carter model, introduced by Lee and Carter (1992), is

an appropriate method to forecast age-specific mortality rates under this condition. This model describes the log-mortality rate at age x and time t by

$$\log(m_{x,t}) = \alpha_x + \beta_x k_t + \epsilon_{x,t} \ , \tag{1}$$

where α_x represents the average level of the age-specific mortality rates, k_t is a time-trend index of the general mortality level, β_x represents the variation factor of the age-specific rates as k_t varies and $\epsilon_{x,t}$ is the error term. For now, we have considered the dynamic model proposed by Pedroza (2006) to forecast some maternal mortality rates. This model is a fully Bayesian approach to the Lee-carter model displayed in (1). As the original Lee-Carter model only incorporates uncertainty from the forecast of the mortality rates, the Bayesian approach proposed by Pedroza (2006) incorporates the uncertainty from all the parameters in the Lee-Carter formulation, providing credible intervals to the estimates of α_x, β_x and k_t.

In Figure 1, we present the maternal log-mortality rates predicted for the years 2011-2018 under the Bayesian approach proposed by Pedroza (2006). These estimates consider the observed age-specific rates from 1979 to 2010. The observed rates are higher for the older ages and present a decreasing trend for all age groups. The credible intervals for the predicted rates embody the observed rates, which indicates the used model as an adequate choice to forecast the maternal log-mortality rates according to the purposes of the study.

Alternative models are currently under analysis and can also be considered to forecast the maternal mortality rates. The dynamic Bayesian beta model proposed by Da-Silva et al. (2011) may be considered to forecast the rates for each age group separately. Also, incorporating available covariates to the model proposed by Pedroza (2006) may improve the forecasting accuracy.

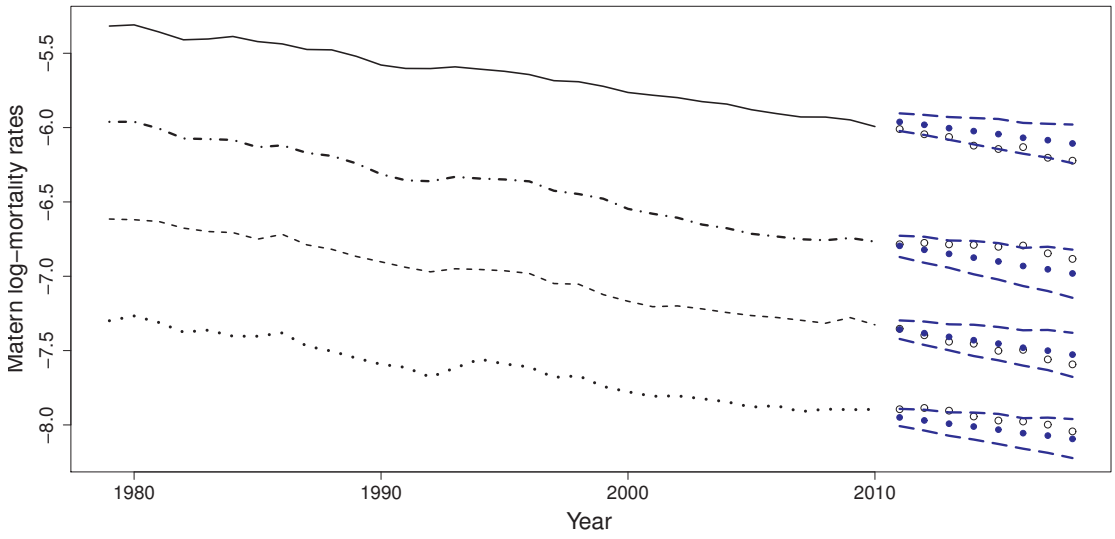

Figure 1: Observed matern log-mortalilty rates in Brazil for the age ranges 10-19 (dotted line), 20-29 (dashed line), 30-39 (dot-dashed line) and 40-49 (solid line), for the years 1979-2018. For the years 2011-2018, the circles indicate the observed values, the blue bullets indicate the estimated rates and the blue dashed lines indicate the 95% central credible interval of such estimates.

2 Future Analysis

- Forecast maternal mortality by regions and educational level.
- Present results of maternal mortality rates by age and maternal mortality ratios up to 2030
- Substantive analysis of the results (more detailed discussion with current literature).

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