Using Functional Principal Components Analysis (FPCA) to improve deterministic household projections in Brazil

Gustavo Pedroso de Lima Brusse[1]
Tirza Aidar[2]

Abstract

Household projection has been gaining increasingly attention in the literature. Applications are considerable relevant on studies concerning social housing demand, family formation and environmental issues such as consumption of water, energy and durable goods. Most of the Brazilian household projection experiences uses Headship Rate Method and assumes that the headship rates will be constant over time, not considering sex or household type differences. The objective of this study is to propose a new alternative approach for headship rates forecasting that avoid constant rate scenarios in household projections. Instead of the scenario-based approach, the new approach will use confidence intervals of the stochastic forecasting to build high, low and medium variants. The results will be compared with PNAD observation from 2019. The model for projecting headship rates proposed here follows the Functional Principal Components Analysis (FPCA) (Booth et al, 2014) based on Lee-Carter (1992) approach, which uses the SVD decomposition to decompose the log of a defined rate into three effects: a general mean pattern, an effect of change at each age and other effect of change over time.

Keywords: Household Projection; Headship Rate Method; Lee Carter;

[1] Universidade Estadual de Campinas (NEPO/IFCH - UNICAMP); e-mail: gustavo.brusse@gmail.com
[2] Universidade Estadual de Campinas (NEPO/IFCH - UNICAMP); e-mail: tirza@nepo.unicamp.br

Introduction

Household projection has been gaining increasingly attention in the literature. Applications are considerable relevant on studies concerning social housing demand, family formation and environmental issues such as consumption of water, energy and durable goods (ZENG ET AL., 2014; GU et al., 2015; MARTINEZ, 2010; KEILMAN, 2018).

Most of the Brazilian household projection experiences uses Headship Rate Method (Kono, 1987) and assumes that the headship rates will be constant over time, not considering sex or household type differences (EMPRESA DE PESQUISA ENERGÉTICA, 2004; CENTRO DE DESENVOLVIMENTO E PLANEJAMENTO REGIONAL, 2007; Andrade and Pinheiro, 2014;; ELECTROBRAS, 2007; DAE, 2017; SEADE, 2017;). However, in Brazil, males experienced a great headship rate decrease in the period 2000-2010, while for females there was a marked increase (Giviziez and Oliveira, 2006; Giviziez and Oliveira, 2018). Also, if different household types are considered, some household types have different headship rates trends than others, breaking the usual constancy assumption.

The headship rates calculated here were taken from the Brazilian Household National Sample Survey (PNAD) from 2001 to 2015. Unlike the Demographic Census, the PNADs have maintained the same head identification question since 1992 until 2015, which avoids the misinterpretation of census question that changed from 2000 to 2010.

The objective of this study is to propose a new alternative approach for headship rates forecasting that avoid constant rate scenarios in household projections. Instead of the scenario-based approach, the new approach will use confidence intervals of the stochastic forecasting to build high, low and medium variants. The results will be compared with PNAD observation from 2019.

Materials and method

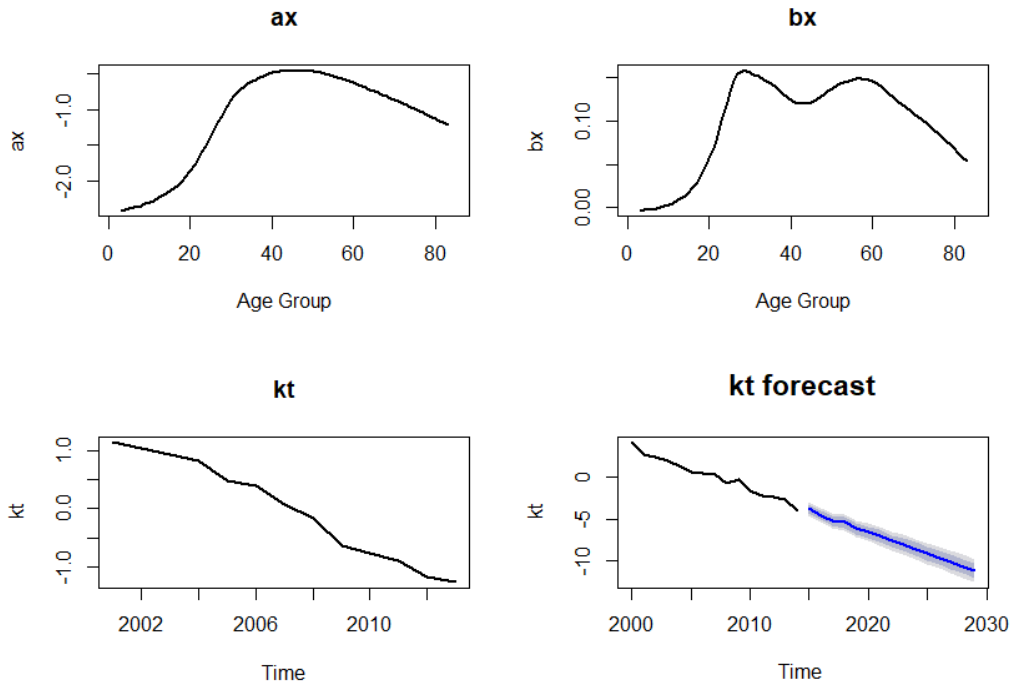
The model for projecting headship rates proposed here follows the Functional Principal Components Analysis (FPCA) (Booth et al, 2014) based on Lee-Carter (1992) approach, which uses the SVD decomposition to decompose the log of a defined rate into three effects: a general mean pattern, an effect of change at each age and other effect of change over time. The headship rates can be written as:

$$\ln[h(x,t)] = a(x) + b(x)k(x) + e(x,t)$$

Where $h(x,t)$ is the headship rate at age x in year t; $k(t)$ is the level of headship rate over time; $a(x)$ is the general pattern of headship rate by age, $b(x)$ is the relative speed of headship rate change at each age and $e(x,t)$ the residual error at age x and time t, with Normal distribution $(0, \sigma^2)$. To illustrate the procedure, the figure below shows the decomposition effects ($a(x)$, $b(x)$ and $k(t)$) for Brazilian South East males living in household type "couple with children" during 2000 to 2015. Using time series ARIMA models, it possible to forecast the trend of the time effect $k(t)$ for h = 15 years towards 2030 and obtain future headship rates.

Results

FIGURE 1 - a(x), b(x), k(t) effects and k(t) forecast for Brazilian South East Region males living in household of a couple with children.



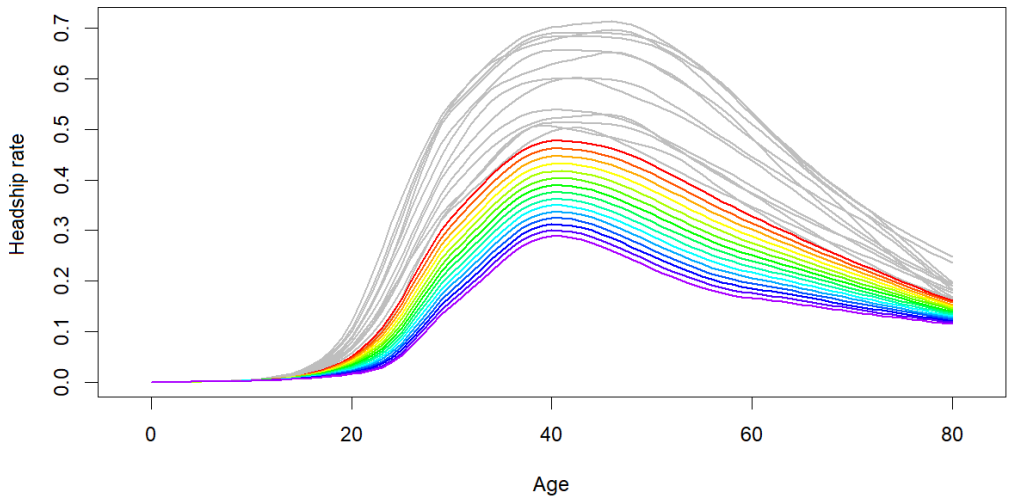
Source: Self-elaborated

Having obtained $a(x)$, $b(x)$ and forecast $k(t)$, we can estimate future headship rates ($h(x,t+h)$) as showing in the graph 2. Because of the linear decreasing trend of $k(t)$, the future headship rates for males living in the household "couple with children" will have the same shape ($b(x)$ is constant in time) and each year will be smaller. Its important to note that, if $k(t)$ keep this linear trend constant over time, the headship rate

will tend to zero. In a more distant forecast horizon, an asymptote (and consequently, new assumptions about this asymptote) would be necessary to restrict such trend and avoid loss of consistency. However, as the forecast horizon is reasonable short (15 years), it will be assumed that the trend observed during 2000-2015 will continue without any restriction.

Another strong assumption that should be discussed is related to sex and household type consistency. Considering one Lee Carter model for each household type and sex yields independent results for each category. For example, a decreasing headship rate forecast for male living in “couple with children” household type will necessarily increase others male’s household types. Also, it will directly increase female’s headship rate forecast of the same household type. Because of that, the household number distribution resulting from this approach should be interpreted independently by sex and household type.

FIGURE 2 - Headship rate forecast, male: couple with children, Southeast region Brazil (2018 – 2030),



Source: Self-elaborated

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