IMPACTS OF THE COVID-19 PANDEMIC ON INTERNATIONAL FERTILITY – A STOCHASTIC PRINCIPAL COMPONENT APPROACH
Background

- COVID-19 pandemic has affected a multitude of areas in life
- Direct effects investigated well: increased mortality, morbidity, healthcare demand
- Understanding of long-term effects, such as worsening mental health due to the NPIs or behavioral effects still limited
  - Less research thus far focused on these aspects
  - Inherent uncertainty since effects only show in the long run (time series lacking thus far)
- Potential long-term effects on behavior after full vaccinations and lifting of NPIs unclear
- Trends in fertility influenced by many factors
  - Previous fertility level
  - Socioeconomics of countries
  - Cultural aspects such as gender equality and female education (opportunities)
  - Social and family policy
Motivation

Potential impacts of pandemic on fertility

- Biological effect after infection
  - Higher infertility
  - Different timing of births (e.g. premature)
  - Higher risk of stillbirths
  - Higher propensity of neonatal deaths

- Behavioral change
  - Changed tempo of births
    - Delay because of insecurity about future
    - prepone births because of better opportunities of home office
  - Changed quantum of births
    - Decreased fertility because of fear of the pandemic consequences and more negative outlook on the future
    - Increased fertility because of intensified contacts between couples living together, including increased sexual and reproductive activity
Motivation

- Fertility response of high-income countries may differ from that of middle- and low-income countries¹

- We try to quantify differential fertility observed thus far during the pandemic based on an adjusted version of a stochastic approach suggested earlier² for excess mortality estimation

- Classification of countries by fertility response to pandemic conditions

- Stochastic projection of long-term impact of pandemic on fertility by country


Data

- Monthly birth numbers since January 2000 of 32 countries: STFF provided by HFD
- End-of-year population estimates since 1999 of females in reproductive age group (13-54) gathered from HMD, WorldBank, and national statistical offices
- Compute monthly pseudo fertility rates (MPFRs) by dividing monthly births by end-of-year fertile female population of previous year:

\[
l_{f_{c,y,m}} := \ln \left( \frac{B_{c,y,m}}{P_{c,y-1}} \right)
\]

\Rightarrow\text{ rough adjustment of raw births to population size}
Methods

- Check first hypothesis of impact of SARS-CoV-2 on biological fertility, which may appear since the beginning of the pandemic, i.e. January 2020

- problem: we don’t know how many births we would have observed under normal circumstances

- We only observe births under pandemic conditions

  ⇒ Direct effect of pandemic on fertility not directly observable; question of counterfactuals

- Approach: estimate distribution of births if had not have this unusual observation

  ⇒ Compare stochastic forecast of births (hypothetical ex-ante development without pandemic) observed births (ex-post with pandemic), including stochastisticity
Methods

- Perform principal component analysis (PCA) on collection of log-MPFR time series of all countries for baseline period January 2000 – December 2019:

\[ p_{i,y,m} := \sum_{c=1}^{32} \lambda_{i,c} \cdot l_{f,c,y,m} \]

- Fit SARIMAX models to time series of PCAs
- Simulate PCs for January – September 2020 via Monte Carlo simulation
- Retransform trajectories for PCs into trajectories of the log-MPFRs
- Exponentiation of log-MPFR trajectories gives trajectories of MPFRs
- Multiply MPFR trajectories by estimates of female fertile population => distribution of births
- Compare forecast of births to observed numbers
Methods

- PC 1 explains 41% of variance of all log-MPFR time series

- Long-term international fertility development; loadings vary between countries
  - Differs by intensity
  - Differs by direction
    ⇒ Modeled by logarithmic function

- High innerannual seasonality
  ⇒ Modeled by linear combination of cosine function and monthly dummies, as suggested by Vanella et al. (2021)

- Remaining noise based on ACF and PACF identified as \( SAR(1)x(1)_{12} \) model
Methods

- PC 2 explains further 27% of variance
- Loadings positive for all countries, except GER, LVA, and LTU
- Long-term negative trend since beginning of 2008

⇒ Negative effect of *Great Recession*\(^2\) on fertility
  - Germany appears robust; increasing fertility due to deceleration of tempo effect and simultaneously successful demography-related social policy measures\(^3\)
  - Trends in Latvia and Lithuania unclear (input very welcome!)

⇒ Modeled by quadratic trend function

- Seasonality modeled by monthly dummies; \(SIMA(1,1)x(1,0)_{12}\) for nuisance


Methods

- Remaining 30 PCs assumed random walk processes
- Simulations of PCs retransformed as described
- Depending on outcome of first hypothesis test, baseline period is defined
Results

Figure 1. Observed monthly births (dots) against rejection area of one-sided null hypothesis of no increased biological infertility (gray area)

Sources: Human Fertility Database (2021); own computation and illustration
Results

Figure 2. Observed monthly births (dots) against rejection area of two-sided null hypothesis of no differential fertility (gray area).

Sources: Human Fertility Database (2021); own computation and illustration.
Results

- No evidence for higher biological infertility because of pandemic
  - Forecast October 2020 – December 2021

- Overall fertility response differs very much between countries
  - No increased fertility for any country
  - 18 countries with no statistically significant differences
  - 14 countries show lower fertility: tendency among Mediterranean, Northern European, and East Asian countries
Further steps

- Next, we will develop an approach for adjustment of fertility projections amidst pandemic effects
- For unaffected countries, no adjustment to fertility forecasts necessary
- For countries with substantial differential (i.e. lower) fertility, previous fertility forecast should be adjusted
- Idea: divide observed monthly births by forecasts to and fit distributions of some differential parameter
- E.g., adjust UN WPP by multiplication with simulations of differential parameter, similar as in Bayesian updating
- Include different scenarios on the future development of the parameter based on the literature (e.g., see Berington et al. 2021\textsuperscript{4} or Goldstein 2020\textsuperscript{5})

\[ \Rightarrow \text{Stochastic fertility projection based on ensemble sampling} \]


\textsuperscript{5} Goldstein, J.R (2020): „Rebirth after Disaster: Models of Post-Pandemic Fertility and Marriage.“ Keynote at Wittgenstein Centre Conference 2020, available at https://www.youtube.com/watch?v=DPWsRG747WM.
Many Thanks! Questions or Remarks?

Figure 3. Course of principal component 1 for baseline period January 2000 – December 2019
Figure 4. Loadings of principal component 2 for baseline period January 2000 - December 2019
Figure 5. Course of principal component 2 for baseline period January 2000 – December 2019
Figure 6. Course of principal component 1 for baseline period January 2000 – September 2020
Figure 7. Loadings of principal component 2 for baseline period
January 2000 - September 2020
Figure 8. Course of principal component 2 for baseline period January 2000 – September 2020