Probabilistic Projection of Net International Migration Rates For All Countries

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Outline

- Population projections and international migration
- Bayesian hierarchical model for net international migration rates
- Ensuring balance
- Assessment of method
- Examples

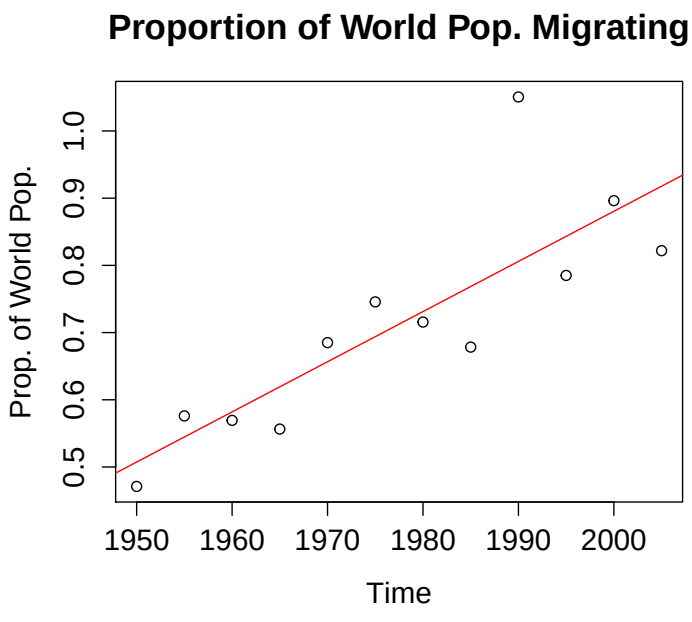
Population Projections and International Migration

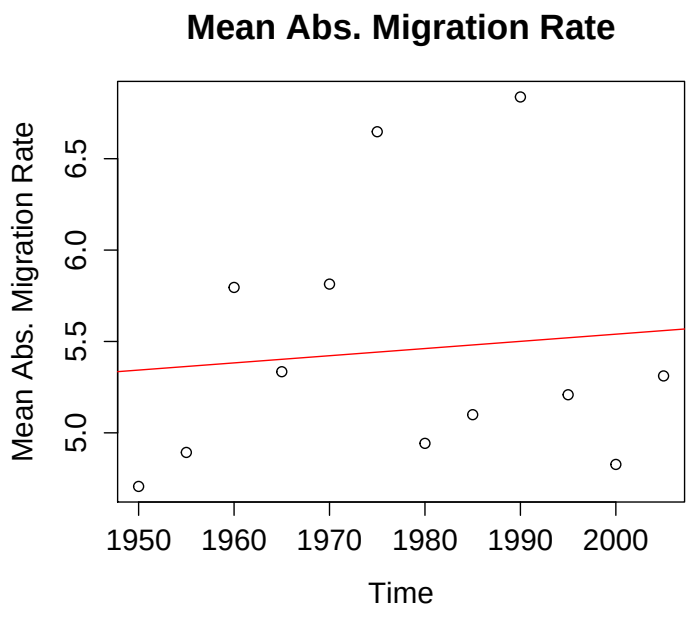
- In November 2012, UN Population Division issued experimental probabilistic population projections for all countries
  - http://esa.un.org/unpd/ppp/
  - Probabilistic fertility projections based on a Bayesian hierarchical model (BHM) for TFR (Alkema et al 2011, *Demography*)
  - Probabilistic mortality projections based on a BHM for life expectancy (Raftery et al 2013, *Demography*)
  - BUT deterministic migration projections: persistence in the medium term, then declining to zero (with some exceptions).
- Probabilistic projections of net international migration needed for all countries
  - Should give calibrated intervals, e.g. 80% prediction intervals should contain the truth 80% of the time on average.

Some Stylized Facts About International Migration

(from WPP estimates)

- It sums to zero across the globe for all sex-age groups
- Countries often cross over from sending to receiving countries:
  - 46% of countries were either sending countries in 1950–55 and receiving countries in 2005–2010, or vice versa.
- Trends:
  - Proportion of world population migrating has been increasing (proxied by sum of absolute net migration)
  - BUT average absolute net international migration has barely changed. Paradox?





Bayesian Hierarchical Model for Net International Migration Rates

- We model the net international migration rate, $r_{c,t}$, in country c and time period t by an AR(1) time series model as

$$(r_{c,t} - \mu_c) = \phi_c(r_{c,t-1} - \mu_c) + \varepsilon_{c,t}$$

- Too few data points (12) to estimate the model reliably in each country by itself
  - Solution: For each country, draw on information from other countries
- Bayesian hierarchical model:
  - Model parameters for countries distributed about "world average"
  - World average parameters have a prior distribution
  - Bayesian estimation using Markov chain Monte Carlo (MCMC)
  - Estimate for a country $\approx$ weighted average of its estimate and world average estimate
- Gives a sample of many possible future trajectories of migration in all countries and periods

Ensuring Balance

- Net migration counts sum to zero across the globe for all periods and sex-age groups
  - But trajectories from the BHM do not do so
- Solution: Postprocess each trajectory to ensure balance. Method:
  1. For the k-th simulated parameter vector, project net migration rates for all countries one time period into the future.
  2. Convert net migration rate projections into counts.
  3. Break down migration counts by age and sex via model migration schedules
  4. Redistribute overflow migrants to all countries, in proportion to their projected populations.
  5. Continue projecting trajectories one time step at a time into the future, repeating steps 1-4.

Cross-Validation Prediction Experiment: Calibration of Prediction Intervals

- Net migration rates for 1950–2010 in 5-year periods from WPP
- Estimate the model for (e.g.) 1950–1995, generate predictions for 1995-2010, and compare them with data.
- Coverage of prediction intervals (%):

Validation time period	80% PI	95% PI
5 years	91	96
15 years	85	93
30 years	77	89

- Method reasonably well calibrated at all forecast horizons

Accuracy of Projections

- Compare point predictions with
  - Persistence model: Migration rates remain constant at current values. Similar to WPP projection.
  - Gravity model (Cohen 2012)
- Mean Absolute Errors by validation time period (smaller is better):

Method	5 years	15 years	30 years
Persistence	3.6	6.7	7.2
Gravity	4.7	6.6	12.3
Bayesian	3.2	4.8	5.1

- Bayesian method outperformed others at all forecast horizons

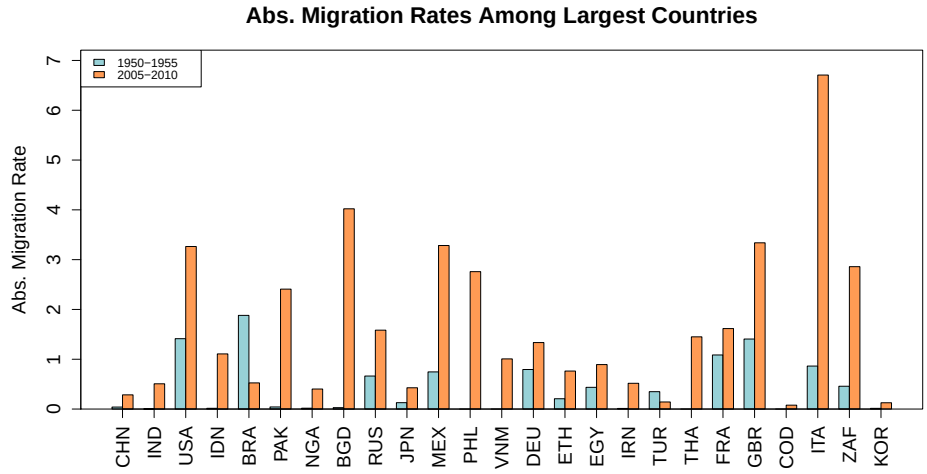
Frequency of Cross-Overs Between Being a Sending and Receiving Country

- Over the past 60 years, 46% of countries have crossed over from being a sending to a receiving country, or vice-versa.
- Proportions predicted over the next 60 years:

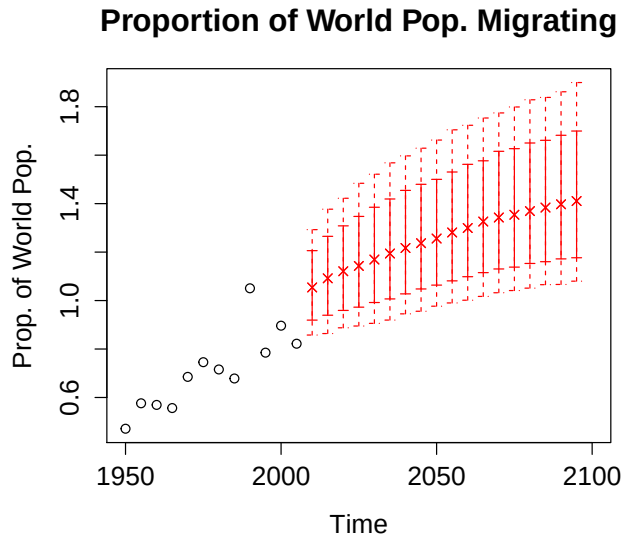
Persistence:	0%
Gravity:	29%
Bayesian:	49%
Observed:	46%

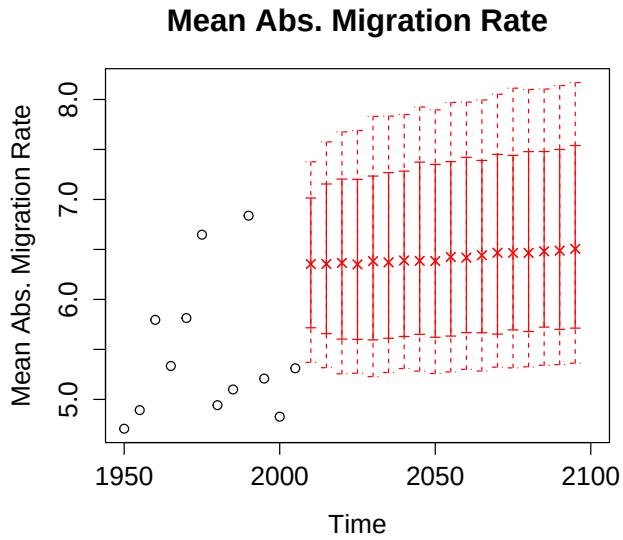
Resolution of Global Migration Trends Paradox

- Propn. migrating increasing, but average migration rate constant
  - Resolution: Due to low migration rates for big countries:

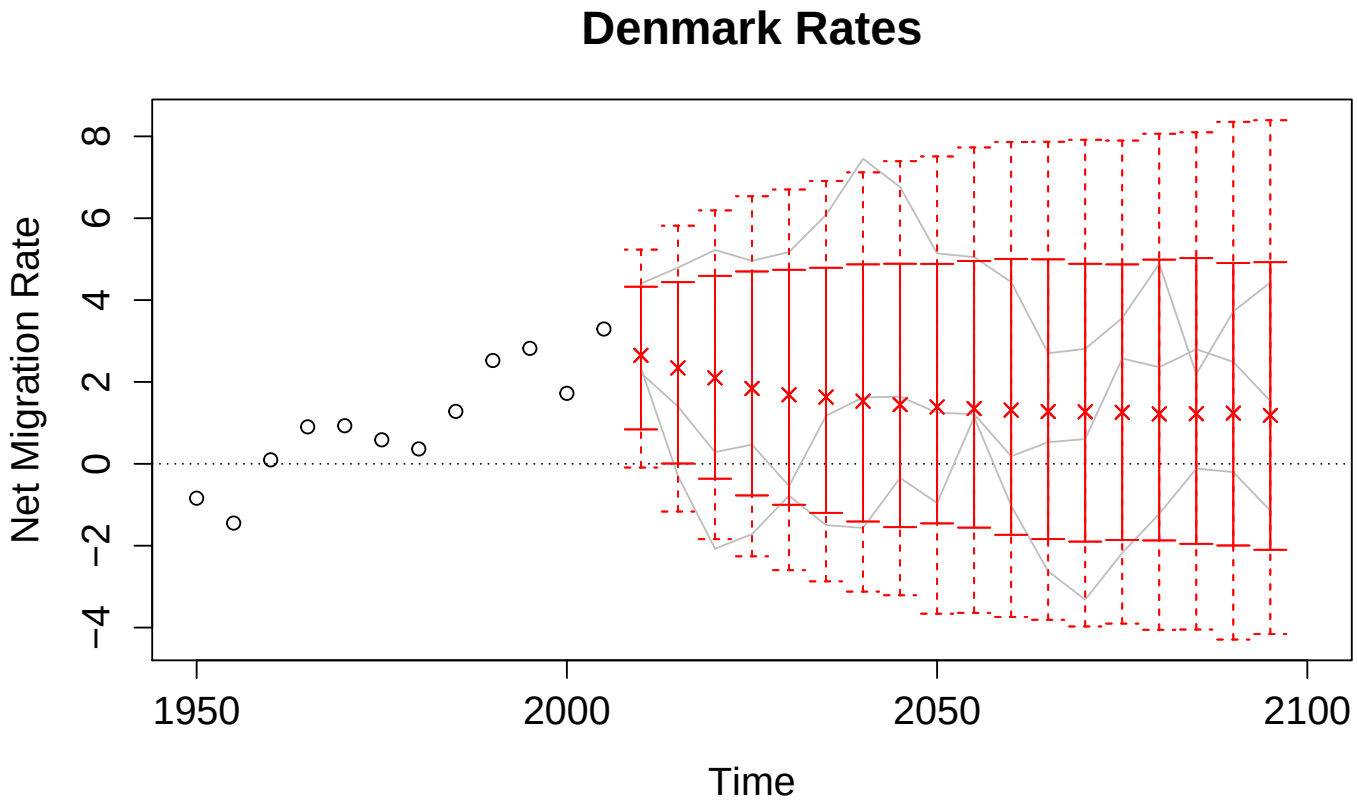


- Bayesian model successfully reproduces it:



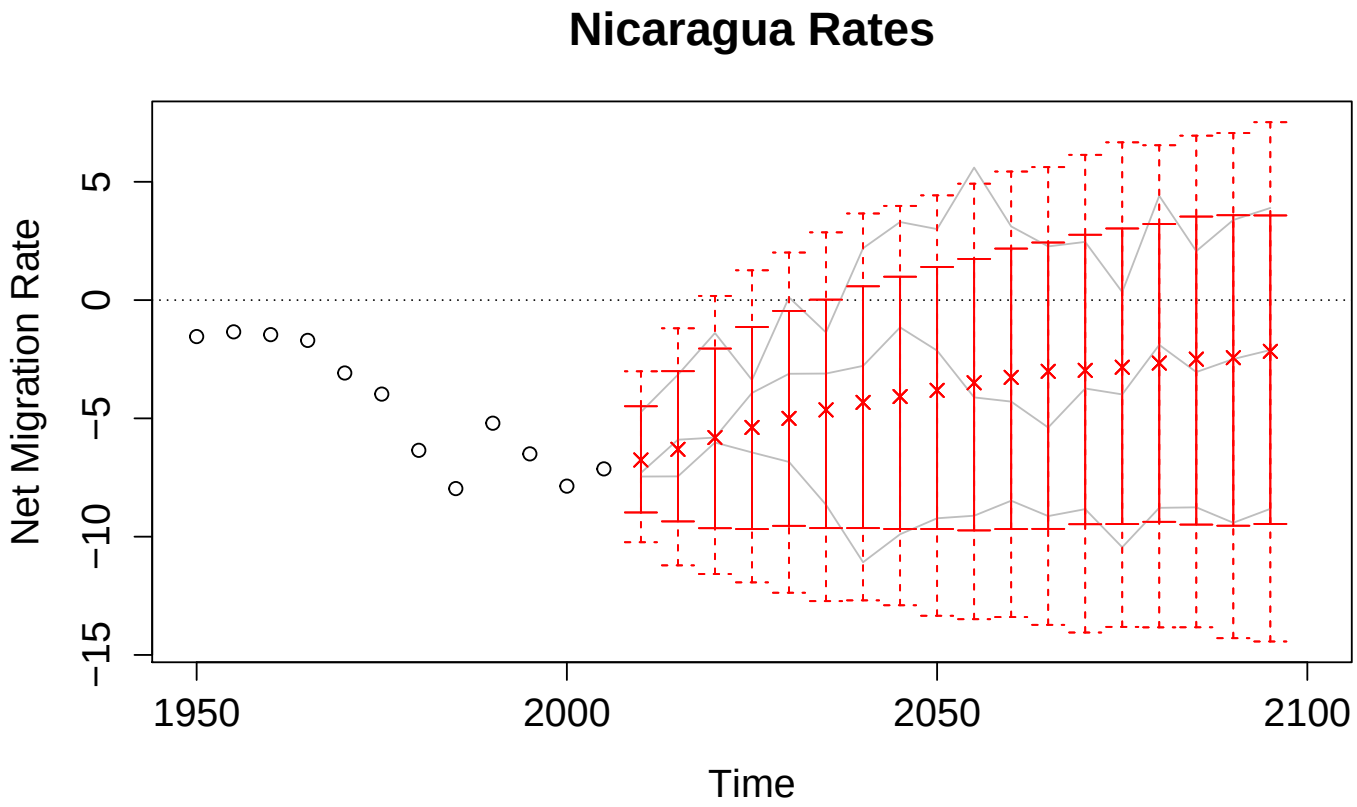


Denmark



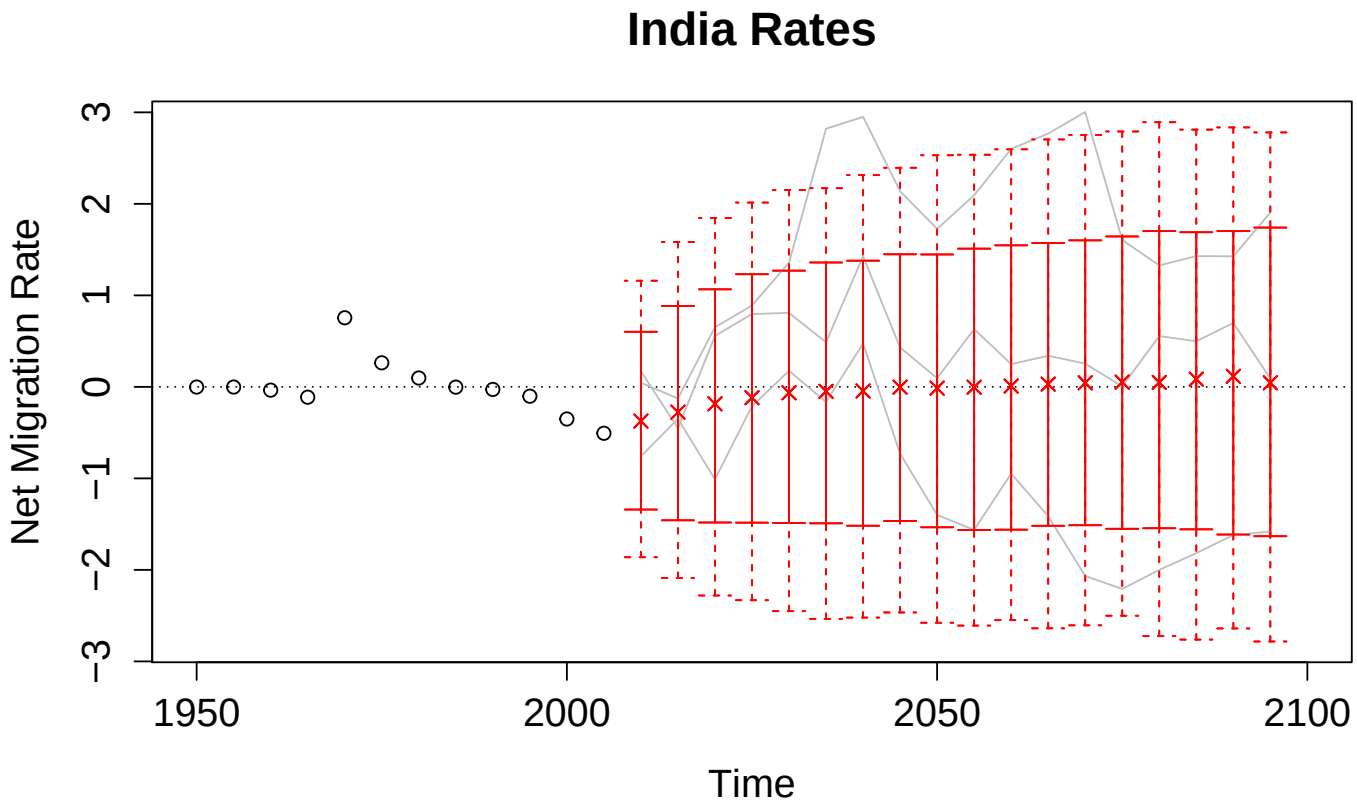
- Crossed over from sending to receiving country
- Median projection: continuing (but declining) in-migration
- But nonnegligible probability of renewed out-migration
  - and also of increased in-migration

Nicaragua



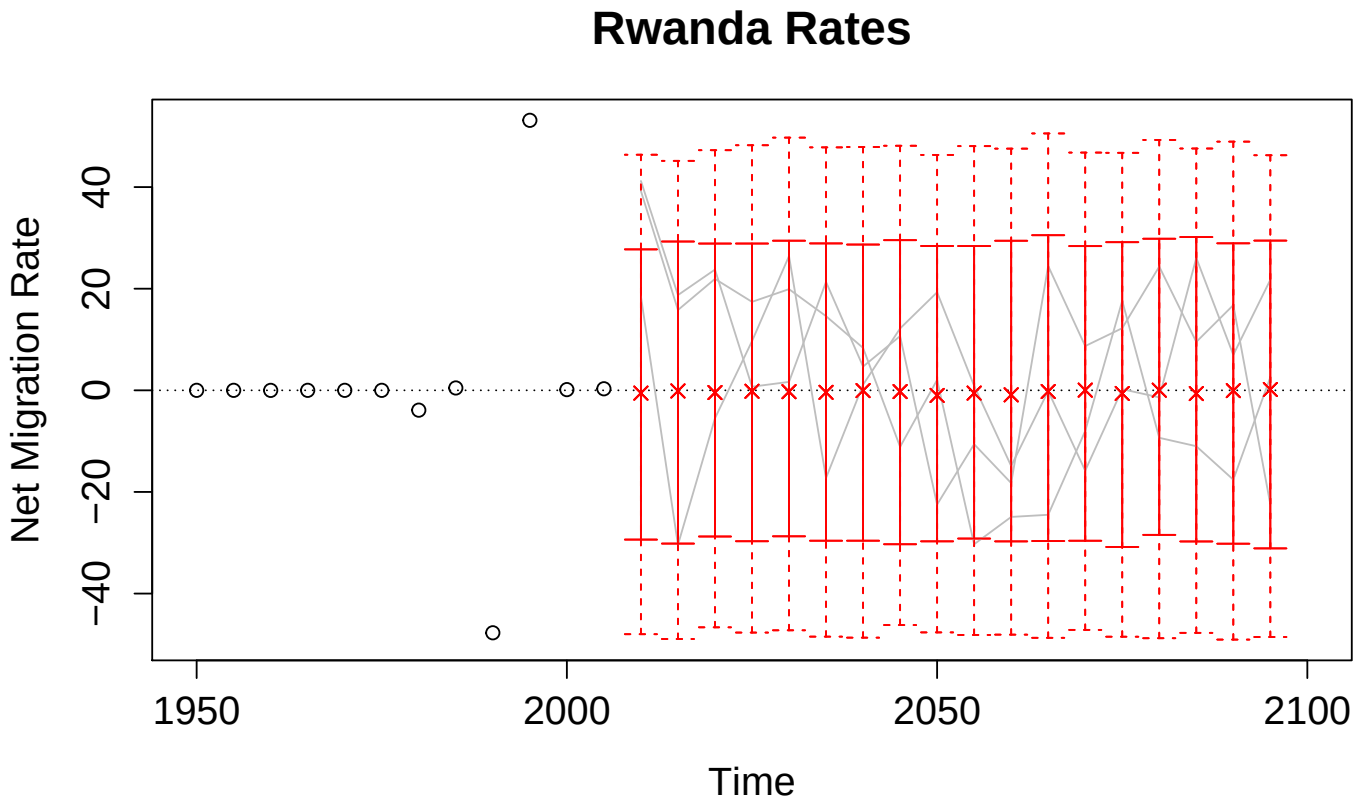
- Classic sending country with high out-migration
- Median projection is for this to continue, but at a reduced rate
- Continued high out-migration, and becoming a receiving country by 2100, also (less likely) possibilities

India



- Large country with very low migration rates ($<$ 1 per 1,000)
- Median projection continues near zero
- But *absolute* migration rates projected to increase, closer to the world average (across countries) of 5 per 1,000.

Rwanda



- Dominated by large spikes in 1990s
- Median projection is close to zero
- But allows for the possibility of future large spikes

Summary

- Probabilistic migration projections needed for fully probabilistic population projections. They should:
  - sum to zero across the globe for all periods and sex-age groups
  - give calibrated prediction intervals
  - allow for cross-overs between sending and receiving (46% of countries in past 60 years)
  - reproduce the migration "paradox": total migration increasing but average migration constant
- We propose a Bayesian hierarchical AR(1) model for projecting net international migration rates for all countries
- Reasonably well calibrated and outperformed some other methods in cross-validation prediction experiment
  - Also predicted cross-overs and reproduced the migration paradox
- Possible improvements:
  - Better data (Abel 2013)
  - Apply to in-migration and out-migration (Abel, Sander, Samir 2013)
  - Demographic covariates (Kim & Cohen 2010; Billari & Dalla-Zuana 2012)
- Probabilistic population projection references at www.stat.washington.edu/raftery/Research/soc.html