Package ‘bayesTFR’

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bayesTFR-package

Bayesian Fertility Projection

Description

Collection of functions for making probabilistic projections of total fertility rate (TFR) for all countries of the world, using a Bayesian hierarchical model (BHM) and the United Nations demographic time series. Functions for subnational projections are also available.
The projection follows a method developed by Alkema et al. (2011) and Raftery et al (2013). It uses historical data provided by the United Nations to simulate a posterior distribution of total fertility rates for all countries in the world simultaneously.

The estimation is split into two parts:

1. BHM for fertility in a transition phase (Phase II), as described in Alkema et al. (2011),
2. BHM for fertility in a post-transition phase (Phase III), as described in Raftery et al (2013).

The second part is optional and can be replaced by a simple AR(1) process.

The main functions of the package are:

- **run.tfr.mcmc**: Evokes running a Markov Chain Monte Carlo (MCMC) simulation for TFR in Phase II using one or more chains, possibly in parallel. It results in a posterior sample of the mcmc parameters. Existing simulation runs can be resumed using continue.tfr.mcmc.
- **run.tfr3.mcmc**: Starts MCMCs for TFR in Phase III. Existing simulation runs can be resumed using continue.tfr3.mcmc.
- **tfr.predict**: Using the posterior parameter samples it derives posterior trajectories of the total fertility rate for all countries.
- **run.tfr.mcmc.extra**: Runs MCMC for extra countries or regions, i.e. for countries not included in the Bayesian hierarchical model. It can be also used for aggregations.
- **tfr.predict.extra**: Generates predictions for extra countries or aggregated regions.

The order of the functions above roughly corresponds to a typical workflow when using the package: 1. run a Phase II MCMC simulation, 2. run a Phase III MCMC simulation (optional but recommended), 3. generate predictions, 4. analyze results (using the functions below). If there are countries that were not included in steps 1.-3., or if there are aggregated regions for which a prediction is desired, one proceeds with the two functions at the bottom of the list above, followed by the analyzing functions below.

A number of functions analyzing results are included in the package:

- **tfr.trajectories.plot**: Shows the posterior trajectories for a given country, including their median and given probability intervals.
- **tfr.trajectories.table**: Shows the posterior trajectories for a given country in a tabular form.
- **tfr.map**: Shows a TFR world map for a given projection period.
- **DLcurve.plot**: Shows the posterior curves of the double logistic function used in the simulation of PhaseII, including their median and given probability intervals.
• `tfr.partraces.plot` and `tfr.partraces.cs.plot`: Plot the Phase II MCMC traces of country-independent
  parameters and country-specific parameters, respectively. `tfr3.partraces.plot` and `tfr3.partraces.cs.plot` do
  the same for Phase III MCMCs.

• `tfr.pardensity.plot` and `tfr.pardensity.cs.plot`: Plot the posterior density of the Phase II MCMCs
  for country-independent parameters and country-specific parameters, respectively. `tfr3.pardensity.plot` and
  `tfr3.pardensity.cs.plot` do the same for Phase III MCMCs.

• `summary.bayesTFR.mcmc.set`: Summary function for the MCMC results.

• `summary.bayesTFR.prediction`: Summary function for the prediction results.

For MCMC diagnostics, functions `coda.list.mcmc` and `coda.list.mcmc3` create an object of type
“mcmc.list” that can be used with the `coda` package. Furthermore, function `tfr.diagnose` and `tfr3.diagnose`
analyze the MCMCs using the Raftery diagnostics implemented in the `coda` package and gives information
about parameters that did not converge.

Existing simulation results can be accessed using the `get.tfr.mcmc` (Phase II) and `get.tfr3.mcmc`
(Phase III) functions. An existing prediction can be accessed via `get.tfr.prediction`. Existing convergence
diagnostics can be accessed using the `get.tfr.convergence`, `get.tfr.convergence.all`, `get.tfr3.convergence` and
`get.tfr3.convergence.all` functions.

The historical national TFR data are taken from one of the packages `wpp2017` (default), `wpp2015`,
`wpp2012` or `wpp2010`, depending on users settings.

Subnational TFR projections can be generated using `tfr.predict.subnat`. In this case, historical data
must be provided by the user. Existing projections can be accessed from disk via `get.regTFR.prediction`.

**Note**

There is a directory `exMdata` shipped with the package which contains results from an example
simulation, containing one chain with 60 iterations. The Example section below shows how these
results were created. These data are used in Example sections throughout the manual. The user can
either reproduce the data in her/his local directory, or use the ones from the package.

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**References**

Hana Sevcikova, Leontine Alkema, Adrian E. Raftery (2011). bayesTFR: An R Package for
http://www.jstatsoft.org/v43/i01/.

Probabilistic Projections of the Total Fertility Rate for All Countries. Demography, Vol. 48, 815-839.

Examples

```r
## Not run:
# This command produces output data such as in the directory ex-data
sim.dir <- tempfile()
# Phase II MCMCs
m <- run.tfr.mcmc(nr.chains=1, iter=60, output.dir=sim.dir, seed=1, verbose=TRUE)
# Phase III MCMCs (not included in the package)
m3 <- run.tfr3.mcmc(sim.dir=sim.dir, nr.chains=2, iter=100, thin=1, seed=1, verbose=TRUE)
# Prediction
pred <- tfr.predict(m, burnin=30, burnin3=50, verbose=TRUE)
summary(pred, country='Ghana')
unlink(sim.dir, recursive=TRUE)

## End(Not run)
```

---

**bayesTFR.mcmc**  
*MCMC Simulation Object*

**Description**

MCMC simulation object **bayesTFR.mcmc** containing information about one MCMC chain, either from Phase II or Phase III simulation. A set of such objects belonging to the same simulation together with a **bayesTFR.mcmc.meta** object constitute a **bayesTFR.mcmc.set** object.

**Details**

An object **bayesTFR.mcmc** points to a place on disk (element output.dir) where MCMC results from all iterations are stored. They can be retrieved to the memory using **get.tfr.mcmc(...)** (Phase II) or **get.tfr3.mcmc(...)** (Phase III), and **tfr.mcmc(...)**.

The object is in standard cases not to be manipulated by itself, but rather as part of a **bayesTFR.mcmc.set** object.

**Value**

A **bayesTFR.mcmc** object contains parameters of the Bayesian hierarchical model, more specifically, their values from the last iteration. If it is a **Phase II** object these parameters are:

- `psi`, `chi`, `a_sd`, `b_sd`, `const_sd`, `S_sd`, `sigma0`, `mean_eps`, `sd`, `mean_eps`, `tau`, `Triangle4` - non-country specific parameters, containing one value each.
- `alpha`, `delta` - non-country specific parameters, containing three values each.
- `U_c`, `d_c`, `Triangle_c4` - country-specific parameters (1d array).
- `gamma_ci` - country-specific parameter with three values for each country, i.e. an `n x 3` matrix where `n` is the number of countries.

**Phase III** MCMC objects contain single-value parameters `mu`, `rho`, `sigma.mu`, `sigma.rho`, `sigma.eps` and `n`-size vectors `mu.c` and `rho.c`.

Furthermore, the object (independent of Phase) contains components:

- `iter`  
  Total number of iterations the simulation was started with.
finished.iter  Number of iterations that were finished. Results from the last finished iteration are stored in the parameters above.

length  Length of the MCMC stored on disk. It differs from finished.iter only if thin is larger than one.

thin  Thinning interval used when simulating the MCMCs.

id  Identifier of this chain.

output.dir  Subdirectory (relative to output.dir in the bayestfr.mcmc.meta object) where results of this chain are stored.

traces  This is a placeholder for keeping whole parameter traces in the memory. If the processing operates in a low memory mode, it will be 0. It can be filled in using the function `get.tfr.mcmc(...)`, `low.memory=FALSE`). In such a case, traces is a $I \times J$ array where $I$ is the MCMC length and $J$ is the number of parameters.

traces.burnin  Burnin used to retrieve the traces, i.e. how many stored iterations are missing from the beginning in the traces array comparing to the ‘raw’ traces on the disk.

rng.state  State of the random number generator at the end of the last finished iteration.

compression.type  Type of compression of the underlying files.

meta  Object of class bayestfr.mcmc.meta used for simulation of this chain.

Author(s)
Hana Sevcikova

See Also
run.tfr.mcmc, get.tfr.mcmc, run.tfr3.mcmc, get.tfr3.mcmc, bayestfr.mcmc.set, bayestfr.mcmc.meta

Examples

```r
sim.dir <- file.path(find.package("bayestfr"), "ex-data", "bayestfr.output")
# loads traces from one chain
m <- get.tfr.mcmc(sim.dir, low.memory=FALSE, burnin=35, chain.ids=1)
# should have 25 rows, since 60 iterations in total minus 35 burnin
dim(tfr.mcmc(m, 1)$traces)
summary(m, chain.id=1)
```

Description
Simulation meta object bayestfr.mcmc.meta used by all chains of the same MCMC simulation. It contains information that is common to all chains. It is part of a bayestfr.mcmc.set object.
Details

The object is in standard cases not to be manipulated by itself, but rather as part of a `bayesTFR.mcmc.set` object.

Value

A `bayesTFR.mcmc.meta` object contains various components that correspond to the input arguments of the `run.tfr.mcmc` and `run.tfr3.mcmc` functions. Furthermore, it contains components:

- `nr.chains` Number of MCMC chains.
- `phase` Value 2 or 3, depending which Phase the object belongs to.
- `output.dir` Directory for storing simulation output.

Value - Phase II

Furthermore, Phase II meta objects contain components:

- `tfr_matrix_all` A $q \times n$ matrix with the United Nations TFR estimates. $q$ is number of years (see $T_{end}$ below), $n$ is number of countries (see `nr_countries` below). The first $n_e$ columns correspond to countries included in the MCMC estimation (see `nr_countries_estimation` below), where $n_e < n$.
- `tfr_matrix_observed` Like `tfr_matrix_all`, but it has NA values for years where no historical data is available (i.e. after the last observed time period).
- `tfr_matrix` Like `tfr_matrix_observed`, but it has NA values before and after country’s fertility transition.
- `nr_countries` Number of countries included in the tfr matrices.
- `nr_countries_estimation` Number of countries included in the MCMC estimation. It must be smaller or equal to `nr_countries`.
- `tau_c` Estimated start year of the fertility decline for each country (as a row index within the tfr matrices). -1 means that the decline started before `start.year`.
- `id_Tistau` Index of countries for which `present.year` is equal to `tau_c`.
- `id_DL` Index of countries for which the projection is made using the double logistic function, i.e. high fertility countries.
- `id_early` Index of countries with early decline, i.e. countries for which `tau_c`=-1.
- `id_notearly` Index of countries with not early decline.
- `lambda_c` Start period of the recovery phase for each country (as an index of the `tfr_matrix`).
- `start_c` Maximum of `tau_c` and 1 for each country. Thus, it is a row index of the `tfr_matrix` where the fertility decline starts.
- `proposal_cov_gammas_cii` Proposal covariance matrices of $\gamma_{ci}$ for each country.
- `T_end` Number of years for which United Nations historical data are available (i.e. number of rows of `tfr_matrix`).
- `T_end_c` Like `T_end` but country specific.
regions List of arrays of length nr_countries. These are:
  name - Region name for each country.
  code - Region code for each country.
  area_name - Area name for each country.
  area_code - Area code for each country.
  country_name - Array of country names.
  country_code - Array of country codes.
Any country indices in the bayesTFR.mcmc.meta object are derived from this component.

Value - Phase III

Phase III meta objects contain additional components:

  id_phase3 Indices of countries included in the Phase III estimation. It is relative to the order of
  countries in the region object in the parent meta object.
  nr.countries Number of countries included in the estimation.
  parent Link to the Phase II meta object.

Author(s)

  Hana Sevcikova, Leontine Alkema

See Also

  run.tfr.mcmc, get.tfr.mcmc, run.tfr3.mcmc, get.tfr3.mcmc

Examples

  sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
  m <- get.tfr.mcmc(sim.dir)
  summary(m, meta.only = TRUE)
  names(m$meta)

---

**coda.list.mcmc**  
*Conversion to coda’s Objects*

**Description**

The functions convert MCMC traces (simulated using run.tfr.mcmc and run.tfr3.mcmc) into objects that can be used with the coda package.
Usage

coda.list.mcmc(mcmc = NULL, country = NULL, chain.ids = NULL,
   sim.dir = file.path(getwd(), "bayesTFR.output"),
   par.names = tfr.parameter.names(),
   par.names.cs = tfr.parameter.names.cs(),
   rm.const.pars = FALSE, burnin = 0,
   low.memory = FALSE, ...)

coda.list.mcmc3(mcmc = NULL, country = NULL, chain.ids = NULL,
   sim.dir = file.path(getwd(), "bayesTFR.output"),
   par.names = tfr3.parameter.names(),
   par.names.cs = tfr3.parameter.names.cs(),
   burnin = 0, low.memory = FALSE, ...)

## S3 method for class 'bayesTFR.mcmc'
coda.mcmc(mcmc, country = NULL,
   par.names = NULL, par.names.cs = NULL,
   burnin = 0, thin = 1, ...)

Arguments

mcmc In coda.mcmc, it is an object of class bayesTFR.mcmc. In coda.list.mcmc and
coda.list.mcmc3, it is either a list of bayesTFR.mcmc objects, or an object of
class bayesTFR.mcmc.set or in case of coda.list.mcmc it can be bayesTFR.prediction.
If it is NULL, the MCMCs are loaded from sim.dir. Either mcmc or sim.dir
must be given.

country Country name or code. It is used in connection with the par.names.cs argument (see below).

chain.ids Vector of chain identifiers. By default, all chains available in the mcmc.list
object are included.

sim.dir Directory with the MCMC simulation results. Only used if mcmc.list is NULL.

par.names Names of country-independent parameters to be included. In coda.mcmc the
default names are tfr.parameter.names() if the mcmc object is an MCMC of
phase II or tfr3.parameter.names() if the MCMC is of phase III.

par.names.cs Names of country-specific parameters to be included. The argument country is
used to filter out traces that correspond to a specific country. If country is not
given, for each parameter, traces for all countries are included. In coda.mcmc the
default names are tfr.parameter.names.cs() if the mcmc object is an MCMC of
phase II or tfr3.parameter.names.cs() if the MCMC is of phase III.

rm.const.pars Logical indicating if parameters with constant values should be removed.

burnin Burnin indicating how many iterations should be removed from the beginning
of each chain.

low.memory Logical indicating if the function should run in a memory-efficient mode.

thin Thinning interval.

... Additional arguments passed to the coda’s mcmc function.
Details

Function `coda.list.mcmc` is for accessing all chains of phase II MCMCs; Function `coda.list.mcmc3` is for accessing all chains of phase III MCMCs.

Value

The function `coda.list.mcmc` and `coda.list.mcmc3` return an object of class “mcmc.list”. The function `coda.mcmc` returns an object of class “mcmc”, both defined in the `coda` package.

Author(s)

Hana Sevcikova

---

### convert.tfr.trajectories

*Converting TFR Trajectories into ASCII Files*

**Description**

Converts TFR trajectories stored in a binary format into two CSV files of a UN-specific format.

**Usage**

```r
convert.tfr.trajectories(dir = file.path(getwd(), 'bayesTFR.output'),
                          n = 1000, output.dir = NULL, verbose = FALSE)
```

**Arguments**

- `dir` Directory containing the prediction object. It should correspond to the `output.dir` argument of the `tfr.predict` function.
- `n` Number of trajectories to be stored. It can be either a single number or the word “all” in which case all trajectories are stored.
- `output.dir` Directory in which the resulting files will be stored. If NULL the same directory is used as for the prediction.
- `verbose` Logical switching log messages on and off.

**Details**

The function creates two files. One is called “ascii_trajectories.csv”, it is a comma-separated table with the following columns:

- “LocID” country code
- “Period” prediction interval, e.g. 2015-2020
- “Year” middle year of the prediction interval
- “Trajectory” identifier of the trajectory
The second file is called “ascii_trajectories_wide.csv”, it is also a comma-separated table and it contains the same information as above but in a ‘transposed’ format. I.e. the data for one country are ordered in columns, thus, there is one column per country. The country columns are ordered alphabetically.

If \( n \) is smaller than the total number of trajectories, the trajectories are selected using equal spacing.

**Note**

This function is automatically called from the `tfr.predict` function, therefore in standard cases it will not be needed to call it directly. However, it can be useful for example, if different number of trajectories are to be converted, without having to re-run the prediction.

**Author(s)**

Hana Sevcikova

**See Also**

`write.projection.summary`, `tfr.predict`

**Examples**

```r
## Not run:
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
pred.dir <- file.path(getwd(), "exampleTFRpred")

# stores 10 trajectories out of 35 (1x(60-25)) into
# exampleTFRpred/predictions/ascii_trajectories.csv
# exampleTFRpred/predictions/ascii_trajectories.csv
# stores all 35 trajectories into the current directory
# stores all 35 trajectories into the current directory
tfr.predict(sim.dir = sim.dir, output.dir = pred.dir, use.tfr3 = FALSE,
            burnin = 25, save.as.ascii = 10, verbose = TRUE)

# Note: If the output.dir argument in tfr.predict is omitted,
# call convert_tfr_trajectories with dir=sim.dir

## End(Not run)
```

---

**country.names**

Accessing Country Names

**Description**

The function returns country names for countries given either by their codes or by index.
Usage

```r
country.names(meta, countries = NULL, index = FALSE)
```

Arguments

- `meta`: Object of class `bayesTFR.mcmc.meta, bayesTFR.mcmc.set, bayesTFR.mcmc,` or `bayesTFR.prediction.`
- `countries`: Vector of country codes or indices. If it is not given, names of all countries are returned.
- `index`: Logical indicating if the argument `countries` is an index.

Details

The function considers countries that are included in the simulations and predictions. If the argument `countries` is not given, all countries are returned in the same order as they are stored in the `meta` object.

Value

Vector of country names.

Author(s)

Hana Sevcikova

See Also

`get.countries.table, get.country.object`

Examples

```r
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
m <- get.tfr.mcmc(sim.dir)
country.names(m)
# these two calls should give the same answer
country.names(m, c(800, 120))
country.names(m, c(15, 20), index=TRUE)
```

Description

The functions for plotting and retrieving the posterior distribution of the double logistic function used in the simulation of Phase II. Plots include the median and given probability intervals of the distribution.
Usage

```r
DLcurve.plot(mcmc.list, country, burnin = NULL, pi = 80, tfr.max = 10,
nr.curves = NULL, predictive.distr = FALSE, ylim = NULL,
xlab = 'TFR (reversed)', ylab = 'TFR decrement', main = NULL,
show.legend = TRUE, col=c('black', 'red', '#00000020'), ...)
```

```r
DLcurve.plot.all(mcmc.list = NULL, sim.dir = NULL,
output.dir = file.path(getwd(), 'DLcurves'),
output.type = "png", burnin = NULL, verbose = FALSE, ...)
```

```r
tfr.world.dlcurves(x, mcmc.list, burnin=NULL, countryUc=NULL, ...)
```

```r
tfr.country.dlcurves(x, mcmc.list, country, burnin=NULL, ...)
```

Arguments

- **mcmc.list**: List of `bayestfr.mcmc` objects, an object of class `bayestfr.mcmc.set` or of class `bayestfr.prediction`. In case of `DLcurve.plot.all` if it is `NULL`, it is loaded from `sim.dir`.
- **country**: Name or numerical code of a country.
- **burnin**: Number of iterations to be discarded from the beginning of parameter traces.
- **pi**: Probability interval. It can be a single number or an array.
- **tfr.max**: Maximum TFR to be shown in the plot.
- **nr.curves**: Number of curves to be plotted. If `NULL`, all curves are plotted.
- **predictive.distr**: Logical. If `TRUE`, an error term is added to each trajectory.
- **ylim, xlab, ylab, main**: Graphical parameters passed to the `plot` function.
- **show.legend**: Logical determining if the legend should be shown.
- **col**: Vector of colors in this order: 1. observed data points, 2. quantiles, 3. trajectories
- **...**: For the plotting functions, there are additional graphical parameters. For `DLcurve.plot.all`, `...` contains also arguments `pi`, `tfr.max` and `nr.curves`. For the `tfr.*.dlcurves` functions, these are arguments passed to the underlying functions (`predictive.distr` and `return.sigma` for obtaining a sample of the standard deviation of the error term).
- **sim.dir**: Directory with the simulation results. Only relevant, if `mcmc.list` is `NULL`.
- **output.dir**: Directory into which resulting graphs are stored.
- **output.type**: Type of the resulting files. It can be “png”, “pdf”, “jpeg”, “bmp”, “tiff”, or “postscript”.
- **verbose**: Logical switching log messages on and off.
- **x**: TFR values for which the double logistic should be computed.
- **countryUc**: Country to use the parameter $U_c$ from (start of the fertility transition). If it is not given, the middle point of the prior distribution is used.
Details

\texttt{dlcurve.plot} plots double logistic curves for the given country. \texttt{dlcurve.plot.all} creates such plots for all countries and stores them in output.dir. Parameters inputting the double logistic function are either thinned traces created by the \texttt{tfr.predict} function (if \texttt{mcmc.list} is an object of class \texttt{bayestfr.prediction}), or they are selected by equal spacing from the MCMC traces. In the former case, burnin is set automatically; in the latter case, burnin defaults to 0 since such object has already been “burned”. If \texttt{nr.curves} is smaller than 2000, the median and probability intervals are computed on a sample of 2000 equally spaced data points, otherwise on all plotted curves.

Function \texttt{tfr.world.dlcurves} returns the DL curves of the hierarchical distribution, conditioned on the starting point of the fertility transition in a given country (given by the \texttt{countryuc} argument). Function \texttt{tfr.country.dlcurves} returns DL curves for a given country. If \texttt{mcmc.list} is a prediction object, burnin should not be given, as such object has already been “burned”.

Value

tfr.world.dlcurves and \texttt{tfr.country.dlcurves} return a matrix of size $N \times M$ where $N$ is the number of trajectories and $M$ is the number of values of $x$. If the argument \texttt{return.sigma} is set to \texttt{TRUE}, the return value is a list with the first element being the DL values and the second element being a matrix of the standard deviation of the DL error term $\sigma_{eps}$.

Author(s)

Hana Sevcikova, Leontine Alkema

Examples

```r
## Not run:
sim.dir <- file.path(find.package("bayestfr"), "ex-data", "bayestfr.output")
mcmc.set <- get.tfr.mcmc(sim.dir=sim.dir)
dlcurve.plot(country="Burkina Faso", mcmc.set, burnin=15)

# add the median of the hierarchical DL curves
x <- seq(0, 10, length=100)
world <- tfr.world.dlcurves(x, mcmc.set, burnin=15, countryUc="Burkina Faso")
qw <- apply(world, 2, median)
tlines(x, qw, col='blue')
## End(Not run)
```

get.country.object

Accessing Country Information

Description

Function \texttt{get.country.object} returns an object containing country name, code and index. Functions \texttt{get.countries.table} return a data frame containing codes and names of all countries.
get.country.object

Usage

get.country.object(country, meta = NULL, country.table = NULL, index = FALSE)
## S3 method for class 'bayesTFR.mcmc.set'
get.countries.table(object, ...)
## S3 method for class 'bayesTFR.prediction'
get.countries.table(object, ...)

Arguments

country        Country name, code or index. If it is an index, the argument index must be set
to TRUE.
meta           Object of class bayesTFR.mcmc.meta. If it is not given, the argument country.table
               must be given.
country.table  A table containing columns “name” and “code” from which the country info can
               be extracted. Only relevant, if meta is NULL.
index          Logical determining if the argument country is an index.
object         Object of class bayesTFR.mcmc.set or bayesTFR.prediction.
...            Not used.

Details

Given partial information about a country (i.e. having either name or code or index), the function
get.country.object returns an object containing all three pieces of information. Only countries
are considered that are included in the simulations and predictions. Country index is an internal
index used in various components of a bayesTFR.mcmc.meta object.

Value

Function get.country.object returns a list with components:

ame           Country name
code           Country code
index          Country index

Function get.countries.table return a data frame with columns code and name.

Author(s)

Hana Sevcikova

See Also

country.names
Examples

```r
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
m <- get.tfr.mcmc(sim.dir)
# all four calls should give the same answer
get.country.object('China', m$meta)
get.country.object(156, m$meta)
get.country.object(56, m$meta, index=TRUE)
get.country.object(156, NULL, country.table=get.countries.table(m))
```

---

**get.cov.gammas**  
*Covariance Matrices of Gamma Parameters*

### Description

From a given MCMC, obtain a covariance matrix of the $\gamma_{ci}$ ($i = 1, 2, 3$) parameters for each country $c$.

### Usage

```r
get.cov.gammas(mcmc.set = NULL, sim.dir = NULL, burnin = 200, chain.id = 1)
```

### Arguments

- `mcmc.set` Object of class `bayesTFR.mcmc.set`. If it is `NULL`, the `sim.dir` is used to load existing simulation results.
- `sim.dir` Directory with existing MCMC simulation results. It is only used if `mcmc.set` is `NULL`.
- `burnin` Number of burn-in iterations to be discarded from the beginning of the chain.
- `chain.id` Identifier of the MCMC to be used. By default the first chain is used.

### Details

In order to speed-up MCMC convergence, the package contains default values of gamma covariance that were obtained from a previous run (they can be loaded using `data(proposal_cov_gammas_cii)`). However, this function allows to obtain new values and overwrite the default values by passing the resulting object to the `run.tfr.mcmc` function as the `proposal_cov_gammas` argument.

### Value

A list with components:

- `values` An array of size `nr_countries` $\times$ $3 \times 3$ containing values of the covariance matrix of $\gamma_{ci}$ ($i = 1, 2, 3$) for each country $c$.
- `country_codes` A vector of size `nr_countries`. A covariance matrix values[i, ,] corresponds to a country with the code `country_codes[i]`. 
Description

Retrieve subnational (regional) prediction results produced by `tfr.predict.subnat`, either for one country or for all available countries.

Usage

```r
get.reg.tfr.prediction(sim.dir, country = NULL)
```

Arguments

- `sim.dir` Simulation directory of the subnational predictions. It corresponds to the argument `output.dir` in `tfr.predict.subnat`.
- `country` Numerical country code. If it is not given, all available subnational predictions are retrieved.

Details

Predictions for country \( x \) are assumed to be stored in “sim.dir/subnat/c\(x\)”.

Value

If argument `country` is given, the function returns an object of class `bayesTFR.prediction`. If it is `NULL`, it returns a list of such objects. Names of the list items are the country codes.

See Also

`tfr.predict.subnat`
Examples

# Subnational example data
my.subtfr.file <- file.path(find.package("bayesTFR"), 'extdata', 'subnational_tfr_template.txt')
subtfr <- read.delim(my.subtfr.file, check.names=FALSE, stringsAsFactors=FALSE)
countries <- unique(subtfr[, , c("country_code", "country")])

# Directory with national projections (contains 30 trajectories for each country)
nat.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")

# Subnational projections for all three countries
subnat.dir <- tempfile()
tfr.predict.subnat(countries$cOUNTRY_CODE, my.tfr.file=my.subtfr.file,
                   sim.dir=nat.dir, output.dir=subnat.dir, start.year=2013)

# Retrieve results for all countries
preds <- get.regTfr.predict(subnat.dir)
names(preds)

# View tables of subregions for each country
for(i in 1:nrow(countries)) {
  cat("\n", countries$cOUNTRY_CODE[i], "\n")
  print(get.countries.table(preds[[as.character(countries$cOUNTRY_CODE[i])]]))
}

# Quantiles for individual subregions
tfr.trajectories.table(preds[["218"]], "Bolivar")

# Retrieve results for one country
pred <- get.regTfr.predict(subnat.dir, 218)
tfr.trajectories.plot(pred, "Loja")

# Cleanup
unlink(subnat.dir)

# See more examples in ?tfr.predict.subnat

---

get.tfr.convergence  
**Accessing a Convergence Object**

Description

The function loads objects of class `bayesTFR.convergence` from disk.

Usage

```r
get.tfr.convergence(sim.dir = file.path(getwd(), "bayesTFR.output"),
                     thin=80, burnin = 2000)

get.tfr.convergence.all(sim.dir = file.path(getwd(), "bayesTFR.output"))
```
get.tfr3.convergence(sim.dir = file.path(getwd(), "bayesTFR.output"),
   thin=50, burnin = 10000)

get.tfr3.convergence.all(sim.dir = file.path(getwd(), "bayesTFR.output"))

**Arguments**

- **sim.dir** Simulation directory used for computing the diagnostics.
- **thin** Thinning interval used with this diagnostics.
- **burnin** Burnin used for computing the diagnostics.

**Details**

Function `get.tfr3.convergence` loads an object of class `bayestfr.convergence` for the specific thin and burnin generated for Phase II MCMCs. Function `get.tfr3.convergence.all` loads all Phase II `bayestfr.convergence` objects available for `sim.dir`. Functions `get.tfr3.convergence` and `get.tfr3.convergence.all` do the same thing for Phase III MCMCs.

**Value**

`get.tfr.convergence` and `get.tfr3.convergence` return an object of class `bayestfr.convergence`; `get.tfr.convergence.all` and `get.tfr3.convergence.all` return a list of objects of class `bayestfr.convergence`.

**Author(s)**

Hana Sevcikova

**See Also**

`bayestfr.convergence`, `summary.bayestfr.convergence`.

---

**get.tfr.mcmc**

---

**Accessing MCMC Results**

**Description**

The function `get.tfr.mcmc` retrieves results of an MCMC simulation of Phase II and creates an object of class `bayestfr.mcmc.set`. Function `has.tfr.mcmc` checks the existence of such results. Functions `get.tfr.mcmc` and `has.tfr.mcmc` do the same for Phase III MCMCs. Function `tfr.mcmc` extracts a single chain and `tfr.mcmc.list` extracts several or all chains from the simulation results.
Usage

```r
get.tfr.mcmc(sim.dir = file.path(getwd(), "bayesTFR.output"),
    chain.ids = NULL, low.memory = TRUE, burnin = 0, verbose = FALSE)

has.tfr.mcmc(sim.dir)

get.tfr3.mcmc(sim.dir = file.path(getwd(), "bayesTFR.output"), ...)

has.tfr3.mcmc(sim.dir)

tfr.mcmc(mcmc.set, chain.id)

tfr.mcmc.list(mcmc.set, chain.ids=NULL)
```

Arguments

- `sim.dir`: Directory where the simulation results are stored.
- `chain.ids`: Chain identifiers in case only specific chains should be included in the resulting object. By default, all available chains are included.
- `low.memory`: If FALSE full MCMC traces are loaded into memory.
- `burnin`: Burnin used for loading traces. Only relevant, if `low.memory`=FALSE.
- `verbose`: Logical switching log messages on and off.
- `chain.id`: Chain identifier.
- `mcmc.set`: Object of class `bayesTFR.mcmc.set`.
- `...`: Arguments passed to `get.tfr.mcmc`.

Details

Function `get.tfr.mcmc` is an accessor of results generated using `run.tfr.mcmc` and `continue.tfr.mcmc`.
Function `get.tfr3.mcmc` can be used to access results generated using `run.tfr3.mcmc` and `continue.tfr3.mcmc`.

Value

`get.tfr.mcmc` and `get.tfr3.mcmc` return an object of class `bayesTFR.mcmc.set`. `has.tfr.mcmc` and `has.tfr3.mcmc` return a logical value. `tfr.mcmc` returns an object of class `bayesTFR.mcmc`, and `tfr.mcmc.list` returns a list of `bayesTFR.mcmc` objects.

Author(s)

Hana Sevcikova

See Also

`bayesTFR.mcmc.set`
Examples

```r
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
m <- get.tfr.mcmc(sim.dir)
summary(m)

# summary of the single chains
for(mc in tfr.mcmc.list(m)) print(summary(mc))
```

Accessing MCMC Parameter Traces

Description

Functions for accessing traces of the MCMC parameters, either country-independent or country-specific. Functions `get.tfr.parameter.traces` and `get.tfr.parameter.traces.cs` access Phase II MCMCs; Functions `get.tfr3.parameter.traces` and `get.tfr3.parameter.traces.cs` access Phase III MCMCs.

Usage

```r
get.tfr.parameter.traces(mcmc.list, par.names = tfr.parameter.names(),
                         burnin = 0, thinning.index = NULL, thin = NULL)

get.tfr.parameter.traces.cs(mcmc.list, country.obj,
                          par.names=tfr.parameter.names.cs(),
                          burnin=0, thinning.index=NULL, thin=NULL)

get.tfr3.parameter.traces(mcmc.list, par.names = tfr3.parameter.names(), ...)

get.tfr3.parameter.traces.cs(mcmc.list, country.obj,
                         par.names=tfr3.parameter.names.cs(), ...)
```

Arguments

- `mcmc.list` List of `bayesTFR.mcmc` objects.
- `country.obj` Country object list (see `get.country.object`).
- `par.names` Names of country-independent parameters (in case of `get.tfr.parameter.traces`) or country-specific parameters (in case of `get.tfr.parameter.traces.cs`) to be included.
- `burnin` Burnin indicating how many iterations should be removed from the beginning of each chain.
- `thinning.index` Index of the traces for thinning. If it is `NULL`, `thin` is used. `thinning.index` does not include `burnin`. For example, if there are two MCMC chains of length 1000, `burnin`=200 and we want a sample of length 400, then the value should be `thinning.index=seq(1,1600, length=400)`.
thin

Alternative to thinning.index. In the above example it would be thin=4.

...

Arguments passed to underlying functions (i.e. to get.tfr.parameter.traces or get.tfr3.parameter.traces.cs).

Value

All functions return a matrix with columns being the parameters and rows being the MCMC values, attached to one another in case of multiple chains. get.tfr.parameter.traces and get.tfr3.parameter.traces return country-independent parameters, get.tfr.parameter.traces.cs and get.tfr3.parameter.traces.cs return country-specific parameters.

Author(s)

Hana Sevcikova

See Also
coda.list.mcmc for another way of retrieving parameter traces.

Examples

```r
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
m <- get.tfr.mcmc(sim.dir)
tfr.values <- get.tfr.parameter.traces(m$mcmc.list, burnin=10, par.names="sigma0")
## Not run:
hist(tfr.values, main=colnames(tfr.values))

## End(Not run)
tfr.values.cs <- get.tfr.parameter.traces.cs(m$mcmc.list,
get.country.object("Canada", meta=m$meta),
burnin=10, par.names="Triangle_c4")
## Not run:
hist(tfr.values.cs, main=colnames(tfr.values.cs))
## End(Not run)
```

get.tfr.prediction Accessing a Prediction Object

Description

Function get.tfr.prediction retrieves results of a prediction and creates an object of class bayesTFR.prediction. Function has.tfr.prediction checks an existence of such results.

Usage

```r
get.tfr.prediction(mcmc = NULL, sim.dir = NULL, mcmc.dir = NULL)
has.tfr.prediction(mcmc = NULL, sim.dir = NULL)
```
Accessing TFR Trajectories

Function for accessing TFR trajectories.

Arguments

mcmc Object of class bayesTFR.mcmc.set used to make the prediction. It must correspond to a Phase II MCMC. If it is NULL, the prediction is loaded from directory given by sim.dir.

sim.dir Directory where the prediction is stored. It should correspond to the value of the output.dir argument used in the tfr.predict function. Only relevant if mcmc is NULL.

mcmc.dir Optional argument to be used only in a special case when the mcmc object contained in the prediction object was estimated in different directory than in the one to which it points to (for example due to moving or renaming the original directory). The argument causes that the mcmc is redirected to the given directory. It can be set to NA if no loading of the mcmc object is desired.

Details

If mcmc is not NULL, the search directory is set to mcmc$meta$output.dir. This approach assumes that the prediction was stored in the same directory as the MCMC simulation, i.e. the output.dir argument of the tfr.predict function was set to NULL. If it is not the case, the argument mcmc.dir should be used.

Value

Function has.tfr.prediction returns a logical indicating if a prediction exists for the given mcmc.

Function get.tfr.prediction returns an object of class bayesTFR.prediction.

Author(s)

Hana Sevcikova

See Also

bayesTFR.prediction, tfr.predict, summary.bayesTFR.prediction

Examples

sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
pred <- get.tfr.prediction(sim.dir=sim.dir)
summary(pred, country="Canada")

Description

Function for accessing TFR trajectories.
Usage

```r
get.tfr.trajectories(tfr.pred, country)
```

Arguments

- `tfr.pred` Object of class `bayesTFR.prediction`.
- `country` Name or numerical code of a country.

Details

The function loads TFR trajectories for the given country from disk, offsets it if needed (see `tfr.median.shift`) and returns it as a matrix.

Value

Array of size number of projection periods (including the present year) times the number of trajectories. The row names correspond to the mid-years of the prediction periods.

Author(s)

Hana Sevcikova

See Also

`bayesTFR.prediction`, `get.tfr.prediction`, `tfr.trajectories.table`, `tfr.median.shift`

Examples

```r
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
pred <- get.tfr.prediction(sim.dir=sim.dir)
get.tfr.trajectories(pred, "Germany")
```

---

**Creating and Accessing Thinned MCMCs**

Description

The function `get.thinned.tfr.mcmc` accesses a thinned and burned version of the given Phase II MCMC set. `create.thinned.tfr.mcmc` creates such a set.

Usage

```r
get.thinned.tfr.mcmc(mcmc.set, thin = 1, burnin = 0)
create.thinned.tfr.mcmc(mcmc.set, thin = 1, burnin = 0,
                       output.dir = NULL, verbose = TRUE)
```
Arguments

- `mcmc.set`: Object of class `bayesTFR.mcmc.set` of Phase II.
- `thin`, `burnin`: Thinning interval and burnin used for creating or identifying the thinned object.
- `output.dir`: Output directory. It is only used if the output goes to a non-standard directory.
- `verbose`: Logical switching log messages on and off.

Details

The function `create.thinned.tfr.mcmc` is called from `tfr.predict` and thus, the resulting object contains exactly the same MCMCs used for generating projections. In addition, it can be also called from `tfr.diagnose` if desired, so that the projection process can re-use such a set that lead to a convergence.

The thinning is done as follows: The given `burnin` is removed from the beginning of each chain in the original MCMC set. Then each chain is thinned by `thin` using equal spacing and all chains are collapsed into one single chain per parameter. They are stored in the main simulation directory under the name `thinned_mcmc_t_b` where `t` is the value of `thin` and `b` the value of `burnin`.

Value

Both functions return an object of class `bayesTFR.mcmc.set`. `get.thinned.tfr.mcmc` returns NULL if such object does not exist.

Author(s)

Hana Sevcikova

See Also

`bayesTFR.mcmc.set`, `tfr.predict`, `tfr.diagnose`

Examples

```r
## Not run:
sim.dir <- tempfile()
m <- run.tfr.mcmc(nr.chains=2, iter=30, seed=1, output.dir=sim.dir, verbose=TRUE)
tfr.predict(m, burnin=15, use.tfr3=FALSE) # creates thinned MCMCs
mb <- get.thinned.tfr.mcmc(m, thin=1, burnin=15)
summary(mb, meta.only=TRUE) # length 30 = 2chains x (30-15)iters.
unlink(sim.dir, recursive=TRUE)
## End(Not run)
```
get.total.iterations  Total Number of Iterations

Description
Function get.total.iterations gives the total number of iterations of MCMCs summed over chains with burnin being subtracted from each chain. Function get.stored.mcmc.length gives the total length of the MCMCs stored on disk minus those iterations that correspond to burnin. Result of the latter will be different from the former only if the MCMCs were run with value of thin larger than one.

Usage
get.total.iterations(mcmc.list, burnin = 0)
get.stored.mcmc.length(mcmc.list, burnin = 0)

Arguments
mcmc.list  List of bayesTFR.mcmc objects.
burnin  Number of iterations to be subtracted from each chain.

Value
A single number.

Author(s)
Hana Sevcikova

See Also
bayesTFR.mcmc

Examples
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
mcmc.set <- get.tfr.mcmc(sim.dir=sim.dir)
get.total.iterations(mcmc.set$mcmc.list) # 60=1chain x 60iters
get.total.iterations(mcmc.set$mcmc.list, burnin=20) # 40=1x(60-20)

## Not run:
sim.dir <- tempfile()
m <- run.tfr.mcmc(iter=10, nr.chains=2, output.dir=sim.dir, thin=5, verbose=TRUE)
get.total.iterations(m$mcmc.list) # 20=2x10
get.stored.mcmc.length(m$mcmc.list) # 6=2x3
unlink(sim.dir, recursive=TRUE)

## End(Not run)
**Inclusion Codes**

**Description**

Data sets containing codes that determine which countries are to be included into a simulation or/and projections.

**Usage**

```r
data(include_2017)
data(include_2015)
data(include_2012)
data(include_2010)
```

**Format**

Data frames containing one record per country or region. It has the following variables:

- **country**: Name of country or region. Not used.
- **include_code**: Entries for which `include_code=2` are included in MCMC simulations (i.e. estimation of the model parameters). Entries for which `include_code` is 1 or 2 are included in the prediction.

**Details**

In a simulation, an `include_*` dataset is selected that corresponds to the given `wpp.year` passed to the function `run.tfr.mcmc`. It is merged with a `tfr` dataset from the corresponding `wpp` package using the `country_code` column. Thus, the country entries in this dataset should correspond to entries in the `tfr` dataset.

The package contains also a dataset called `my_tfr_template` (in `extdata` directory) which is a template for user-specified TFR time series. It has the same structure as the `tfr` dataset, except that most of the columns are optional. The only required column is `country_code` (see description of the argument `my.tfr.file` in `run.tfr.mcmc`).

**Source**

Data provided by the United Nations Population Division.

**Examples**

```r
data(include_2017)
head(include_2017)
```
run.tfr.mcmc  Running Markov Chain Monte Carlo for Parameters of Total Fertility Rate in Phase II

Description

Runs (or continues running) MCMCs for simulating the total fertility rate of all countries of the world (phase II), using a Bayesian hierarchical model.

Usage

run.tfr.mcmc(nr.chains = 3, iter = 62000, 
output.dir = file.path(getwd(), “bayesTFR.output”), 
thin = 1, replace.output = FALSE, 
start.year = 1950, present.year = 2015, wpp.year = 2017, 
my.tfr.file = NULL, my.locations.file = NULL, buffer.size = 100, 
U.c.low = 5.5, U.up = 8.8, U.width = 3, 
mean.eps.tau0 = -0.25, sd.eps.tau0 = 0.4, nu.tau0 = 2, 
Triangle_c4.low = 1, Triangle_c4.up = 2.5, 
Triangle_c4.trans.width = 2, 
Triangle4.0 = 0.3, delta4.0 = 0.8, nu4 = 2, 
S.low = 3.5, S.up = 6.5, S.width = 0.5, 
a.low = 0, a.up = 0.2, a.width = 0.02, 
b.low = a.low, b.up = a.up, b.width = 0.05, 
sigma0.low = 0.01, sigma0.up = 0.6, sigma0.width = 0.1, 
sigma0.min = 0.001, 
const.low = 0.6, const.up = 2, const.width = 0.3, 
d.low = 0.05, d.up = 0.5, d.trans.width = 1, 
chi0 = -1.5, psi0 = 0.6, nu.psi0 = 2, 
alpha0.p = c(-1, 0.5, 1.5), delta0 = 1, nu.delta0 = 2, 
dl.p1 = 9, dl.p2 = 9, 
S.ini = NULL, a.ini = NULL, b.ini = NULL, sigma0.ini = NULL, 
Triangle_c4.ini = NULL, const.ini = NULL, gamma.ini = 1, 
proposal_cov.gammas = NULL, 
seed = NULL, parallel = FALSE, nr.nodes = nr.chains, 
save.all.parameters = FALSE, compression.type = ’None’, 
auto.conf = list(max.loops=5, iter=62000, iter.incr=10000, 
nr.chains=3, thin=80, burnin=2000), 
verbose = FALSE, verbose.iter = 10, ...) 

continue.tfr.mcmc(iter, chain.ids=NULL, 
output.dir=file.path(getwd(), “bayesTFR.output”), 
parallel = FALSE, nr.nodes = NULL, auto.conf = NULL, 
verbose=FALSE, verbose.iter = 10, ...)

Arguments

nr.chains  Number of MCMC chains to run.
Number of iterations to run in each chain. In addition to a single value, it can have the value ‘auto’ in which case the function runs for the number of iterations given in the auto.conf list (see below), then checks if the MCMCs converged (using the auto.conf settings). If it did not converge, the procedure is repeated until convergence is reached or the number of repetition exceeded auto.conf$max.loops.

Directory which the simulation output should be written into.

Thinning interval between consecutive observations to be stored on disk.

If TRUE, existing outputs in output.dir will be replaced by results of this simulation.

Start year for using historical data.

End year for using historical data.

Year for which WPP data is used. The functions loads a package called wppx where x is the wpp.year and uses the tfr* datasets.

File name containing user-specified TFR time series for one or more countries. See Details below.

File name containing user-specified locations. See Details below.

Buffer size (in number of iterations) for keeping data in the memory. The smaller the buffer.size the more often will the process access the hard disk and thus, the slower the run. On the other hand, the smaller the buffer.size the less data will be lost in case of failure.

Lower and upper bound of the parameter $U_c$, the start level of the fertility transition. The lower bound is set for each country as the maximum of $U_c.low$ and the minimum of historical TFR for that country.

Width for slice sampling used when updating the $U_c$ parameter.

Mean and standard deviation of the prior distribution of $m_\tau$ which is the mean of the distortion terms $\epsilon_{c,\tau}$ in start periods $\tau_c$.

The shape parameter of the prior Gamma distribution of $1/s_4^2$ is $nu.tau0/2$. $s_4$ is standard deviation of the distortion terms in start periods $\tau_c$.

Lower and upper bound of the $\Delta_{c4}$ parameter.

Width for slice sampling used when updating the logit-transformed $\Delta_{c4}$ parameter.

Mean and standard deviation of the prior distribution of the $\Delta_4$ parameter which is the hierarchical mean of the logit-transformed $\Delta_{c4}$.

The shape parameter of the prior Gamma distribution of $1/\delta_4^2$ is $nu4/2$. $\delta_4$ is standard deviation of the logit-transformed $\Delta_{c4}$.

Lower and upper bound of the uniform prior distribution of the $S$ parameter which is the TFR at which the distortion has maximum variance.

Width for slice sampling used when updating the $S$ parameter.
a.low, a.up  Lower and upper bound of the uniform prior distribution of the $a$ parameter which is a coefficient for linear decrease of the TFR for TFR larger than $S$.

a.width  Width for slice sampling used when updating the $a$ parameter.

b.low, b.up  Lower and upper bound of the uniform prior distribution of the $b$ parameter which is a coefficient for linear decrease of the TFR for TFR smaller than $S$.

b.width  Width for slice sampling used when updating the $b$ parameter.

sigma0.low, sigma0.up  Lower and upper bound of the uniform prior distribution of the $\sigma_0$ parameter. $\sigma_0^2$ is the maximum variance of the distortions at TFR equals $S$.

sigma0.width  Width for slice sampling used when updating the $\sigma_0$ parameter.

sigma0.min  Minimum value that $\sigma_0$ can take.

const.low, const.up  Lower and upper bound of the uniform prior distribution of the $c$ parameter which is the multiplier of standard deviation of the distortions before 1975.

const.width  Width for slice sampling used when updating the $c$ parameter.

d.low, d.up  Lower and upper bound of the parameter $d_c$, the maximum annual decrement for country $c$. (Note that in Alkema et al. this parameter is a five-years decrement.)

d.trans.width  Width for slice sampling used when updating the logit-transformed $d_c$ parameter.

chi0, psi0  Prior mean and standard deviation of the $\chi$ parameter which is the hierarchical mean of logit-transformed maximum decline parameter $d_c$.

nu.psi0  The shape parameter of the prior Gamma distribution of $1/\psi^2$ is $\nu.\psi0/2$. $\psi$ is the standard deviation of logit-transformed maximum decline parameter $d_c$.

alpha0.p  Vector of prior means of the $\alpha_i$ parameters, $i = 1, 2, 3$. $\alpha_i$ is the hierarchical mean of $\gamma_{ci}$.

delta0  Prior standard deviation of the $\alpha_i$ parameters. It is a single value, i.e. the same standard deviation is used for all $i$.

nu.delta0  The shape parameter of the prior Gamma distribution of $1/\delta_i^2$ is $\nu.\delta0/2$. $\delta_i$ is the standard deviation of $\gamma_{ci}$.

dl.p1, dl.p2  Values of the parameters $p_1$ and $p_2$ of the double logistic function.

S.ini  Initial value for the $S$ parameter. It can be a single value or an array of the size $nr.chains$. By default, if $nr.chains$ is 1, it is the middle point of the interval $[S.low, S.up]$. Otherwise, it is equally spaced distributed between $S.low$ and $S.up$.

a.ini  Initial value for the $a$ parameter. It can be a single value or an array of the size $nr.chains$. By default, if $nr.chains$ is 1, it is the middle point of the interval $[a.low, a.up]$. Otherwise, it is equally spaced distributed between $a.low$ and $a.up$.

b.ini  Initial value for the $b$ parameter. It can be a single value or an array of the size $nr.chains$. By default, if $nr.chains$ is 1, it is the middle point of the interval $[b.low, b.up]$. Otherwise, it is equally spaced distributed between $b.low$ and $b.up$. 

sigma0.ini Initial value for the $\sigma_0$ parameter. It can be a single value or an array of the size nr.chains. By default, if nr.chains is 1, it is the middle point of the interval [sigma0.low, sigma0.up]. Otherwise, it is equally spaced distributed between sigma0.low and sigma0.up.

Triangle_c4.ini Initial value for the $\Delta_{c4}$ parameter. It can be a single value or an array of the size nr.chains. By default, if nr.chains is 1, it is the middle point of the interval [Triangle_c4.low, Triangle_c4.up]. Otherwise, it is equally spaced distributed between Triangle_c4.low and Triangle_c4.up.

const.ini Initial value for the $c$ parameter. It can be a single value or an array of the size nr.chains. By default, if nr.chains is 1, it is the middle point of the interval [const.low, const.up]. Otherwise, it is equally spaced distributed between const.low and const.up.

gamma.ini Initial value for the $\gamma_c$ parameter. The same value is used for all countries.

proposal_cov_gammas Proposal for the gamma covariance matrices for each country. It should be a list with two values: values and country_codes. The structure corresponds to the object returned by the function get.cov.gammas. By default the covariance matrices are obtained using data(proposal_cov_gammas_cii). This argument overwrite the defaults for countries contained the argument.

seed Seed of the random number generator. If NULL no seed is set. It can be used to generate reproducible results.

parallel Logical determining if the simulation should run multiple chains in parallel. If it is TRUE, the package snowFT is required. In such a case further arguments can be passed, see description of ....

nr.nodes Relevant only if parallel is TRUE. It gives the number of nodes for running the simulation in parallel. By default it equals to the number of chains.

save.all.parameters If TRUE, the distortion terms $\epsilon_{c,t}$ for all $t$ are stored on disk, otherwise not.

compression.type One of ‘None’, ‘gz’, ‘xz’, ‘bz’, determining type of a compression of the MCMC files. Important: Do not use this option for a long MCMC simulation as this tends to cause very long run times due to slow reading!

auto.conf List containing a configuration for an ‘automatic’ run (see description of argument iter). Item iter gives the number of iterations in the first chunk of the MCMC simulation; item iter.incr gives the number of iterations in the following chunks; nr.chains gives the number of chains in all chunks of the MCMC simulation; items thin and burnin are used in the convergence diagnostics following each chunk; max.loops controls the maximum number of chunks. All items must be integer values. This argument is only used if the function argument iter is set to ‘auto’.

verbose Logical switching log messages on and off.

verbose.iter Integer determining how often (in number of iterations) log messages are outputted during the estimation.
Additional parameters to be passed to the function `performParallel`, if parallel is TRUE. For example `cltype` which is ‘SOCK’ by default but can be set to ‘MPI’.

Array of chain identifiers that should be resumed. If it is NULL, all existing chains in output.dir are resumed.

Details

The function `run.tfr.mcmm` creates an object of class `bayesTFR.mcmm.meta` and stores it in output.dir. It launches `nr.chains` MCMCs, either sequentially or in parallel. Parameter traces of each chain are stored as (possibly compressed) ASCII files in a subdirectory of output.dir, called `mcx` where `x` is the identifier of that chain. There is one file per parameter, named after the parameter with the suffix “.txt”, possibly followed by a compression suffix if `compression.type` is given. Country-specific parameters (`U,d,γ`) have the suffix `_cy` where `γ` is the country code. In addition to the trace files, each `mcx` directory contains the object `bayestfr.mcmm` in binary format. All chain-specific files are written into disk after the first, last and each buffer.size-th iteration.

Using the function `continue.tfr.mcmm` one can continue simulating an existing MCMCs by `iter` iterations for either all or selected chains.

The function loads observed data (further denoted as WPP dataset) from the `tfr` and `tfr_supplemental` datasets in a `wppx` package where `x` is the `wpp.year`. It is then merged with the `include` dataset that corresponds to the same `wpp.year`. The argument `my.tfr.file` can be used to overwrite those default data. Such a file can include a subset of countries contained in the WPP dataset, as well as a set of new countries. In the former case, the function replaces the corresponding country data from the WPP dataset by values in this file. Only columns are replaced that match column names of the WPP dataset, and in addition, columns ‘last.observed’ and ‘include_code’ are used, if present. Countries are merged with WPP using the column ‘country_code’. In addition, in order the countries to be included in the simulation, in both cases (whether they are included in the WPP dataset or not), they must be contained in the table of locations (UNlocations). In addition, their corresponding `include_code` must be set to 2. If the column ‘include_code’ is present in `my.tfr.file`, its value overwrites the default include code, unless is -1.

The default UN table of locations mentioned above can be overwitten/extended by using a file passed as the `my.locations.file` argument. Such a file must have the same structure as the `UNlocations` dataset. Entries in this file will overwrite corresponding entries in `UNlocations` matched by the column ‘country_code’. If there is no such entry in the default dataset, it will be appended. This option of appending new locations is especially useful in cases when `my.tfr.file` contains new countries/regions that are not included in `UNlocations`. In such a case, one must provide a `my.locations.file` with a definition of those countries/regions.

For simulation of the hyperparameters of the Bayesian hierarchical model, all countries are used that are included in the WPP dataset, possibly complemented by the `my.tfr.file`, that have `include_code` equal to 2. The hyperparameters are used to simulate country-specific parameters, which is done for all countries with `include_code` equal 1 or 2. The following values of `include_code` in `my.tfr.file` are recognized: -1 (do not overwrite the default include code), 0 (ignore), 1 (include in prediction but not estimation), 2 (include in both, estimation and prediction). Thus, the set of countries included in the estimation and prediction can be fully user-specific.

Optionally, `my.tfr.file` can contain a column called `last.observed` containing the year of the last observation for each country. In such a case, the code would ignore any data after that time point. Furthermore, the function `tfr.predict` fills in the missing values using the median of the
BHM procedure (stored in `tfr_matrix_reconstructed` of the `bayesTFR.prediction` object). For last observed values that are below a middle year of a time interval \([t_i, t_{i+1}]\) (computed as \(t_i + 3\)) the last valid data point is the time interval \([t_{i-1}, t_i]\), whereas for values larger equal a middle year, the data point in \([t_i, t_{i+1}]\) is valid.

The package contains a dataset called ‘my_tfr_template’ (in ‘extdata’ directory) which is a template for user-specified `my.tfr.file`.

Value

An object of class `bayesTFR.mcmc.set` which is a list with two components:

- `meta`: An object of class `bayesTFR.mcmc.meta`
- `mcmc.list`: A list of objects of class `bayesTFR.mcmc`, one for each MCMC.

Author(s)

Hana Sevcikova, Leontine Alkema

References


See Also

- `get.tfr.mcmc`, `summary.bayesTFR.mcmc.set`

Examples

```r
## Not run:
m <- run.tfr.mcmc(nr.chains=1, iter=5, verbose=TRUE)
summary(m)
m <- continue.tfr.mcmc(iter=5, verbose=TRUE)
summary(m)
## End(Not run)
```

### Description

Run MCMC for extra countries, areas or regions. It uses the posterior distribution of model hyperparameters from an existing simulation to generate country-specific parameters.
**run.tfr.mcmc.extra**

**Usage**

```r
run.tfr.mcmc.extra(sim.dir = file.path(getwd(), "bayesTFR.output"),
                  countries = NULL, my.tfr.file = NULL,
                  iter = NULL, thin = 1, burnin = 2000,
                  parallel = FALSE, nr.nodes = NULL, my.locations.file = NULL,
                  verbose = FALSE, verbose.iter = 100, ...)
```

**Arguments**

- **sim.dir**
  Directory with an existing simulation.

- **countries**
  Vector of country codes. These include codes of areas and regions (see column country_code in UNlocations).

- **my.tfr.file**
  File name containing user-specified TFR time series for countries for which the simulation should run (see Details below).

- **iter**
  Number of iterations to be used for sampling from the posterior distribution of the hyperparameters. By default, the number of iterations used in the existing simulation is taken.

- **thin**
  Thinning interval for sampling from the posterior distribution of the hyperparameters.

- **burnin**
  Number of iterations discarded before sampling from the posterior distribution of the hyperparameters. It is also used when computing proposal of gamma covariance matrices (see `get.cov.gammas`).

- **parallel**
  Logical determining if the simulation should run multiple chains in parallel.

- **nr.nodes**
  Relevant only if `parallel` is TRUE. It gives the number of nodes for running the simulation in parallel. By default it equals to the number of chains contained in the existing simulation.

- **my.locations.file**
  File name containing user-specified locations. See Details below.

- **verbose**
  Logical switching log messages on and off.

- **verbose.iter**
  Integer determining how often (in number of iterations) log messages are outputted during the estimation.

- **...**
  Additional parameters to be passed to the function `performParallel`, if `parallel` is TRUE.

**Details**

The function can be used to make predictions for countries, areas or regions (further denoted as ‘countries’) that were not included in the MCMC estimation (invoked by `run.tfr.mcmc`). It creates MCMC traces for country-specific parameters. The purpose of this function is to have country-specific parameters available in order to be able to generate projections for additional countries or their aggregations, without having to re-run the often time-expensive MCMC simulation.

The set of countries to be considered by this function can be given either by their codes, using the argument `countries`, in which case the countries must be included in the UN WFP tfr dataset. Or, it can be given by a user-specific TFR file, using the argument `my.tfr.file`. The function considers a union of both arguments. The function will ignore all countries that were used in the existing
MCMC simulation for estimating the hyperparameters. Countries that already own country-specific parameters (e.g. because they were included in my.tfr.file passed to `run.tfr.mcmc`) get their parameters recomputed. Note that all countries should be included in the `UNlocations` dataset, but unlike in `run.tfr.mcmc`, their `include_code` is ignored. As in the case of `run.tfr.mcmc`, the default dataset of locations `UNlocations` can be overwritten using a file of the same structure as `UNlocations` passed via the `my.locations.file` argument. This file should be especially used, if TFR is simulated for new locations that are not included in `UNlocations`.

Value
An object of class `bayesTFR.mcmc.set`.

Note
If there is an existing projection for the directory `sim.dir`, use `tfr.predict.extra` to obtain projections for the extra countries used in this function.

Author(s)
Hana Sevcikova, Leontine Alkema

See Also
`run.tfr.mcmc`, `tfr.predict.extra`

Examples
```r
## Not run:
sim.dir <- tempfile()
m <- run.tfr.mcmc(nr.chains=1, iter=20, output.dir=sim.dir, verbose=TRUE)
m <- run.tfr.mcmc.extra(sim.dir=sim.dir, countries=c(908,924), burnin=10, verbose=TRUE)
summary(m, country=924)
pred <- tfr.predict(m, burnin=10, use.tfr3=FALSE, verbose=TRUE)
summary(pred, country=908)
unlink(sim.dir, recursive=TRUE)
## End(Not run)
```

Description
Runs (or continues running) MCMCs for simulating phase III total fertility rate, using a Bayesian hierarchical version of an AR(1) model.
Usage

run.tfr3.mcmc(sim.dir, nr.chains = 3, iter = 50000, thin = 10,
  replace.output = FALSE, my.tfr.file = NULL, buffer.size = 100,
  use.extra.countries = FALSE,
  mu.prior.range = c(0, 2.1), rho.prior.range = c(0, 1 - .Machine$double.xmin),
  sigma.mu.prior.range = c(1e-05, 0.318), sigma.rho.prior.range = c(1e-05, 0.289),
  sigma.eps.prior.range = c(1e-05, 0.5),
  mu.ini = NULL, mu.ini.range = mu.prior.range,
  rho.ini = NULL, rho.ini.range = rho.prior.range,
  sigma.mu.ini = NULL, sigma.mu.ini.range = sigma.mu.prior.range,
  sigma.rho.ini = NULL, sigma.rho.ini.range = sigma.rho.prior.range,
  sigma.eps.ini = NULL, sigma.eps.ini.range = sigma.eps.prior.range,
  seed = NULL, parallel = FALSE, nr.nodes = nr.chains, compression.type = "None",
  auto.conf = list(max.loops = 5, iter = 50000, iter.incr = 20000, nr.chains = 3,
    thin = 50, burnin = 10000),
  verbose = FALSE, verbose.iter = 1000, ...)

continue.tfr3.mcmc(sim.dir, iter, chain.ids=NULL,
  parallel = FALSE, nr.nodes = NULL, auto.conf = NULL,
  verbose=FALSE, verbose.iter = 1000, ...)

Arguments

**sim.dir** Directory with an existing simulation of phase II TFR (see run.tfr3.mcmc).

**nr.chains** Number of MCMC chains to run.

**iter** Number of iterations to run in each chain. In addition to a single value, it can have the value ‘auto’ in which case the function runs for the number of iterations given in the auto.conf list (see below), then checks if the MCMCs converged (using the auto.conf settings). If it did not converge, the procedure is repeated until convergence is reached or the number of repetition exceeded auto.conf$max.loops.

**thin** Thinning interval between consecutive observations to be stored on disk.

**replace.output** If TRUE, previously stored results of a phase III simulation will be overwritten.

**my.tfr.file** File name containing user-specified TFR time series for one or more countries. See description of this argument in run.tfr3.mcmc.

**buffer.size** Buffer size (in number of iterations) for keeping data in the memory.

**use.extra.countries** By default, only countries are used in the MCMCs that were assigned for estimation (i.e. their ‘include_code’ is 2 in the include) dataset and are in phase III at present time (argument present.year in run.tfr3.mcmc). If this argument is TRUE, countries that were added using run.tfr3.mcmc.extra and are in phase III are also included.

**mu.prior.range**, **rho.prior.range**, **sigma.mu.prior.range**, **sigma.rho.prior.range**, **sigma.eps.prior.range** Min and max for the prior (uniform) distribution of these parameters.

**mu.ini**, **rho.ini**, **sigma.mu.ini**, **sigma.rho.ini**, **sigma.eps.ini** Initial value(s) of the parameters. It can be a single value or an array of the size nr.chains. By default, if nr.chains is 1, it is the middle point of the
corresponding range. Otherwise, it is uniformly randomly distributed within the range.

\texttt{mu.ini.range}, \texttt{rho.ini.range}, \texttt{sigma.mu.ini.range}, \texttt{sigma.rho.ini.range}, \texttt{sigma.eps.ini.range}

Min and max for the initial values.

\texttt{seed}

Seed of the random number generator. If \texttt{NULL} no seed is set.

\texttt{parallel}

Logical determining if the simulation should run multiple chains in parallel. If it is \texttt{TRUE}, the package \texttt{snowFT} is required.

\texttt{nr.nodes}

Relevant only if \texttt{parallel} is \texttt{TRUE}. It gives the number of nodes for running the simulation in parallel.

\texttt{compression.type}

One of ‘None’, ‘gz’, ‘xz’, ‘bz’, determining type of a compression of the MCMC files. Important: Do not use this option for a long MCMC simulation as this tends to cause very long run times due to slow reading!

\texttt{auto.conf}

List containing a configuration for an ‘automatic’ run (see description of argument \texttt{iter}). Item \texttt{iter} gives the number of iterations in the first chunk of the MCMC simulation; item \texttt{iter.incr} gives the number of iterations in the following chunks; \texttt{nr.chains} gives the number of chains in all chunks of the MCMC simulation; items \texttt{thin} and \texttt{burnin} are used in the convergence diagnostics following each chunk; \texttt{max.loops} controls the maximum number of chunks. All items must be integer values. This argument is only used if the function argument \texttt{iter} is set to ‘auto’.

\texttt{verbose}

Logical switching log messages on and off.

\texttt{verbose.iter}

Integer determining how often (in number of iterations) messages are outputted during the estimation.

\...\texttt{...}

Additional parameters to be passed to the function \texttt{performParallel}, if \texttt{parallel} is \texttt{TRUE}.

\texttt{chain.ids}

Array of chain identifiers that should be resumed. If it is \texttt{NULL}, all existing chains are resumed.

Details

The MCMCs are stored in \texttt{sim.dir} in a subdirectory called “phaseIII”. It has exactly the same structure as phase II MCMCs described in \texttt{run.tfr.mcmc}.

Value

An object of class \texttt{bayesTFR.mcmc.set} which is a list with two components:

\texttt{meta}

An object of class \texttt{bayesTFR.mcmc.meta}.

\texttt{mcmc.list}

A list of objects of class \texttt{bayesTFR.mcmc}, one for each MCMC.

Author(s)

Hana Sevcikova
References


See Also

run.tfr.mcmc, get.tfr.mcmc

Examples

```r
## Not run:
sim.dir <- tempfile()
# Runs Phase II MCMCs (must be run before Phase III)
m <- run.tfr.mcmc(nr.chains=1, iter=5, output.dir=sim.dir, verbose=TRUE)
# Runs Phase III MCMCs
m3 <- run.tfr3.mcmc(sim.dir=sim.dir, nr.chains=2, iter=50, thin=1, verbose=TRUE)
m3 <- continue.tfr3.mcmc(sim.dir=sim.dir, iter=10, verbose=TRUE)
summary(m3, burnin=10)
unlink(sim.dir, recursive=TRUE)
## End(Not run)
```

summary.bayesTFR.convergence

---

**Summary of a TFR Convergence Object**

Description

Summary of an object of class bayesTFR.convergence created using the tfr.diagnose or tfr3.diagnose functions. It gives an overview about parameters that did not converge.

Usage

```r
## S3 method for class 'bayesTFR.convergence'
summary(object, expand = FALSE, ...)
```

Arguments

- **object**
  - Object of class bayesTFR.convergence.
- **expand**
  - By default, the function does not show parameters for each country for which there was no convergence, if the status is ‘red’. This argument can switch that option on.
- ...
  - Not used.

Author(s)

Hana Sevcikova
See Also
tfr.diagnose, tfr3.diagnose

---

### Description

Summary of an object `bayesTFR.mcmc.set` or `bayesTFR.mcmc`, computed via `run.tfr.mcmc` or `run.tfr3.mcmc`. It can be obtained either for all countries or for a specific country, and either for all parameters or for specific parameters. The function uses the `summary.mcmc` function of the `coda` package.

### Usage

```r
## S3 method for class 'bayesTFR.mcmc.set'
summary(object, country = NULL, chain.id = NULL,
         par.names = NULL, par.names.cs = NULL, meta.only = FALSE,
         thin = 1, burnin = 0, ...)

## S3 method for class 'bayesTFR.mcmc'
summary(object, country = NULL, par.names = NULL, par.names.cs = NULL,
         thin = 1, burnin = 0, ...)
```

### Arguments

- **object**: Object of class `bayesTFR.mcmc.set` or `bayesTFR.mcmc`.
- **country**: Country name or code if a country-specific summary is desired. By default, summary for all countries is generated.
- **chain.id**: Identifiers of MCMC chains. By default, all chains are considered.
- **par.names**: Country independent parameters to be included in the summary. If the underlying object is an MCMC of phase II, the default names are given by `tfr.parameter.names()`, if it is phase III the names are `tfr3.parameter.names()`.
- **par.names.cs**: Country-specific parameters to be included in the summary. If the underlying object is an MCMC of phase II, the default names are given by `tfr.parameter.names.cs()`, if it is phase III the names are `tfr3.parameter.names.cs()`.
- **meta.only**: If it is TRUE, only meta information of the simulation is included.
- **thin**: Thinning interval. Only used if larger than the `thin` argument used in `run.tfr.mcmc` or `run.tfr3.mcmc`.
- **burnin**: Number of iterations to be discarded from the beginning of each chain before computing the summary.
- **...**: Additional arguments passed to the `summary.mcmc` function of the `coda` package.
Summary of a Prediction of the Total Fertility Rate

**Description**

Country-specific summary of an object of class `bayesTFR.prediction`, created using the function `tfr.predict`. The summary contains the mean, standard deviation and several commonly used quantiles of the simulated trajectories.

**Usage**

```r
## S3 method for class 'bayesTFR.prediction'
summary(object, country=NULL, compact = TRUE, ...)
```

**Arguments**

- `object` Object of class `bayesTFR.prediction`.
- `country` Country name or code. If it is NULL, only prediction parameters are included.
- `compact` Logical switching between a smaller and larger number of displayed quantiles.
- `...` A list of further arguments.

**Author(s)**

Hana Sevcikova

**See Also**

- `bayesTFR.mcmc.set`, `summary.mcmc`
tfr.diagnose

Convergence Diagnostics of TFR Markov Chain Monte Carlo

Description

Functions tfr.diagnose and tfr3.diagnose run convergence diagnostics of existing TFR MCMCs for phase II and phase III, respectively, using the raftery.diag function from the coda package. has.mcmc.converged checks if the existing diagnostics converged.

Usage

```
tfr.diagnose(sim.dir, thin = 80, burnin = 2000, express = FALSE, 
             country.sampling.prop = NULL, keep.thin.mcmc=FALSE, verbose = TRUE)
```

```
tfr3.diagnose(sim.dir, thin = 60, burnin = 10000, express = TRUE, 
              country.sampling.prop = NULL, verbose = TRUE, ...)
```

```
has.mcmc.converged(diag)
```

Arguments

- **sim.dir**
  Directory with the MCMC simulation results.
- **thin**
  Thinning interval.
- **burnin**
  Number of iterations to be discarded from the beginning of the parameter traces.
- **express**
  Logical. If TRUE, the convergence diagnostics is run only on the country-independent parameters. If FALSE, the country-specific parameters are included in the diagnostics. The number of countries can be controlled by country.sampling.prop.
- **country.sampling.prop**
  Proportion of countries that are included in the diagnostics. If it is NULL and express=FALSE, all countries are included. Setting here a number between 0 and 1, one can limit the number of countries which are then randomly sampled. Note that for long MCMCs, this argument may significantly influence the run-time of this function.
keep.thin.mcmc Logical. If TRUE the thinned traces used for computing the diagnostics are stored on disk (see create.thinned.tfr.mcmc). It is only available for phase II MCMCs.

verbose Logical switching log messages on and off.

diag Object of class bayesTFR.convergence.

Details

The diagnose functions invoke the tfr.raftery.diag (or tfr3.raftery.diag) function separately for country-independent parameters and for country-specific parameters. It results in two possible states: red, i.e. it did not converge, and green, i.e. it converged. The resulting object from tfr.diagnose is stored in '{sim.dir}/diagnostics/bayesTFR.convergence_{thin}_{burnin}.rda' and can be accessed using the function get.tfr.convergence. Function tfr3.diagnose stores its result into '{sim.dir}/phaseIII/diagnostics/bayesTFR.convergence_{thin}_{burnin}.rda' which can be accessed via get.tfr3.convergence.

Value

has.mcmc.converged returns a logical value determining if there is convergence or not.

tfr.diagnose and tfr3.diagnose return an object of class bayesTFR.convergence with components:

result Table containing all not-converged parameters. Its columns include ‘Total iterations needed’ and ‘Remaining iterations’.

lresult.country.independent Number of rows in result that correspond to country-independent parameters. These rows are grouped at the beginning of the table.

country.independent Result of tfr.raftery.diag processed on country-independent parameters.

country.specific Result of tfr.raftery.diag processed on country-specific parameters.

iter.nEEDED Number of additional iterations suggested in order to achieve convergence.

iter.total Total number of iterations of the original unthinned set of chains.

use.nr.traj Suggestion for number of trajectories in generating predictions.

burnin Burnin used.

thin Thinning interval used.

status Vector of character strings containing the result status. Possible values: ‘green’, ‘red’.

mcmc.set Object of class bayesTFR.mcmc.set that corresponds to the original set of MCMCs on which the diagnostics was run.

thin.mcmc If keep.thin.mcmc is TRUE, it is an object of class bayesTFR.mcmc.set that corresponds to the thinned mcmc set on which the diagnostics was run, otherwise NULL.
Goodness of Fit of the Double Logistic Function

Description

The function computes coverage, i.e. the ratio of observed data fitted within the given probability intervals of the predictive posterior distribution of the double logistic function, as well as the root mean square error and mean absolute error of the simulation.

Usage

tfr.dl.coverage(sim.dir, pi = c(80, 90, 95), burnin = 2000, verbose = TRUE)

Arguments

- sim.dir: Directory with the MCMC simulation results. If a prediction and its corresponding thinned MCMCs are available in the simulation directory, those are taken for assessing the goodness of fit.
- pi: Probability interval. It can be a single number or an array.
- burnin: Burnin. Only relevant if sim.dir does not contain thinned chains.
- verbose: Logical switching log messages on and off.

Value

List with the following components:

- total.coverage: Vector of the coverage, one element per probability interval. For each pi, it is the ratio of the number of observed data points that fall within the probability interval of the posterior distribution over the total number of data points, i.e. TFR for all countries and historical time periods.
- time.coverage: Matrix corresponding to the coverage computed per time period. (Rows correspond to probability intervals, columns correspond to time.) It is derived like total.coverage except that both, the nominator and denominator, contain only data points belonging to the corresponding time period.
country.coverage

Matrix corresponding to the coverage computed per country. (Rows correspond to probability intervals, columns correspond to countries.) It is derived like total.coverage except that both, the nominator and denominator, contain only data points belonging to the corresponding country.

total.rmse

Root mean square error as \( \sqrt{\frac{1}{n}\sum(x - m)^2} \) where \( x \) are observed data points, \( m \) is the mean of the posterior distribution and \( n \) is the number of data points. Here the sum is taken over all countries and historical time periods.

time.rmse

Like total.rmse except that each time period is considered separately.

country.rmse

Like total.rmse except that each country is considered separately.

total.mae

Mean absolute error as \( \frac{1}{n}\sum|x - m| \) where \( x \) are observed data points, \( m \) is the median of the posterior distribution and \( n \) is the number of data points. Here the sum is taken over all countries and historical time periods.

time.mae

Like total.mae except that each time period is considered separately.

country.mae

Like total.mae except that each country is considered separately.

pred.cdf

\( T \times C \) matrix (with \( T \) being the number of time periods and \( C \) being the number of countries), containing the predictive CDF of the observation, i.e. the quantile of each data point within the predictive posterior distribution.

n

0-1 \( T \times C \) matrix indicating if the corresponding data point was included in the goodness of fit computation. Zeros indicate missing historical values.

Note

To see the fit visually per country, use DLcurve.plot(..., predictive.distr=TRUE,...).

Author(s)

Hana Sevcikova

See Also

DLcurve.plot

Examples

```r
## Not run:
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
tfr <- get.tfr.mcmc(sim.dir)
# Note that this simulation is a toy example and thus has not converged.
gof <- tfr.dl.coverage(sim.dir)
gof$time.coverage
DLcurve.plot(tfr, country=608, predictive.distr=TRUE, pi=c(80, 90, 95))

## End(Not run)
```
tfr.map

**TFR World Map**

**Description**

Generates a world map of the total fertility rate for given projection period and quantile. In addition, country specific Phase II MCMC parameters can be projected into the world map.

**Usage**

```r
tfr.map(pred, quantile = 0.5,  
year = NULL, par.name = NULL, adjusted = FALSE,  
projection.index = 1, device = "dev", main = NULL,  
resolution=c("coarse","low","less islands","li","high"),  
device.args = NULL, data.args = NULL, ...)  
```

```r
tfr.map.all(pred, output.dir, output.type = "png",  
tfr.range = NULL, nr.cats = 50, same.scale = TRUE,  
quantile = 0.5, file.prefix='TFRwrldmap_', ...)  
```

```r
get.tfr.map.parameters(pred, tfr.range = NULL,  
nr.cats = 50, same.scale = TRUE, quantile = 0.5, ...)  
```

```r
tfr.map.gvis(pred, year = NULL, quantile = 0.5, pi = 80,  
par.name = NULL, adjusted = FALSE, ...)  
```

**Arguments**

- **pred** Object of class `bayesTFR.prediction`.
- **quantile** Quantile for which the map should be generated. It must be equal to one of the values in `dimnames(pred$quantiles[[2]])`, i.e. 0, 0.025, 0.05, 0.1, 0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.75, 0.8, 0.9, 0.95, 0.975. 1. Value 0.5 corresponds to the median.
- **year** Year to be plotted. It can be a year within a projection period or a year within an estimation period. In the latter case, the observed data are plotted. If not given, `projection.index` determines the projection year.
- **par.name** Name of a country-specific parameter to be plotted. If NULL, the TFR is plotted. Allowed values are any of those returned by `tfr.parameter.names.cs.extended()` and 'lambda' (see Details).
- **adjusted** Logical indicating if the measure to be plotted is based on adjusted TFRs.
- **projection.index** Index of the projection to be displayed. It is only relevant if `year` is NULL. `projection.index`=1 means the present year, `projection.index`=2 means the first projection period after present year, etc..
device

Device for displaying the map. It is passed to the `mapDevice` function of the `rworldmap` package. If it is equal to `dev.cur`, the current device is used. Otherwise, it can be `dev.new`, `png`, `pdf` etc.

main

Title for the map. If it is `NULL`, a default title is constructed from the projection year and quantile.

resolution

Map resolution as implemented in `getMap`. High resolution requires the `rworldextra` package.

device.args

List of additional arguments to be passed to the `mapDevice` function of the `rworldmap` package.

data.args

List of additional arguments to be passed to the underlying data retrieving function.

output.dir

Directory into which resulting maps are stored.

output.type

Type of the resulting files. It can be “png”, “pdf”, “jpeg”, “bmp”, “tiff”, or “postscript”.

tfr.range

Range of the total fertility rate to be displayed. It is of the form \(c(tfr.min, tfr.max)\). By default, the whole range is considered. Note that countries with values outside of the given range will appear white.

nr.cats

Number of color categories.

same.scale

Logical controlling if maps for all projection years of this prediction object should be on the same color scale.

file.prefix

Prefix for file names.

... Arguments passed to the `mapCountryData` function of the `rworldmap` package. In case of `tfr.map.gvis` these are passed to the underlying data retrieving function (the same as `data.args`).

pi

Probability interval to be shown when a country is selected in an interactive map. The corresponding quantiles must be available (see argument `quantile` above).

Details

tfr.map creates a single map for a given projection period and quantile using the `rworldmap` package. `tfr.map.all` generates a sequence of such maps, namely one for each projection period. If the package fields is installed, a color bar legend at the bottom of the map is created.

Function `get.tfr.map.parameters` can be used in combination with `tfr.map`. (Note that `get.tfr.map.parameters` is called from inside of `tfr.map.all`) It sets breakpoints for the color scheme using quantiles of a fitted gamma distribution.

Function `tfr.map.gvis` creates an interactive map using the `googleVis` package and opens it in an internet browser. It also generates a table of TFRs that can be sorted by columns interactively in the browser.

By default, both `tfr.map` and `tfr.map.gvis` produce maps of TFRs. Alternatively, the functions can be used to plot country-specific Phase II MCMC parameters into a world map. They are given by the argument `par.name`. In addition to the MCMC parameters, if `par.name='lambda'`, the period of the end of TFR decline (i.e. start of Phase III) is computed for each country and projected into the map. In such a case, we recommend to adjust the color scale in `tfr.map` e.g. using the arguments `catMethod='pretty'` and `numCats=20` (see `mapCountryData`).
tfr.median.set

Value

get.tfr.map.parameters returns a list with elements:

- **pred**: The object of class `bayesTFR.prediction` used in the function.
- **quantile**: Value of the argument `quantile`.
- **catMethod**: If the argument `same.scale` is TRUE, this element contains breakpoints for categorization. It is generated from a fitted gamma distribution. Otherwise, it is NULL.
- **numCats**: Number of categories.
- **coulourPalette**: Subset of the rainbow palette, starting from dark blue and ending at red.
- **...**: Additional arguments passed to the function.

Author(s)

Hana Sevcikova, Patrick Gerland, Adrian Raftery

Examples

```r
## Not run:
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
pred <- get.tfr.prediction(sim.dir=sim.dir)
# Uses heat colors and seven categories by default
tfr.map(pred)
# Uses more colors with more suitable categorization
params <- get.tfr.map.parameters(pred)
do.call("tfr.map", params)
# Another projection year on the same scale
do.call("tfr.map", c(list(year=2043), params))

# Using Google Vizualization tool
tfr.map.gvis(pred)
## End(Not run)
```

---

tfr.median.set

Editing Medians of the Projection

Description

These functions are to be used by expert analysts. They allow to change the projection medians either to specific values or shift the medians by a given constant, or by a specific adjusting procedure.
Usage

tfr.median.set(sim.dir, country, values, years = NULL)

tfr.median.shift(sim.dir, country, reset = FALSE, shift = 0,
from = NULL, to = NULL)

tfr.median.adjust(sim.dir, countries, factor1 = 2/3, factor2 = 1/3, forceAR1 = FALSE)

tfr.median.reset(sim.dir, countries)

Arguments

sim.dir Directory containing the prediction object.
country Name or numerical code of a country.
countries Vector of country names or codes.
values Array of the new median values.
years Numeric vector giving years which values correspond to. Ideally it should be
of the same length as values. If it is NULL, values are set starting from the
first prediction period. If values correspond to consecutive years, only the first
year might be given here. A year \( t \) represents a prediction period \([t_i, t_{i+1}]\) if
\( t_i < t \leq t_{i+1} \).
reset Logical. If TRUE medians in a range of from and to are reset to their original
values.
shift Constant by which the medians should be offset. It is not used if reset is TRUE.
from Year from which the offset/reset should start. By default, it starts at the first
prediction period.
to Year until which the offset/reset should be done. By default, it is set to the last
prediction period.
factor1, factor2 Adjusting factors for the first and second projection period, respectively (see
below).
forceAR1 Logical. If TRUE, the given countries are forced to enter Phase III (i.e. the AR(1)
process) in the first projection period.

Details

The function \texttt{tfr.median.set} can be used to set the medians of the given country to specific values.
Function \texttt{tfr.median.shift} can be used to offset the medians by a specific constant, or to reset the
medians to their original BHM values. Function \texttt{tfr.median.adjust} runs the prediction procedure
for the given countries with an additional decrement in the model in the first two projection periods.
In the first projection period it is computed as \( \text{factor1} \times S \) where \( S \) is a difference between observed
decrement and the expected decrement (by the double logistic function) in the last observed period.
In the second projection period, in the formula \text{factor1} is replaced by \text{factor2}. If \text{forceAR1} is set
to TRUE, we recommend to set \text{factor1} and \text{factor2} to 0. The function then calls \texttt{tfr.median.set}
in order to store the new median for each country. Function \texttt{tfr.median.reset} resets medians of
the given countries to the original values.
In all four functions, if a median is modified, the corresponding offset is stored in the prediction object (element \texttt{median.shift}) and the updated prediction object is written back to disk. All functions in the package that use trajectories and trajectory statistics use the \texttt{median.shift} values to offset the results correspondingly.

**Value**

All three functions return an updated object of class \texttt{bayesTFR.prediction}.

**Author(s)**

Hana Sevcikova, Leontine Alkema

---

### \texttt{tfr.parameter.names} Accessing Parameter Names

**Description**

Functions for accessing names of the MCMC parameters, either country-independent or country-specific.

**Usage**

\begin{verbatim}
tfr.parameter.names(trans = NULL)
tfr.parameter.names.cs(country.code = NULL, trans = NULL, back.trans = TRUE)
tfr.parameter.names.extended()
tfr.parameter.names.cs.extended(country.code = NULL)
\end{verbatim}

**Arguments**

- \texttt{trans} It can be \texttt{NULL} or logical. If \texttt{TRUE}, names of the transformable parameters (i.e. \texttt{‘alpha’} in case of country-independent parameters, or \texttt{‘gamma’} in case of country-specific parameters) are replaced by the names of the transformed parameters (i.e. \texttt{‘alphat’}, or \texttt{‘gammat’}). If \texttt{trans=FALSE}, there is no such replacement. If \texttt{trans=NULL}, all parameter names, including the transformable parameters are returned.

- \texttt{country.code} Country code. If it is given, the country-specific parameter names contain the postfix \texttt{‘_cx’} where \texttt{x} is the \texttt{country.code}.

- \texttt{back.trans} Logical indicating if back-transformable parameter names (i.e. \texttt{‘Triangle_c1’}, \texttt{‘Triangle_c2’}, \texttt{‘Triangle_c3’}) should be returned.
Value

`tfr.parameter.names` returns names of the country-independent Phase II parameters.
`tfr.parameter.names.cs` returns names of the country-specific Phase II parameters.
`tfr.parameter.names.extended` returns names of all country-independent Phase II parameters, including the transformed parameters. Parameters ‘alpha’, ‘delta’, ‘alphat’, and ‘deltat’ are in their extended format with the postfix ‘_1’, ‘_2’ and ‘_3’.
`tfr.parameter.names.cs.extended` returns names of all country-specific Phase II parameters, including the transformed parameters. Parameters ‘gamma’ and ‘gammat’ are in their extended format with the postfix ‘_1’, ‘_2’ and ‘_3’.
`tfr3.parameter.names` returns names of the country-independent Phase III parameters.
`tfr3.parameter.names.cs` returns names of the country-specific Phase III parameters.

Author(s)

Hana Sevcikova

Examples

```r
  tfr.parameter.names()
  tfr.parameter.names.extended()
  tfr.parameter.names.cs()
  tfr.parameter.names.cs.extended()
  tfr3.parameter.names()
  tfr3.parameter.names.cs()
```

---

**tfr.pardensity.plot**  
*Plotting MCMC Parameter Density*

Description

Functions for plotting density of the posterior distribution of the MCMC parameters.

Usage

```r
  tfr.pardensity.plot(mcmc.list = NULL,  
                    sim.dir = file.path(getwd(), "bayesTFR.output"),  
                    chain.ids = NULL, par.names = tfr.parameter.names(trans = TRUE),  
                    burnin = NULL, dev.ncol=5, low.memory = TRUE, ...)

  tfr.pardensity.cs.plot(country, mcmc.list=NULL,  
                         sim.dir=file.path(getwd(), "bayesTFR.output"),  
                         chain.ids=NULL, par.names=tfr.parameter.names.cs(trans=TRUE),  
                         burnin=NULL, dev.ncol=3, low.memory=TRUE, ...)

  tfr3.pardensity.plot(mcmc.list = NULL,  
                       sim.dir = file.path(getwd(), "bayesTFR.output"),  
                       ...)```
Arguments

country  Name or numerical code of a country.
mcmc.list  List of \texttt{bayesTFR.mcmc} objects, or an object of class \texttt{bayesTFR.mcmc.set} or of class \texttt{bayesTFR.prediction} (allowed only for Phase II MCMCs). If it is \texttt{NULL}, the parameter values are loaded from \texttt{sim.dir}.
sim.dir  Directory with the MCMC simulation results. It is only used if \texttt{mcmc.list} is \texttt{NULL}.
chain.ids  List of MCMC identifiers to be plotted. If it is \texttt{NULL}, all chains found in \texttt{mcmc.list} or \texttt{sim.dir} are plotted.
par.names  Names of parameters for which density should be plotted. By default all (possibly transformed) country-independent parameters are plotted if used within \texttt{tfr.pardensity.plot} and \texttt{tfr3.pardensity.plot}, or country-specific parameters are plotted if used within \texttt{tfr.pardensity.cs.plot} and \texttt{tfr3.pardensity.cs.plot}.
burnin  Number of iterations to be discarded from the beginning of each chain.
dev.ncol  Number of column for the graphics device. If the number of parameters is smaller than \texttt{dev.ncol}, the number of columns is automatically decreased.
low.memory  Logical indicating if the processing should run in a low-memory mode. If it is \texttt{FALSE}, traces of all available parameters are loaded into memory. Otherwise, parameters are loaded as they are needed and are not kept in the memory.

Details

The functions plot the density of the posterior distribution either for country-independent parameters (\texttt{tfr.pardensity.plot} for phase II MCMCs and \texttt{tfr3.pardensity.plot} for phase III MCMCs) or for country-specific parameters (\texttt{tfr.pardensity.cs.plot} for phase II and \texttt{tfr3.pardensity.cs.plot} for phase III), one graph per parameter. One can restrict it to specific chains by setting the \texttt{chain.ids} argument and to specific parameters by setting the \texttt{par.names} argument.

If \texttt{mcmc.list} is an object of class \texttt{bayesTFR.prediction} (which is allowed in \texttt{tfr.pardensity.plot} and \texttt{tfr.pardensity.cs.plot} only) and if this object contains thinned traces, they are used instead of the full chains. In such a case, \texttt{burnin} and \texttt{chain.ids} cannot be modified - their value is set to the one used when the thinned traces were created, namely when running \texttt{tfr.predict}. In a situation with long MCMC chains, this approach can significantly speed-up creation of the density plots.
Author(s)

Hana Sevcikova

See Also

tfr.partraces.plot

Examples

```r
## Not run:
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
tfr.partraces.plot(sim.dir=sim.dir)
tfr.partraces.cs.plot(country="Ireland", sim.dir=sim.dir, bw=0.2)
## End(Not run)
```

---

tfr.partraces.plot Plotting MCMC Parameter Traces

Description

Functions for plotting the MCMC parameter traces.

Usage

```r
tfr.partraces.plot(mcmc.list = NULL,
  sim.dir = file.path(getwd(), "bayesTFR.output"), chain.ids = NULL,
  par.names = tfr.parameter.names(trans = TRUE),
  nr.points = NULL, dev.ncol=5, low.memory = TRUE, ...)

tfr.partraces.cs.plot(country, mcmc.list = NULL,
  sim.dir = file.path(getwd(), "bayesTFR.output"), chain.ids = NULL,
  par.names = tfr.parameter.names.cs(trans = TRUE),
  nr.points = NULL, dev.ncol=3, low.memory = TRUE, ...)

tfr3.partraces.plot(mcmc.list = NULL,
  sim.dir = file.path(getwd(), "bayesTFR.output"), chain.ids = NULL,
  par.names = tfr3.parameter.names(),
  nr.points = NULL, dev.ncol=3, low.memory = TRUE, ...)

tfr3.partraces.cs.plot(country, mcmc.list = NULL,
  sim.dir = file.path(getwd(), "bayesTFR.output"), chain.ids = NULL,
  par.names = tfr3.parameter.names.cs(),
  nr.points = NULL, dev.ncol=2, low.memory = TRUE, ...)
```
tfr.partraces.plot

Arguments

- **country**: Name or numerical code of a country.
- **mcmc.list**: List of bayesTFR.mcmc objects, or an object of class bayesTFR.mcmc.set or of class bayesTFR.prediction (allowed only for Phase II MCMCs). If it is NULL, the traces are loaded from sim.dir.
- **sim.dir**: Directory with the MCMC simulation results. It is only used if mcmc.list is NULL.
- **chain.ids**: List of MCMC identifiers to be plotted. If it is NULL, all chains found in mcmc.list or sim.dir are plotted.
- **par.names**: Names of parameters for which traces should be plotted. By default all (possibly transformed) country-independent parameters are plotted if used within tfr.partraces.plot and tfr3.partraces.plot, or country-specific parameters are plotted if used within tfr.partraces.cs.plot and tfr3.partraces.cs.plot.
- **nr.points**: Number of points to be plotted. If NULL, all points are plotted, otherwise the traces are thinned evenly.
- **dev.ncol**: Number of column for the graphics device. If the number of parameters is smaller than dev.ncol, the number of columns is automatically decreased.
- **low.memory**: Logical indicating if the processing should run in a low-memory mode. If it is FALSE, traces of all available parameters are loaded into memory. Otherwise, parameters are loaded as they are needed and are not kept in the memory.
- **...**: Additional graphical arguments.

Details

The functions plot MCMC traces either for country-independent parameters (tfr.partraces.plot for phase II MCMCs and tfr3.partraces.plot for phase III MCMCs) or for country-specific parameters (tfr.partraces.cs.plot for phase II MCMCs and tfr3.partraces.cs.plot for phase III MCMCs), one graph per parameter. One can restrict it to specific chains by setting the chain.ids argument, and to specific parameters by setting the par.names argument.

Author(s)

Hana Sevcikova

See Also

coda.list.mcmc for retrieving raw values of the traces.

Examples

```r
## Not run:
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
tfr.partraces.plot(sim.dir=sim.dir)
tfr.partraces.cs.plot(country="Netherlands", sim.dir=sim.dir)
```

## End(Not run)
Generating Posterior Trajectories of the Total Fertility Rate

**Description**

Using the posterior parameter samples simulated by `run.tfr.mcmc` (and possibly `run.tfr3.mcmc`) the function generates posterior trajectories for the total fertility rate for all countries of the world.

**Usage**

```r
tfr.predict(mcmc.set = NULL, end.year = 2100,
            sim.dir = file.path(getwd(), "bayesTFR.output"),
            replace.output = FALSE, start.year = NULL,
            nr.traj = NULL, thin = NULL, burnin = 2000,
            use.diagnostics = FALSE, use.tfr3 = TRUE, burnin3 = 10000,
            mu = 2.1, rho = 0.8859, sigmaAR1 = 0.1016, min.tfr = 0.5,
            use.correlation = FALSE, save.as.ascii = 1000, output.dir = NULL,
            low.memory = TRUE, seed = NULL, verbose = TRUE, ...)
```

**Arguments**

- `mcmc.set` Object of class `bayesTFR.mcmc.set` corresponding Phase II MCMCs. If it is `NULL`, the object is loaded from the directory given by `sim.dir`.
- `end.year` End year of the prediction.
- `sim.dir` Directory with the MCMC simulation results. It should equal to the `output.dir` argument in `run.tfr.mcmc`.
- `replace.output` Logical. If `TRUE`, existing predictions in `output.dir` will be replaced by results of this run.
- `start.year` Start year of the prediction. By default the prediction is started at the next time period after `present.year` set in the estimation step. If `start.year` is smaller than the default, projections for countries and time periods that have data available after `start.year` are set to those data.
- `nr.traj` Number of trajectories to be generated. If `NULL`, the argument `thin` is taken to determine the number of trajectories. If both are `NULL`, the number of trajectories corresponds to the size of the parameter sample.
- `thin` Thinning interval used for determining the number of trajectories. Only relevant, if `nr.traj` is `NULL`.
- `burnin` Number of iterations to be discarded from the beginning of the parameter traces.
- `use.diagnostics` Logical determining if an existing convergence diagnostics for phase II MCMCs should be used for choosing the values of `thin` and `burnin`. In such a case, arguments `nr.traj`, `thin` and `burnin` are ignored. The 'best' values are chosen from results of running the `tfr.diagnose` function. Only diagnostics can be used that suggest a convergence of the underlying MCMCs. If there are more than one such objects, the one is chosen whose recommendation for the number of trajectories is larger and closest to 2000.
### Details

The trajectories are generated using a distribution of country-specific decline curves (Alkema et al 2011) and either a classic AR(1) process or a country-specific AR(1) process (Raftery et al 2013). Phase II parameter samples simulated using `run.tfr.mcmc` are used from all chains, from which the given burnin was discarded. They are evenly thinned to match `nr.traj` or using the `thin` argument. Such thinned parameter traces, collapsed into one chain, if they do not already exist, are stored on disk into the sub-directory ‘`(thinned_mcmc_t_b’ where `i` is the value of `thin` and `b` the value of burnin (see `create.thinned.tfr.mcmc`).

If Phase III is projected using a BHM (i.e. if `use.tfr3` is TRUE), parameter samples simulated via `run.tfr3.mcmc` are used from which burnin (given by `burnin3`) is discarded and the chains are

```r
tfr.predict

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>use.tfr3</code></td>
<td>Logical determining if phase III should be predicted via MCMCs (simulated via <code>run.tfr3.mcmc</code>) or a classic AR(1) process. If TRUE but no phase III MCMCs were simulated, a warning is given and the prediction switches automatically to a classic AR(1) process.</td>
</tr>
<tr>
<td><code>burnin3</code></td>
<td>Burnin used for phase III MCMCs. Only relevant if <code>use.tfr3</code> is TRUE.</td>
</tr>
<tr>
<td><code>save.as.ascii</code></td>
<td>Either a number determining how many trajectories should be converted into an ASCII file, or “all” in which case all trajectories are converted. It should be set to 0, if no conversion is desired.</td>
</tr>
<tr>
<td><code>output.dir</code></td>
<td>Directory into which the resulting prediction object and the trajectories are stored. If it is NULL, it is set to either <code>sim.dir</code>, or to <code>output.dir</code> of <code>mcmc.set$meta</code> if <code>mcmc.set</code> is given.</td>
</tr>
<tr>
<td><code>low.memory</code></td>
<td>Logical indicating if the prediction should run in a low-memory mode. If it is FALSE, the whole traces of all parameters, including the burnin, are loaded into memory. Otherwise, burnins are discarded and parameters are loaded as they are needed and are not kept in the memory.</td>
</tr>
<tr>
<td><code>mu</code></td>
<td>Long-term mean $\mu$ in the AR(1) projection model. Only used if <code>use.tfr3</code> is FALSE.</td>
</tr>
<tr>
<td><code>rho</code></td>
<td>Autoregressive parameter $\rho$ in AR(1) projection model. If it is NULL it is estimated from the data. Only used if <code>use.tfr3</code> is FALSE.</td>
</tr>
<tr>
<td><code>sigmaAR1</code></td>
<td>Standard deviation $s$ of AR(1) distortion terms in short-term projections. If it is NULL it is estimated from the data. It can be a single value or a vector giving the standard deviations for single projections. If the vector is shorter than the number of projections simulated via the AR(1) process, the last value is repeated for the remaining projections. In case of a single value (default), the standard deviation is kept constant over all AR(1) projections. Only used if <code>use.tfr3</code> is FALSE.</td>
</tr>
<tr>
<td><code>min.tfr</code></td>
<td>Smallest TFR value allowed.</td>
</tr>
<tr>
<td><code>use.correlation</code></td>
<td>Logical. If TRUE the model errors are sampled jointly for all countries (Fosdick and Raftery, 2014).</td>
</tr>
<tr>
<td><code>seed</code></td>
<td>Seed of the random number generator. If NULL no seed is set. It can be used to generate reproducible projections.</td>
</tr>
<tr>
<td><code>verbose</code></td>
<td>Logical switching log messages on and off.</td>
</tr>
</tbody>
</table>
````
evenly thinned in a way that the total size corresponds to the final size of the Phase II parameter samples. Countries for which there are no simulated country-specific Phase III parameters (e.g. because their TFR is still in Phase II or it is an aggregated region) use samples of the “world” AR(1) parameters.

The projection is run for all missing values before the present year, if any. Medians over the trajectories are used as imputed values and the trajectories are discarded. The process then continues by projecting the future values where all generated trajectories are kept.

The resulting prediction object is saved into ‘{output.dir}/predictions’. Trajectories for all countries are saved into the same directory in a binary format, one file per country. At the end of the projection, if save.as.ascii is larger than 0, the function converts the given number of trajectories into a CSV file of a UN-specific format. They are selected by equal spacing (see function convert.tfr.trajectories for more details on the conversion). In addition, two summary files are created: one in a user-friendly format, the other using a UN-specific coding of the variants and time (see write.projection.summary for more details).

**Value**

Object of class bayesTFR.prediction which is a list containing components:

- **quantiles** A $n \times q \times p$ array of quantile values computed on all trajectories. $n$ is the number of countries, $q$ is the number of quantile bounds and $p$ is the number of projections.

- **traj.mean.sd** A $n \times 2 \times p$ array holding the mean of all trajectories in the first column and the standard deviation in the second column. $n$ and $p$ are the number of countries and number of projections, respectively.

- **nr.traj** Number of trajectories.

- **trf_matrix_reconstructed** Matrix containing imputed TFR values on spots where the original TFR matrix has missing values, i.e. between the last observed data point and the present year.

- **output.directory** Directory where trajectories corresponding to this prediction are stored.

- **nr.projections** Number of projections.

- **burnin, thin, burnin3, thin3** Burnin and thin used for this prediction for Phase II and Phase III, respectively.

- **end.year** The end year of this prediction.

- **mu, rho, sigma_t, sigmaAR1** Parameters of the AR(1) process. sigma_t is a vector of actual values of the standard deviation $\sigma$ used for each projection.

- **min.tfr** Input value of minimum threshold for TFR.

- **na.index** Index of trajectories for which at least one country got NA values.

- **mcmc.set** Object of class bayesTFR.mcmc.set used for this prediction, i.e. the burned, thinned, and collapsed MCMC chain.

**Author(s)**

Hana Sevcikova, Leontine Alkema, Bailey Fosdick
tfr.predict.extra

References


See Also

run.tfr.mcmc, run.tfr3.mcmc, create.thinned.tfr.mcmc, convert.tfr.trajectories, write.projection.summary, get.tfr.prediction, summary.bayestfr.prediction

Examples

```r
## Not run:
sim.dir <- tempfile()
m <- run.tfr.mcmc(nr.chains=1, iter=10, output.dir=sim.dir, verbose=TRUE)
m3 <- run.tfr3.mcmc(sim.dir=sim.dir, nr.chains=2, iter=40, thin=1, verbose=TRUE)
pred <- tfr.predict(m, burnin=0, burnin3=10, verbose=TRUE)
summary(pred, country="Iceland")
unlink(sim.dir, recursive=TRUE)

## End(Not run)
```

Generating Posterior Trajectories of the Total Fertility Rate for Specific Countries or Regions

Description

Using the posterior parameter samples the function generates posterior trajectories of the total fertility rate for given countries or regions. It is intended to be used after running run.tfr.mcmc.extra, but it can be also used for purposes of testing specific settings on one or a few countries.

Usage

```r
tfr.predict.extra(sim.dir = file.path(getwd(), 'bayestfr.output'),
                 prediction.dir = sim.dir, countries = NULL,
                 save.as.ascii = 1000, verbose = TRUE)
```
Arguments

sim.dir Directory with the MCMC simulation results.
prediction.dir Directory where the prediction object and the trajectories are stored.
countries Vector of country codes for which the prediction should be made. If it is NULL, the prediction is run for all countries that are included in the MCMC object but for which no prediction was generated.
save.as.ascii Either a number determining how many trajectories should be converted into an ascii file, or “all” in which case all trajectories are converted. It should be set to 0, if no conversions is desired. Note that the conversion is done on all countries.
verbose Logical switching log messages on and off.

Details

In order to use this function, a prediction object must exist, i.e. the function `tfr.predict` must have been processed prior to using this function.

Trajectories for given countries or regions are generated and stored in binary format along with other countries (in prediction_dir). The existing prediction object is updated and stored in the same directory. If save.as.ascii is larger than zero, trajectories of ALL countries are converted to an ascii format.

Value

Updated object of class `bayesTFR.prediction`.

Author(s)

Hana Sevcikova

See Also

`tfr.predict`

tfr.predict.subnat

Generating Posterior Trajectories of Subnational TFR

Description

Generates posterior trajectories of the total fertility rate for subregions of given countries, using the Scale-AR(1) method.

Usage

```r
  tfr.predict.subnat(countries, my.tfr.file, 
                   sim.dir = file.path(getwd(), "bayesTFR.output"), 
                   end.year = 2100, start.year = NULL, output.dir = NULL, 
                   nr.traj = NULL, seed = NULL, min.tfr = 0.5, 
                   ar.pars = c(mu = 1, rho = 0.92464, sigma = 0.04522), 
                   save.as.ascii = 0, verbose = TRUE)
```
Arguments

countries Vector of numerical country codes or country names.
my.tfr.file Tab-separated ASCII file containing the subnational TFR data. See Details for more information on its format.
sim.dir Simulation directory with the national projections generated using tfr.predict.
end.year End year of the projections.
start.year Start year of the projections. By default, projections start at the same time point as the national projections.
output.dir Directory into which the resulting prediction objects and the trajectories are stored. See below for details.
rnr.traj Number of trajectories to be generated. If NULL, the number of trajectories in the national projections is used.
seed Seed of the random number generator. If NULL no seed is set. It can be used to generate reproducible projections.
min.tfr Lower bound on TFR.
ar.pars List containing the parameter estimates of the AR(1) process. It must have elements called mu, rho and sigma.
save.as.ascii Either a number determining how many trajectories should be converted into an ASCII file, or “all” in which case all trajectories are converted. By default no conversion is performed.
verbose Logical switching log messages on and off.

Details

The function implements the methodology described in Sevcikova et al (2017). Given a set of national bayesTFR projections, it applies the Scale-AR(1) model to each national trajectory and each subregion of given countries which yield subnational TFR projections.

The file on subnational data passed in my.tfr.file has to have a column “country_code” with numerical values corresponding to countries given in the argument countries, and column “reg_code” giving the numerical identifier of each subregion. Column “name” should be used for subregion name, and column “country” for country name. An optional column “include_code” can be used to eliminate entries from processing. Entries with values of 1 or 2 will be included, all others will be ignored. Column “last.observed” can be used to define which time period contains the last observed data point (given as integer, e.g. year in the middle of the time period). Remaining columns define the time periods, e.g. “2000-2005”, “2005-2010”. The package contains an example of such dataset, see Example below.

Argument output.dir gives a location on disk where results of the function should be stored. If it is NULL (default), results are stored in the same directory as the national projections. In both cases a subdirectory called “subnat” is created in which each country has its own subfolder with the country code in its name. Each such subfolder contains the same type of outputs as in the national case generated using tfr.predict, most importantly a directory “predictions” with trajectories for each region.
Value

A list of objects of class \texttt{bayesTFR.prediction}. The name of each element includes its country code. Not all elements of the class \texttt{bayesTFR.prediction} are available. For example, no \texttt{mcmc.set} is attached to these objects. Thus, not all functions that work with \texttt{bayesTFR.prediction} can be applied to these results.

Note

Even though the resulting object contains subnational results, the names of its elements are the same as in the national case. This allows to apply the same functions on both objects (subnational and national). However, it means that sometimes the meaning of the elements or function arguments does not match the subnational context. For example, various functions expect the argument \texttt{country}. When a subnational object is passed to such a function, \texttt{country} means a subregion.

Author(s)

Hana Sevcikova

References


See Also

\texttt{get.regTFR.prediction}, \texttt{tfr.predict}

Examples

# View the example data
my.subtfr.file <- file.path(find.package("bayesTFR"), 'extdata', 'subnational_tfr_template.txt')
subtfr <- read.delim(my.subtfr.file, check.names=FALSE)
head(subtfr)

# Directory with national projections (contains 30 trajectories for each country)
nat.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")

# Subnational projections for Australia and Canada
subnat.dir <- tempfile()
preds <- tfr.predict.subnat(c(36, 124), my.tfr.file=my.subtfr.file,
sim.dir=nat.dir, output.dir=subnat.dir, start.year=2013)
names(preds)
get.countries.table(preds[["36"]])
summary(preds[["36"]], "Queensland")
tfr.trajectories.plot(preds[["36"]], "Queensland")

# plot subnational and national TFR in one plot
nat.pred <- get.tfr.prediction(nat.dir)
tfr.trajectories.plot(preds[["36"]], 186, pi=80, half.child.variant=FALSE)
tfr.trajectories.plot(nat.pred, "Australia", half.child.variant=FALSE,
add=TRUE, col=rep("darkgreen", 5), nr.traj=0, show.legend=FALSE)
The functions compute the Raftery diagnostics for each parameter of MCMCs of phase II (tfr.raftery.diag) and phase III (tfr3.raftery.diag), taking median over all chains.

### Usage

```r
tfr.raftery.diag(mcmc = NULL,
                sim.dir = file.path(getwd(), "bayesTFR.output"),
                burnin = 0, country = NULL,
                par.names = tfr.parameter.names(trans = TRUE),
                par.names.cs = tfr.parameter.names.cs(trans = TRUE, back.trans = FALSE),
                country.sampling.prop = 1, verbose=TRUE, ...)
```

```r
tfr3.raftery.diag(mcmc = NULL,
                  sim.dir = file.path(getwd(), "bayesTFR.output"),
                  burnin = 0, country = NULL,
                  par.names = tfr3.parameter.names(),
                  par.names.cs = tfr3.parameter.names.cs(),
                  country.sampling.prop = 1, verbose=TRUE, ...)
```

### Arguments

- **mcmc**: A bayesTFR.mcmc or bayesTFR.mcmc.set object.
- **sim.dir**: Directory with the MCMC simulation results. Only used if mcmc is NULL.
- **burnin**: Burnin.
- **country**: Name or code of a country. If it is given, country-specific parameters are reduced to parameters of that country.
- **par.names**: Names of country-independent parameters for which the Raftery diagnostics should be computed.
- **par.names.cs**: Names of country-specific parameters for which the Raftery diagnostics should be computed.

### Description

The functions compute the Raftery diagnostics for each parameter of MCMCs of phase II (tfr.raftery.diag) and phase III (tfr3.raftery.diag), taking median over all chains.
country.sampling.prop

Proportion of countries that are included in the diagnostics. It should be between 0 and 1. If it is smaller than 1, the countries are randomly sampled. It is only relevant if par.names.cs is not NULL.

verbose

Logical switching log messages on and off.

Additional arguments passed to the coda.list.mcmc function.

Details

The Raftery diagnostics is computed for each parameter, using coda's raftery.diag with r=0.0125, q=0.025 and q=0.975. Values of $N$ and burnin are taken as the median over chains. For each country-specific parameter, the maximum over all included countries of such medians is taken.

Value

List with the components:

n.median	2-d array of $N$ values (processed as described in Details) with two rows: first corresponding to q=0.025, second corresponding to q=0.975. Each column corresponds to one parameter.

burnin	2-d array of the same structure as n.median, containing the burnin values (processed as described in Details).

not.converged.parameters	List with two elements, each of which is a data frame containing columns “parameter.name”, “chain.id”, and “N”. These are parameters for which the computed value of Raftery diagnostics $N$ is larger than the total number of finished iterations summed over all chains. The first element of the list corresponds to q=0.025, second corresponds to q=0.975.

not.converged.inchain.parameters	List of the same structure as not.converged.parameters. The parameters included are those for which the computed value of Raftery diagnostics $N$ is larger than the number of finished iterations in the corresponding chain.

N.country.indep	Data frame containing columns “parameter.name”, “chain.id”, “N.0.025”, and “N.0.975”. Each row gives $N$ computed with the two different $q$ for each country-independent parameter and chain.

N.country.spec	The same as N.country.indep, but here the country-specific parameters are considered.

n.median.country.spec	2-d array of $N$ values for country-specific parameters containing medians over chains.

thin.ind	List with elements ’0.025’, ’0.975’ and median. The first two elements are matrices with one row per chain and one column per parameter. They contain values of thin that makes the MCMC independent, for q=0.025 and q=0.975, respectively. The median element is of the same structure as n.median, containing medians over rows in the two matrices in this list.

nr.countries	Vector with elements used (number of countries used in this diagnostics) and total (number of countries that this mcmc object was estimated on).
tfr.trajectories.plot

Author(s)
Hana Sevcikova, Adrian Raftery

See Also
raftery.diag

tfr.trajectories.plot  Output of Posterior Distribution of TFR Trajectories

Description
The functions plot/tabulate the posterior distribution of TFR trajectories for a given country, or for all countries, including their median and given probability intervals.

Usage

```r
tfr.trajectories.plot(tfr.pred, country, pi = c(80, 95),
  half.child.variant = TRUE, nr.traj = NULL,
  adjusted.only = TRUE, typical.trajectory = FALSE,
  mark.estimation.points = FALSE,
  xlim = NULL, ylim = NULL, type = 'b', xlab = 'Year', ylab = 'TFR',
  main = NULL, lwd = c(2, 2, 2, 2, 2, 1),
  col = c('black', 'green', 'red', 'red', 'blue', '#00000020'),
  show.legend = TRUE, add = FALSE, ...)

tfr.trajectories.plot.all(tfr.pred,
  output.dir = file.path(getwd(), 'TFRtrajectories'),
  output.type = "png", main = NULL, verbose = FALSE, ...)

tfr.trajectories.table(tfr.pred, country, pi = c(80, 95),
  half.child.variant = TRUE)
```

Arguments

tfr.pred Object of class bayesTFR.prediction.
country Name or numerical code of a country.
pi Probability interval. It can be a single number or an array.
half.child.variant If TRUE the United Nations variant of “+/- 0.5 child” (relative to the median) is shown.
nr.traj Number of trajectories to be plotted. If NULL, all trajectories are plotted, otherwise they are thinned evenly.
adjusted.only Logical. By default, if the projection median is adjusted using e.g. tfr.median.set, the function plots the adjusted median. If adjusted.only=FALSE the original (non-adjusted) median is plotted as well.
tfr.trajectories.plot  

**typical.trajectory**  
Logical. If TRUE one trajectory is shown that has the smallest distance to the median.

**mark.estimation.points**  
Logical. If TRUE, points that were not used in the estimation (phase I) are shown in lighter color than points in phase II and III.

**xlim, ylim, type, xlab, ylab**  
Graphical parameters passed to the plot function.

**lwd, col**  
Vector of six elements giving the line width and color for: 1. observed data, 2. imputed missing data, 3. median, 4. quantiles, 5. half-child variant, 6. trajectories.

**show.legend**  
Logical controlling whether the legend should be drawn.

**add**  
Logical controlling whether the trajectories should be plotted into a new graphic device (FALSE) or into an existing device (TRUE). One can use this argument to plot trajectories from multiple countries into one graphics.

**...**  
Additional graphical parameters. In addition, for tfr.trajectories.plot.all, ... contains any of the arguments of tfr.trajectories.plot.

**output.dir**  
Directory into which resulting graphs are stored.

**output.type**  
Type of the resulting files. It can be "png", "pdf", "jpeg", "bmp", "tiff", or "postscript".

**main**  
Main title for the plot(s). In tfr.trajectories.plot.all any occurrence of the string "XXX" is replaced by the country name.

**verbose**  
Logical switching log messages on and off.

**Details**

`tfr.trajectories.plot` plots posterior distribution of TFR trajectories for a given country. `tfr.trajectories.table` gives the same output as a table. `tfr.trajectories.plot.all` creates a set of graphs (one per country) that are stored in `output.dir`.

The median and given probability intervals are computed using all available trajectories. Thus, `nr.traj` does not influence those values - it is used only to control the number of trajectories plotted.

**Author(s)**

Hana Sevcikova, Leontine Alkema

**See Also**

bayesTFR.prediction

**Examples**

```r
## Not run:
sim.dir <- file.path(find.package("bayesTFR"), "ex-data", "bayesTFR.output")
pred <- get.tfr.prediction(sim.dir)
tfr.trajectories.plot(pred, country="Burkina Faso", pi=c(80, 95))
```
tfr.trajectories.table(pred, country="Burkina Faso", pi=c(80, 95))

## End(Not run)

---

### Dataset with UN-specific Time Coding

**Description**

Dataset used by the UN for coding time. It is a TAB-separated ASCII file called “UN_time.txt”.

**Usage**

data(UN_time)

**Format**

A data frame with 1034 observations on the following 4 variables.

- **timeid**: Time identifier.
- **tlabel**: Label of the time, with minimum values of 1950 and 1950-1955, and maximum values of 2399, 2400 and 2400-2405.
- **tdate**: Equal to tlabel if it is a single year, or the starting year of tlabel, if it is an interval.
- **tinterval**: Length of the time interval, or zero, if it is a single year.

**Details**

For 5-year period data, fertility rates are defined from 1 July of year (t) to 1 July of year (t+5), with 1 January of year (t+3) as exact mid-date. This means, for example, that data for 2000-2005, refer to the period between 2000.5 and 2005.5, with 2003.0 as exact mid-point.

**Source**

Data provided by the United Nations Population Division

**Examples**

data(UN_time)
str(UN_time)
write.projection.summary

---

**UN_variants**  
*Dataset with UN-specific Coding of Variants*

**Description**

Dataset used by the UN for coding variants. It also includes variants for the lower and upper bounds of the 80 and 95% probability intervals, respectively, resulting from the Bayesian hierarchical model. The dataset is stored in a TAB-separated ASCII file called “UN_variants.txt”.

**Usage**

```r
data(UN_variants)
```

**Format**

A data frame with 23 observations on the following 5 variables.

- `Revid`  Revision identifier.
- `VarID`  Identifier of the variant.
- `Vshort` Short name of the variant.
- `VName`  Full name of the variant.
- `VariantDomain` Domain of the variant.

**Source**

Data provided by the United Nations Population Division

**Examples**

```r
data(UN_variants)
str(UN_variants)
```

---

write.projection.summary

*Writing Projection Summary Files*

**Description**

The function creates two files containing projection summaries, such as the median, the lower and upper bound of the 80 and 90% probability intervals, respectively, the +/- 0.5 child variant and the constant variant. One file is in a user-friendly format, whereas the other is in a UN-specific format with internal coding of the time and the variants. In addition, a file containing some of the model parameters is created.
Usage

write.projection.summary(dir = file.path(getwd(), "bayesTFR.output"),
output.dir = NULL, revision = NULL, adjusted = FALSE)

Arguments

dir Directory containing the prediction object. It should correspond to the output.dir argument of the \textit{tfr.predict} function.

output.dir Directory in which the resulting file will be stored. If NULL the same directory is used as for the prediction.

revision UN WPP revision number. If NULL it is determined from the corresponding WPP year: WPP 2008 corresponds to revision 13, every subsequent WPP increases the revision number by one. Used as a constant in the second file only.

adjusted Logical. By default the function writes summary using the original BHM projections. If the projection medians are adjusted (using e.g. \textit{tfr.median.set}), setting this argument to TRUE causes writing the adjusted projections.

Details

The first file that the function creates is called \texttt{projection\_summary\_user\_friendly.csv} (or \texttt{projection\_summary\_user\_friendly\_adjusted.csv} if \texttt{adjusted=TRUE}), it is a comma-separated table with the following columns:

- “country\_name”: country name
- “country\_code”: country code
- “variant”: name of the variant, such as “median”, “lower 80”, “upper 80”, “lower 95”, “upper 95”, “-0.5child”, “+0.5child”, “constant”
- period1: e.g. “2005-2010”: TFR for the first time period
- period2: e.g. “2010-2015”: TFR for the second time period
- … further columns with TFR projections

The second file, called \texttt{projection\_summary.csv} (or \texttt{projection\_summary\_adjusted.csv} if \texttt{adjusted=TRUE}), also comma-separated table, contains the same information as above in a UN-specific format:

- “RevID”: revision number, passed to the function as an argument
- “VarID”: variant identifier, extracted from the \texttt{UN\_variants} dataset
- “LocID”: country code
- “TimeID”: time identifier, extracted from the \texttt{UN\_time} dataset
- “TFR”: the total fertility rate for this variant, location and time period

The third comma-separated file, called \texttt{projection\_summary\_parameters.csv} contains the following columns:

- “country\_name”: country name
- “country\_code”: country code
• “TF_time_start_decline”: start period of TFR decline
• “TF_max”: TFR at the onset of the fertility transition (median of the \( U_c \) parameter)
• “TF_max_decrement”: maximum decrement of TFR decline (median of the \( d_c \) parameter)
• “TF_end_level”: median of the end level of the fertility transition (\( \Delta_{c4} \) parameter)
• “TF_end_level_low”: 2.5 percentile of the \( \Delta_{c4} \) distribution
• “TF_end_level_high”: 97.5 percentile of the \( \Delta_{c4} \) distribution
• “TF_time_end_decline”: period of the end decline, measured using the prediction median

Note that this file is not created if adjusted=TRUE.

Note
This function is automatically called from the \texttt{tfr.predict} function, therefore in standard cases it will not be needed to call it directly.

Author(s)
Hana Sevcikova

See Also
\texttt{convert.tfr.trajectories, tfr.predict}
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