

Package ‘rmdcev’

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Type Package

Title Kuhn-Tucker and Multiple Discrete-Continuous Extreme Value Models

Version 1.2.4

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Description

Estimates and simulates Kuhn-Tucker demand models with individual heterogeneity. The package implements the multiple-discrete continuous extreme value (MDCEV) model and the Kuhn-Tucker specification common in the environmental economics literature on recreation demand. Latent class and random parameters specifications can be implemented and the models are fit using maximum likelihood estimation or Bayesian estimation. All models are implemented in Stan, which is a C++ package for performing full Bayesian inference (see Stan Development Team, 2019) <<https://mc-stan.org/>>. The package also implements demand forecasting (Pinjari and Bhat (2011) <<https://repositories.lib.utexas.edu/handle/2152/23880>>) and welfare calculation (Lloyd-Smith (2018) <[doi:10.1016/j.jocm.2017.12.002](https://doi.org/10.1016/j.jocm.2017.12.002)>) for policy simulation.

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Imports rstan (>= 2.21.0), rstantools (>= 2.1.1), RcppParallel (>= 5.0.1), dplyr (>= 0.7.8), purrr, tibble, tidyr, utils, stats, Formula

LinkingTo BH (>= 1.72.0), Rcpp, RcppEigen (>= 0.3.3.3.0), RcppParallel (>= 5.0.1), rstan (>= 2.21.0), StanHeaders (>= 2.21.0)

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LazyData true

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Biarch true

Suggests knitr, rmarkdown, testthat

URL <https://github.com/plloydsmith/rmdcev>

BugReports <https://github.com/plloydsmith/rmdcev/issues>

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CreateBlankPolicies *CreateBlankPolicies*

Description

Create 'zero effect' policies that can be modified

Usage

```
CreateBlankPolicies(npols, model, price_change_only = TRUE)
```

Arguments

npols Number of policies to simulate

model Estimated model from mdcev

price_change_only Logical value for whether to include policy changes to dat_psi. Defaults to TRUE. TRUE implies that only price changes are used in simulation.

Examples

```
data_rec <- mdcev.data(data_rec, subset = id <= 500, id.var = "id",
  alt.var = "alt", choice = "quant")
```

```
mdcev_est <- mdcev(~ 0, data = data_rec,
  model = "hybrid0", algorithm = "MLE",
  std_errors = "mvn")
```

```
CreateBlankPolicies(npols = 2, mdcev_est)
```

data_rec

Recreation data from Value of Nature to Canadians Survey

Description

Data from 2000 individuals from the Value of Nature to Canadians (VNC) survey. The travel costs are calculated using the approach described in Lloyd-Smith (2020)

Usage

```
data(data_rec)
```

Format

A tibble with 34000 rows and 8 variables

Source

[Canadian Nature Survey 2012](#)

References

Federal, Provincial, and Territorial Governments of Canada. 2014. "2012 Canadian Nature Survey: Awareness, Participation, and Expenditures in Nature-Based Recreation, Conservation, and Subsistence Activities." Ottawa, ON: Canadian Councils of Resource Ministers. ([PubMed](#))

Lloyd-Smith, P (2020). "The Economic Benefits of Recreation in Canada". University of Saskatchewan Working Paper

GenerateMDCEVData

GenerateMDCEVData

Description

Simulate data for KT models

Usage

```

GenerateMDCEVData(
  model,
  nobs = 1000,
  nalts = 10,
  income = stats::runif(nobs, 1e+05, 150000),
  price = matrix(stats::runif(nobs * nalts, 100, 500), nobs, nalts),
  alpha_parms = 0.5,
  scale_parms = 1,
  gamma_parms = stats::runif(nalts, 1, 10),
  psi_i_parms = c(-1.5, 2, -1),
  psi_j_parms = c(-5, 0.5, 2),
  phi_parms = c(-5, 0.5, 2),
  dat_psi_i = matrix(2 * stats::runif(nobs * length(psi_i_parms)), nobs,
    length(psi_i_parms)),
  dat_psi_j = cbind(matrix(stats::runif(nalts * (length(psi_j_parms))), 0, 1), nrow =
    nalts),
  dat_phi = cbind(matrix(stats::runif(nalts * (length(phi_parms))), 0, 1), nrow =
    nalts),
  nerrs = 1,
  tol = 1e-20,
  max_loop = 999
)

```

Arguments

model	A string indicating which model specification is estimated. The options are "alpha", "gamma", "hybrid" and "hybrid0" for the MDCEV model and "kt_ee" for the environmental economics Kuhn-Tucker specification.
nobs	Number of individuals
nalts	Number of non-numeraire alts
income	Vector of individual income
price	Matrix of prices for non-numeraire alternatives.
alpha_parms	Parameter value for alpha term
scale_parms	Parameter value for scale term
gamma_parms	Parameter value for gamma terms
psi_i_parms	Parameter value for psi terms that vary by individual
psi_j_parms	Parameter value for psi terms that vary by alt (all models except kt_ee)
phi_parms	Parameter value for phi terms that vary by alt (kt_ee model only)
dat_psi_i	(nobs X # psi_i_parms) matrix with individual-specific characteristics
dat_psi_j	(nalts X # psi_j_parms) matrix with alternative-specific variables (all models except kt_ee)
dat_phi	(nalts X # phi_parms) matrix with alternative-specific variables (kt_ee model only)

nerrs	Number of error draws for demand simulation
tol	Tolerance level for simulations if using general approach
max_loop	maximum number of loops for simulations if using general approach

Value

A 'mdcev.data' object, which is a 'data.frame' in long format. Also includes parms_true with parameter values

Examples

```
data <- GenerateMDCEVData(model = "gamma")
```

mdcev	<i>mdcev</i>
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Description

Fit a MDCEV model using MLE or Bayes

Usage

```
mdcev(
  formula = NULL,
  data,
  weights = NULL,
  model = c("alpha", "gamma", "hybrid", "hybrid0", "kt_ee"),
  n_classes = 1,
  fixed_scale1 = 0,
  single_scale = 0,
  trunc_data = 0,
  psi_ascs = NULL,
  gamma_ascs = 1,
  seed = "123",
  max_iterations = 2000,
  jacobian_analytical_grad = 1,
  initial.parameters = "random",
  hessian = TRUE,
  algorithm = c("MLE", "Bayes"),
  flat_priors = NULL,
  print_iterations = TRUE,
  prior_psi_sd = 10,
  prior_gamma_sd = 10,
  prior_phi_sd = 10,
  prior_alpha_shape = 1,
```

```

prior_scale_sd = 1,
prior_delta_sd = 10,
gamma_nonrandom = 0,
alpha_nonrandom = 0,
std_errors = "deltamethod",
n_draws = 50,
keep_loglik = 0,
random_parameters = "fixed",
show_stan_warnings = TRUE,
n_iterations = 200,
n_chains = 4,
n_cores = 4,
max_tree_depth = 10,
adapt_delta = 0.8,
lkj_shape_prior = 4,
...
)

## S3 method for class 'mdcev'
print(
  x,
  digits = max(3, getOption("digits") - 3),
  width = getOption("width"),
  ...
)

## S3 method for class 'mdcev'
summary(object, printCI = FALSE, ...)

## S3 method for class 'summary.mdcev'
print(x, ...)

```

Arguments

formula	Formula for the model to be estimated. The formula is divided in three parts, separated by the symbol . The first part is reserved for alternative-specific and individual-specific variables in the ψ parameters. Note that alternative-specific constants are handled by the <code>psi_ascs</code> argument. The second part corresponds for individual-specific variables that enter in the probability assignment in models with latent classes. The third part is reserved for the q_k variables included in the ϕ_k parameters in the KT model specification used in environmental economics <code>model = "kt_ee"</code> .
data	The (I x J) data to be passed to Stan of class <code>mdcev.data</code> including 1) id, 2) alt, 3) choice, 4) price, 5) income, and columns for alternative-specific and individual specific variables. Note: I is number of individuals and J is number of non-numeraire alternatives.
weights	an optional vector of weights. Default to 1.
model	A string indicating which model specification is estimated. The options are

	"alpha", "gamma", "hybrid" and "hybrid0" for the MDCEV model and "kt_ee" for the environmental economics Kuhn-Tucker specification.
n_classes	The number of latent classes. Note that the LC model is automatically estimated as long as the prespecified number of classes is set greater than 1.
fixed_scale1	Whether to fix scale at 1.
single_scale	For lc models, whether to estimate a single scale parameter
trunc_data	Whether the estimation should be adjusted for truncation of non-numeraire alternatives. This option is useful if the data only includes individuals with positive non-numeraire consumption levels such as recreation data collected on-site. To account for the truncation of consumption, the likelihood is normalized by one minus the likelihood of observing zero consumption for all non-numeraire alternatives (i.e. likelihood of positive consumption) following Englin, Boxall and Watson (1998) and von Haefen (2003).
psi_ascs	Whether to include alternative-specific psi parameters. The first alternative is used as the reference category. Only specify to 1 for MDCEV models.
gamma_ascs	Indicator to include alternative-specific gammas parameters.
seed	Random seed.
max_iterations	Maximum number of iterations in MLE.
jacobian_analytical_grad	indicator whether to use analytical gradient method for Jacobian (=1) or numerical gradient method (=0). For "kt_ee" model only,
initial.parameters	The default for fixed and random parameter specifications is to use random starting values. (except for the scale parameter which a starting value set to 1). For LC models, the default is to use slightly adjusted MLE point estimates from the single class model. Initial parameter values should be included in a named list. For example, the LC "hybrid" specification initial parameters can be specified as: <code>initial.parameters = list(psi = array(0, dim = c(K, num_psi)), gamma = array(1, dim = c(K, num_alt)), alpha = array(0.5, dim = c(K, 0)), scale = array(1, dim = c(K)))</code> where K is the number of classes (i.e. K = 1 is used for single class models), num_psi is number of psi parameters, and num_alt is number of non-numeraire alternatives.
hessian	Whether to keep the Hessian matrix
algorithm	Either "Bayes" for Bayes or "MLE" for maximum likelihood estimation.
flat_priors	indicator if completely uninformative priors should be specified. Defaults to 1 if MLE used and 0 if Bayes used. If using MLE and set flat_priors = 0, penalized MLE is used and the optimizing objective is augmented with the priors.
print_iterations	Whether to print iteration information
prior_psi_sd	standard deviation for normal prior with mean 0.
prior_gamma_sd	standard deviation for half-normal prior with mean 1.
prior_phi_sd	standard deviation for normal prior with mean 0.
prior_alpha_shape	shape parameter for beta distribution.

prior_scale_sd	standard deviation for half-normal prior with mean 0.
prior_delta_sd	standard deviation for normal prior with mean 0.
gamma_nonrandom	indicator set to 1 if gamma parameters should not be random (i.e. no standard deviation).
alpha_nonrandom	indicator set to 1 if alpha parameters should not be random (i.e. no standard deviation).
std_errors	Compute standard errors using the delta method ("deltamethod") or multivariate normal draws ("mvn"). The default is "deltamethod". Note that mvn parameter draws should be used to incorporate parameter uncertainty for demand and welfare simulation. For maximum likelihood estimation only.
n_draws	The number of multivariate normal draws for standard error calculations if "mvn" is specified.
keep_loglik	Whether to keep the log_lik calculations
random_parameters	The form of the covariance matrix for Bayes. Can be 'fixed' for no random parameters, 'uncorr' for uncorrelated random parameters, or 'corr' for correlated random parameters.
show_stan_warnings	Whether to show warnings from Stan.
n_iterations	The number of iterations to use in Bayesian estimation. The default is for the number of iterations to be split evenly between warmup and posterior draws. The number of warmup draws can be directly controlled using the warmup argument (see <code>rstan::sampling</code>).
n_chains	The number of independent Markov chains in Bayesian estimation.
n_cores	The number of cores used to execute the Markov chains in parallel in Bayesian estimation. Can set using <code>options(mc.cores = parallel::detectCores())</code> .
max_tree_depth	https://mc-stan.org/misc/warnings.html#maximum-treedepth-exceeded
adapt_delta	https://mc-stan.org/misc/warnings.html#divergent-transitions-after-warmup
lkj_shape_prior	Prior for Cholesky matrix
...	Additional parameters to pass on to <code>rstan::stan</code> and <code>rstan::sampling</code> .
x, object	an object of class 'mdcev'
digits	the number of digits,
width	the width of the printing,
printCI	set to TRUE to print 95% confidence intervals

Value

A object of class `mdcev`

Examples

```
data(data_rec, package = "rmdcev")

data_rec <- mdcev.data(data_rec, subset = id <= 500, id.var = "id",
                      alt.var = "alt", choice = "quant")

mdcev_est <- mdcev( ~ 0,
                  data = data_rec,
                  model = "hybrid0",
                  algorithm = "MLE")
```

mdcev.data	<i>data.frame for mdcev model</i>
------------	-----------------------------------

Description

shape a 'data.frame' in a suitable form for the use of the 'mdcev' function and complete some data checks

Usage

```
mdcev.data(
  data,
  id.var = "id",
  alt.var = NULL,
  choice = "choice",
  price = "price",
  income = "income",
  alt.levels = NULL,
  drop.index = FALSE,
  subset = NULL,
  ...
)
```

Arguments

data	a 'data.frame',
id.var	the name of the variable that contains the individual index.
alt.var	the name of the variable that contains the alternative index or the name under which the alternative index will be stored (the default name is 'alt'),
choice	the variable indicating the consumption of non-numeraire alternatives that is made: it has to be a numerical vector. Default is "choice".
price	the variable indicating the price of the non-numeraire alternatives. Default is "price"

income	the variable indicating the income of the individual. Default is "income".
alt.levels	the name of the alternatives: if null, they are guessed from the 'alt.var' argument,
drop.index	should the index variables be dropped from the 'data.frame',
subset	a logical expression which defines the subset of observations to be selected,
...	further arguments.

Value

A 'mdcev.data' object, which is a 'data.frame' in long format, *i.e.* one line for each alternative. It has a 'index' attribute, which is a 'data.frame' that contains the index of the individual ('id') and the index of the alternative ('alt').

mdcev.sim	<i>mdcev.sim</i>
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Description

Simulate welfare or demand for MDCEV model

Usage

```
mdcev.sim(
  df_indiv,
  df_common,
  sim_options,
  sim_type = c("welfare", "demand"),
  nerrs = 30,
  cond_error = 1,
  draw_mlhs = 1,
  algo_gen = NULL,
  tol = 1e-20,
  max_loop = 999,
  suppressTime = FALSE,
  stan_seed = 3,
  ...
)

## S3 method for class 'mdcev.sim'
print(
  x,
  digits = max(3, getOption("digits") - 3),
  width = getOption("width"),
  ...
)

## S3 method for class 'mdcev.sim'
```

```
summary(object, ci = 0.95, ...)

## S3 method for class 'summary.mdcev.sim'
print(
  x,
  digits = max(3, getOption("digits") - 2),
  width = getOption("width"),
  ...
)
```

Arguments

<code>df_indiv</code>	Prepared individual level data from <code>PrepareSimulationData</code>
<code>df_common</code>	Prepared common data from <code>PrepareSimulationData</code>
<code>sim_options</code>	Prepared simulation options from <code>PrepareSimulationData</code>
<code>sim_type</code>	Either "welfare" or "demand"
<code>nerrs</code>	Number of error draws for welfare analysis
<code>cond_error</code>	Choose whether to draw errors conditional on actual demand or not. Conditional error draws (=1) or unconditional error draws.
<code>draw_mlhc</code>	Generate draws using Modified Latin Hypercube Sampling algorithm (=1) or uniform (=0)
<code>algo_gen</code>	Type of algorithm for simulation. <code>algo_gen = 0</code> for Hybrid Approach (i.e. constant alphas, only hybrid models) <code>algo_gen = 1</code> for General approach (i.e. heterogeneous alpha's, all models)
<code>tol</code>	Tolerance level for simulations if using general approach
<code>max_loop</code>	maximum number of loops for simulations if using general approach
<code>suppressTime</code>	Suppress simulation time calculation
<code>stan_seed</code>	Seed for pseudo-random number generator <code>get_rng</code> see <code>help(get_rng, package = "rstan")</code>
<code>...</code>	Additional parameters to pass to <code>mdcev.sim</code>
<code>x, object</code>	an object of class 'mdcev.sim'
<code>digits</code>	the number of digits,
<code>width</code>	the width of the printing,
<code>ci</code>	choose confidence interval for simulations. Default is 95 percent.

Value

a object of class `mdcev.sim` which contains a list for each individual holding either 1) `nsims x npols` matrix of welfare changes if welfare is being simulated or 2) `nsims` number of lists of `npols x #` alternatives matrix of Marshallian demands is demand is being simulated.

See Also

[`mdcev()`] for the estimation of `mdcev` models.

Examples

```

data(data_rec, package = "rmdcev")

data_rec <- mdcev.data(data_rec, subset = id <= 500, id.var = "id",
  alt.var = "alt", choice = "quant")

mdcev_est <- mdcev(~ 0, data = data_rec,
  model = "hybrid0", algorithm = "MLE",
  std_errors = "mvn")

policies <- CreateBlankPolicies(npols = 2,
  mdcev_est,
  price_change_only = TRUE)

df_sim <- PrepareSimulationData(mdcev_est, policies)

wtp <- mdcev.sim(df_sim$df_indiv,
  df_common = df_sim$df_common,
  sim_options = df_sim$sim_options,
  cond_err = 1, nerrs = 5, sim_type = "welfare")

```

PrepareSimulationData *PrepareSimulationData*

Description

Prepare Data for WTP simulation

Usage

```
PrepareSimulationData(object, policies, nsims = 30, class = "class1")
```

Arguments

object	an object of class ‘mdcev’
policies	list containing price_p with additive price increases, and dat_psi_p with new psi data
nsims	Number of simulation draws to use for parameter uncertainty
class	The class number for Latent Class models.

Value

A list with individual-specific data (df_indiv) and common data (df_common) and n_classes for number of classes and model_num for model type

Examples

```
data(data_rec, package = "rmdcev")

data_rec <- mdcev.data(data_rec, subset = id <= 500, id.var = "id",
  alt.var = "alt", choice = "quant")

mdcev_est <- mdcev( ~ 0, data = data_rec,
  model = "hybrid0", algorithm = "MLE",
  std_errors = "mvn")

policies <- CreateBlankPolicies(npols = 2, mdcev_est,
  price_change_only = TRUE)

df_sim <- PrepareSimulationData(mdcev_est, policies)
```

rmdcev	<i>rmdcev: Estimating and simulating Kuhn-Tucker and multiple discrete-continuous extreme value (MDCEV) demand models</i>
--------	---

Description

The `rmdcev` R package estimate and simulates Kuhn-Tucker demand models with individual heterogeneity. The models supported by `rmdcev` are the multiple-discrete continuous extreme value (MDCEV) model and Kuhn-Tucker specification common in the environmental economics literature on recreation demand. Latent class and random parameters specifications can be implemented and the models are fit using maximum likelihood estimation or Bayesian estimation. All models are implemented in Stan, which is a C++ package for performing full Bayesian inference (see Stan Development Team, 2019) <<https://mc-stan.org/>>. The `rmdcev` package also implements demand forecasting (Pinjari and Bhat (2011) <<https://repositories.lib.utexas.edu/handle/2152/23880>>) and welfare calculation (Lloyd-Smith (2018) <doi.org/10.1016/j.jocm.2017.12.002>) for policy simulation.

Author(s)

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References

Bhat, CR (2008). The multiple discrete-continuous extreme value (MDCEV) model: Role of utility function parameters, identification considerations, and model extensions. *Transportation Research Part B: Methodological*, 42(3): 274-303. [\(link\)](#) Lloyd-Smith, P (2018). A new approach to calculating welfare measures in Kuhn-Tucker demand models. *Journal of Choice Modeling* 26:19–27. [\(link\)](#) Pinjari, AR, Bhat, CR (2011). Computationally Efficient Forecasting Procedures for Kuhn-Tucker Consumer Demand Model Systems: Application to Residential Energy Consumption Analysis. Department of Civil and Environmental Engineering, University of South Florida. [\(link\)](#) Stan Development Team (2019). RStan: the R interface to Stan. R package version 2.19.2. [\(link\)](#)

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