Package ‘bqror’

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Type Package

Title Bayesian Quantile Regression for Ordinal Models

Version 1.2.0

Imports MASS, pracma, tcltk, GIGrvg, truncnorm, NPflow, invgamma, graphics, stats

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Description Provides functions for estimating Bayesian quantile regression for ordinal models, calculating covariate effects, and computing measures for model comparision. Specifically, the package offers two estimation functions - one for an ordinal model with more than three outcomes. For each ordinal model, the package provides functions to calculate the covariate effect using the MCMC outputs. The package also computes marginal likelihood (recommended) and the Deviance Information Criterion (DIC) for comparing alternative quantile regression models. Besides, the package also contains functions for making trace plots of MCMC draws and other functions that aids the estimation or inference of quantile ordinal models.
Rahman, M. A. (2016).“Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, II(I): 1-24 <doi:10.1214/15-BA939>.
Yu, K., and Moyeed, R. A. (2001). “Bayesian Quantile Regression.” Statistics and Probability Letters, 54(4): 437–447 <doi:10.1016/S0167-7152(01)00124-9>.
Koenker, R., and Bassett, G. (1978).“Regression Quantiles.” Econometrica, 46(1): 33-50 <doi:10.2307/1913643>.
Chib, S. (1995). “Marginal likelihood from the Gibbs output.” Journal of the American Statistical Association, 90(432):1313–1321, 1995. <doi:10.1080/01621459.1995.10476635>.
Chib, S., and Jeliazkov, I. (2001). “Marginal likelihood from the Metropolis-Hastings output.” Journal of the American Statistical Association, 96(453):270–281, 2001. <doi:10.1198/016214501750332848>.

License GPL (>= 2)

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Depends R (>= 3.5.0)

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R topics documented:

alcdf — *Asymmetric Laplace distribution*

Description

This function computes the cumulative distribution function (CDF) of an asymmetric Laplace distribution.

Usage

```
alcdf(x, mu, sigma, p)
```

Arguments

`x`	scalar value.
`mu`	location parameter of ALD.
`sigma`	scale parameter of ALD.
`p`	quantile or skewness parameter, p in (0,1).

Details

Computes the cumulative distribution function of the asymmetric Laplace distribution.

$$CDF(x) = F(x) = P(X \leq x)$$

where X is a random variable

Value

Returns a scalar with cumulative probability value at point “x”.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Yu, K., and Zhang, J. (2005). “A Three-Parameter Asymmetric Laplace Distribution.” Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

cumulative distribution function, asymmetric Laplace distribution

Examples

```
set.seed(101)
x <- -0.5428573
mu <- 0.5
sigma <- 1
p <- 0.25
output <- alcdf(x, mu, sigma, p)

# output
#   0.1143562
```

`alcdfstd` *CDF of standard asymmetric Laplace distribution*

Description

This function computes the CDF of standard asymmetric Laplace distribution i.e. AL$(0, 1, p)$.

Usage

```
alcdfstd(x, p)
```

Arguments

x	scalar value.
p	quantile level or skewness parameter, p in (0,1).

Details

Computes the CDF of a standard asymmetric Laplace distribution.

$$CDF(x) = F(x) = P(X \leq x)$$

where X is a random variable that follows AL$(0, 1, p)$.

Value

Returns the cumulative probability value from the CDF of an asymmetric Laplace distribution.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Yu, K., and Zhang, J. (2005). “A Three-Parameter Asymmetric Laplace Distribution.” Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

asymmetric Laplace distribution

Examples

```
set.seed(101)
x <-  -0.5428573
p <- 0.25
output <- alcdfstd(x, p)

# output
#   0.1663873
```

---

bqror — *Bayesian quantile regression for ordinal models*

Description

Provides functions for estimating Bayesian quantile regression for ordinal models, calculating covariate effects, and computing measures for model comparison. Specifically, the package offers two estimation functions - one for an ordinal model with more than three outcomes. For each ordinal model, the package provides functions to calculate the covariate effect using the MCMC outputs. The package also computes marginal likelihood (recommended) and the Deviance Information Criterion (DIC) for comparing alternative quantile regression models. Besides, the package also contains functions for making trace plots of MCMC draws and other functions that aids the estimation or inference of quantile ordinal models.

Details

$$Package : bqror$$

$$Type : Package$$

$$Version : 1.2.0$$

$$License : GPL(>= 2)$$

Package **bqror** provides the following functions:

- For an Ordinal Model with three outcomes:

`quantreg_or2`, `drawlatent_or2`, `drawbeta_or2`, `drawsigma_or2`, `drawnu_or2`, `deviance_or2`, `qrnegLogLike_or2`, `rndald`, `traceplot_or2`, `infactor_or2`, `covariateEffect_or2`,`logMargLikelihood_or2`

- For an Ordinal Model with more than three outcomes:

`quantreg_or1`, `qrminfundtheorem`, `qrnegLogLikensum_or1`, `drawbeta_or1`, `draww_or1`, `drawlatent_or1`, `drawdelta_or1`, `deviance_or1`, `alcdfstd`, `alcdf`, `traceplot_or1`, `infactor_or1`, `covariateEffect_or1`, `logMargLikelihood_or1`

Author(s)

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References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Yu, K., and Moyeed, R. A. (2001). “Bayesian Quantile Regression.” Statistics and Probability Letters, 54(4): 437–447. DOI: 10.1016/S0167-7152(01)00124-9

Koenker, R., and Bassett, G. (1978).“Regression Quantiles.” Econometrica, 46(1): 33-50. DOI: 10.2307/1913643

Greenberg, E. (2012). “Introduction to Bayesian Econometrics.” Cambridge University Press. Cambridge, DOI: 10.1017/CBO9781139058414

See Also

rgig, mvrnorm, ginv, rtruncnorm, mvnpdf, rinvgamma, mldivide, rand, qnorm, rexp, rnorm, std, sd, acf, Reshape, setTkProgressBar, tkProgressBar, dinvgamma

---

`covariateEffect_or1` *Covariate effect for Bayesian quantile regression for ordinal quantile model with more than 3 outcomes*

Description

This function computes the average covariate effect for different outcomes of the ORI model at the specified quantiles. The covariate effects are calculated marginally of the parameters and the remaining covariates.

Usage

```
covariateEffect_or1(model, y, x, modX, p)
```

Arguments

`model`	outcome of the ORI (quantreg_or1) model.
`y`	observed ordinal outcomes, column vector of dimension $(nx1)$.
`x`	covariate matrix of dimension (nxk) including a column of ones with or without column names. If the covariate of interest is continuous, then the column for the covariate of interest remains unchanged. If it is an indicator variable then replace the column for the covariate of interest with a column of zeros.

modX	matrix x with suitable modification to an independent variable including a column of ones with or without column names. If the covariate of interest is continuous, then add the incremental change to each observation in the column for the covariate of interest. If the covariate is an indicator variable, then replace the column for the covariate of interest with a column of ones.
p	quantile level or skewness parameter, p in (0,1).

Details

This function computes the average covariate effect for different outcomes of the ORI model at the specified quantiles. The covariate effects are calculated marginally of the parameters and the remaining covariates. The computation of covariate effects utilizes the MCMC outputs from estimation.

Value

Returns a list with components:

- avgDiffProb: vector with change in predicted probabilities for each outcome category.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Jeliazkov, I., Graves, J., and Kutzbach, M. (2008). “Fitting and Comparison of Models for Multivariate Ordinal Outcomes.” Advances in Econometrics: Bayesian Econometrics, 23: 115–156. DOI: 10.1016/S0731-9053(08)23004-5

Jeliazkov, I. and Rahman, M. A. (2012). “Binary and Ordinal Data Analysis in Economics: Modeling and Estimation” in Mathematical Modeling with Multidisciplinary Applications, edited by X.S. Yang, 123-150. John Wiley & Sons Inc, Hoboken, New Jersey. DOI: 10.1002/9781118462706.ch6

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
k <- dim(x)[2]
J <- dim(as.array(unique(y)))[1]
D0 <- 0.25*diag(J - 2)
output <- quantreg_or1(y = y,x = x, B0 = 10*diag(k), D0 = D0,
mcmc = 50, p = 0.25, tune = 1, display = FALSE)
modX <- x
modX[,3] <- modX[,3] + 0.02
res <- covariateEffect_or1(output, y, x, modX, p = 0.25)

# Summary of Covariate Effect:

#               Covariate Effect
# Category_1          -0.0073
```

```
# Category_2          -0.0015
# Category_3          -0.0010
# Category_4           0.0098
```

`covariateEffect_or2` *Covariate effect for Bayesian quantile regression for ordinal quantile model with 3 outcomes*

Description

This function computes the average covariate effect for different outcomes of the ORII model at the specified quantiles. The covariate effects are calculated marginally of the parameters and the remaining covariates.

Usage

```
covariateEffect_or2(model, y, x, modX, gamma, p)
```

Arguments

`model`	outcome of the ORII (quantreg_or2) model.
`y`	observed ordinal outcomes, column vector of dimension $(nx1)$.
`x`	covariate matrix of dimension (nxk) including a column of ones with or without column names. If the covariate of interest is continuous, then the column for the covariate of interest remains unchanged. If it is an indicator variable then replace the column for the covariate of interest with a column of zeros.
`modX`	matrix x with suitable modification to an independent variable including a column of ones with or without column names. If the covariate of interest is continuous, then add the incremental change to each observation in the column for the covariate of interest. If the covariate is an indicator variable, then replace the column for the covariate of interest with a column of ones.
`gamma`	one and only cut-point other than 0.
`p`	quantile level or skewness parameter, p in (0,1).

Details

This function computes the average covariate effect for different outcomes of the ORII model at the specified quantiles. The covariate effects are calculated marginally of the parameters and the remaining covariates. The computation of covariate effects utilizes the MCMC outputs from estimation.

Value

Returns a list with components:

- `avgDiffProb`: vector with change in predicted probabilities for each outcome category.

References

Rahman, M. A. (2016). "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Jeliazkov, I., Graves, J., and Kutzbach, M. (2008). "Fitting and Comparison of Models for Multivariate Ordinal Outcomes." Advances in Econometrics: Bayesian Econometrics, 23: 115–156. DOI: 10.1016/S0731-9053(08)23004-5

Jeliazkov, I., and Rahman, M. A. (2012). "Binary and Ordinal Data Analysis in Economics: Modeling and Estimation" in Mathematical Modeling with Multidisciplinary Applications, edited by X.S. Yang, 123-150. John Wiley & Sons Inc, Hoboken, New Jersey. DOI: 10.1002/9781118462706.ch6

Examples

```
set.seed(101)
data("data25j3")
x <- data25j3$x
y <- data25j3$y
k <- dim(x)[2]
output <- quantreg_or2(y, x, b0 = 0, B0 = 10*diag(k), n0 = 5, d0 = 8, gamma = 3,
mcmc = 50, p = 0.25, display = FALSE)
modX <- x
modX[,3] <- modX[,3] + 0.02
res <- covariateEffect_or2(output, y, x, modX, gamma = 3, p = 0.25)

# Summary of Covariate Effect:

#               Covariate Effect
# Category_1         -0.0074
# Category_2         -0.0029
# Category_3          0.0104
```

---

data25j3 *Data containing 500 observations generated from the quantile ordinal model with 3 outcomes and $p = 0.25$ (i.e., 25th quantile)*

Description

Data containing 500 observations generated from the quantile ordinal model with 3 outcomes and $p = 0.25$ (i.e., 25th quantile)

Usage

```
data(data25j3)
```

Details

This data contains 500 observations generated from the quantile ordinal model with 3 outcomes at the 25th quantile (i.e., $p = 0.25$). The model specifications for generating the data are as follows: $\beta = (-4, 6, 5)$, X ~ Unif(0, 1), and ϵ ~ AL$(0, \sigma = 1, p = 0.25)$.

The errors are generated from the asymmetric Laplace distribution using the normal exponential mixture formulation. The cut-points $(0, 3)$ are used to categorize the continuous values into 3 ordinal outcomes.

Value

Returns a list with components

- x: a matrix of covariates.
- y: a matrix of ordinal outcomes.

References

Kozumi, H., and Kobayashi, G. (2011). "Gibbs Sampling Methods for Bayesian Quantile Regression." Journal of Statistical Computation and Simulation, 81(11), 1565–1578. DOI: 10.1080/00949655.2010.496117

Yu, K., and Zhang, J. (2005). "A Three-Parameter Asymmetric Laplace Distribution." Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

mvrnorm, Asymmetric Laplace Distribution

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data25j4 *Data containing 500 observations generated from the quantile ordinal model with 4 outcomes and $p = 0.25$ (i.e., 25th quantile)*

Description

Data containing 500 observations generated from the quantile ordinal model with 4 outcomes and $p = 0.25$ (i.e., 25th quantile)

Usage

```
data(data25j4)
```

Details

This data contains 500 observations generated from the quantile ordinal model with more than 3 outcomes at the 25th quantile (i.e., $p = 0.25$). The model specifications for generating the data are as follows: $\beta = (-4, 5, 6)$, X ~ Unif(0, 1), and ϵ ~ AL$(0, \sigma = 1, p = 0.25)$.

The errors are generated from the asymmetric Laplace distribution using the normal exponential mixture formulation. The cut-points $(0, 2, 4)$ are used to categorize the continuous values into 4 ordinal outcomes.

Value

Returns a list with components

- x: a matrix of covariates.
- y: a matrix of ordinal outcomes.

References

Kozumi, H., and Kobayashi, G. (2011). “Gibbs Sampling Methods for Bayesian Quantile Regression.” Journal of Statistical Computation and Simulation, 81(11), 1565–1578. DOI: 10.1080/00949655.2010.496117

Yu, K., and Zhang, J. (2005). “A Three-Parameter Asymmetric Laplace Distribution.” Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

mvrnorm, Asymmetric Laplace Distribution

---

data50j3 — *Data containing 500 observations generated from the quantile ordinal model with 3 outcomes and $p = 0.5$ (i.e., 50th quantile)*

Description

Data containing 500 observations generated from the quantile ordinal model with 3 outcomes and $p = 0.5$ (i.e., 50th quantile)

Usage

```
data(data50j3)
```

Details

This data contains 500 observations generated from the quantile ordinal model with 3 outcomes at the 50th quantile (i.e., $p = 0.5$). The model specifications for generating the data are as follows: $\beta = (-4, 6, 5)$, X ~ Unif(0, 1), and ϵ ~ AL$(0, \sigma = 1, p = 0.5)$.

The errors are generated from the asymmetric Laplace distribution using the normal exponential mixture formulation. The cut-points $(0, 3)$ are used to categorize the continuous values into 3 ordinal outcomes.

Value

Returns a list with components

- x: a matrix of covariates.
- y: a matrix of ordinal outcomes.

References

Kozumi, H., and Kobayashi, G. (2011). "Gibbs Sampling Methods for Bayesian Quantile Regression." Journal of Statistical Computation and Simulation, 81(11), 1565–1578. DOI: 10.1080/00949655.2010.496117

Yu, K., and Zhang, J. (2005). "A Three-Parameter Asymmetric Laplace Distribution." Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

mvrnorm, Asymmetric Laplace Distribution

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data50j4 — *Data containing 500 observations generated from the quantile ordinal model with 4 outcomes and $p = 0.5$ (i.e., 50th quantile)*

Description

Data containing 500 observations generated from the quantile ordinal model with 4 outcomes and $p = 0.5$ (i.e., 50th quantile)

Usage

```
data(data50j4)
```

Details

This data contains 500 observations generated from the quantile ordinal model with more than 3 outcomes at the 50th quantile (i.e., $p = 0.5$). The model specifications for generating the data are as follows: $\beta = (-4, 5, 6)$, X ~ Unif(0, 1), and ϵ ~ AL$(0, \sigma = 1, p = 0.5)$.

The errors are generated from the asymmetric Laplace distribution using the normal exponential mixture formulation. The cut-points $(0, 2, 4)$ are used to categorize the continuous values into 4 ordinal outcomes.

Value

Returns a list with components

- `x`: a matrix of covariates.
- `y`: a matrix of ordinal outcomes.

References

Kozumi, H., and Kobayashi, G. (2011). "Gibbs Sampling Methods for Bayesian Quantile Regression." Journal of Statistical Computation and Simulation, 81(11), 1565–1578. DOI: 10.1080/00949655.2010.496117

Yu, K., and Zhang, J. (2005). "A Three-Parameter Asymmetric Laplace Distribution." Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

mvrnorm, Asymmetric Laplace Distribution

`data75j3` *Data containing 500 observations generated from the quantile ordinal model with 3 outcomes and $p = 0.75$ (i.e., 75th quantile)*

Description

Data containing 500 observations generated from the quantile ordinal model with 3 outcomes and $p = 0.75$ (i.e., 75th quantile)

Usage

```
data(data75j3)
```

Details

This data contains 500 observations generated from the quantile ordinal model with 3 outcomes at the 75th quantile (i.e., $p = 0.75$). The model specifications for generating the data are as follows: $\beta = (-4, 6, 5)$, X ~ Unif(0, 1), and ϵ ~ $\text{AL}(0, \sigma = 1, p = 0.75)$.

The errors are generated from the asymmetric Laplace distribution using the normal exponential mixture formulation. The cut-points $(0, 3)$ are used to categorize the continuous values into 3 ordinal outcomes.

Value

Returns a list with components

- `x`: a matrix of covariates.
- `y`: a matrix of ordinal outcomes.

References

Kozumi, H., and Kobayashi, G. (2011). "Gibbs Sampling Methods for Bayesian Quantile Regression." Journal of Statistical Computation and Simulation, 81(11), 1565–1578. DOI: 10.1080/00949655.2010.496117

Yu, K., and Zhang, J. (2005). "A Three-Parameter Asymmetric Laplace Distribution." Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

mvrnorm, Asymmetric Laplace Distribution `data75j4` *Data containing 500 observations generated from the quantile ordinal model with 4 outcomes and $p = 0.75$ (i.e., 75th quantile)*

Description

Data containing 500 observations generated from the quantile ordinal model with 4 outcomes and $p = 0.75$ (i.e., 75th quantile)

Usage

```
data(data75j4)
```

Details

This data contains 500 observations generated from the quantile ordinal model with more than 3 outcomes at the 75th quantile (i.e., $p = 0.75$). The model specifications for generating the data are as follows: $\beta = (-4, 5, 6)$, X ~ Unif(0, 1), and ϵ ~ AL$(0, \sigma = 1, p = 0.75)$.

The errors are generated from the asymmetric Laplace distribution using the normal exponential mixture formulation. The cut-points $(0, 2, 4)$ are used to categorize the continuous values into 4 ordinal outcomes.

Value

Returns a list with components

- `x`: a matrix of covariates.
- `y`: a matrix of ordinal outcomes.

References

Kozumi, H., and Kobayashi, G. (2011). "Gibbs Sampling Methods for Bayesian Quantile Regression." Journal of Statistical Computation and Simulation, 81(11), 1565–1578. DOI: 10.1080/00949655.2010.496117

Yu, K., and Zhang, J. (2005). "A Three-Parameter Asymmetric Laplace Distribution." Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

mvrnorm, Asymmetric Laplace Distribution `deviance_or1` *Deviance Information Criteria for ordinal quantile model with more than 3 outcomes*

Description

Function for computing the Deviance information criteria for ordinal quantile model with more than 3 outcomes.

Usage

```
deviance_or1(y, x, deltastore, burn, nsim, postMeanbeta, postMeandelta, beta, p)
```

Arguments

`y`	observed ordinal outcomes, column vector of dimension $(nx1)$.
`x`	covariate matrix of dimension (nxk) including a column of ones.
`deltastore`	MCMC draws of δ.
`burn`	number of discarded MCMC iterations.
`nsim`	total number of samples, including the burn-in.
`postMeanbeta`	mean value of β obtained from MCMC draws.
`postMeandelta`	mean value of δ obtained from MCMC draws.
`beta`	MCMC draw of coefficients, dimension is $(kxnsim)$.
`p`	quantile level or skewness parameter, p in (0,1).

Details

Deviance is $-2*(logLikelihood)$ and has an important role in statistical model comparison because of its relation with Kullback-Leibler information criteria.

Value

Returns a list with components

$$DIC = 2 * avgdDeviance - devpostmean$$

$$pd = avgdDeviance - devpostmean$$

$$devpostmean = -2 * (logLikelihood)$$

.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Spiegelhalter, D. J., Best, N. G., Carlin, B. P. and Linde, A. (2002). “Bayesian Measures of Model Complexity and Fit.” Journal of the Royal Statistical Society B, Part 4: 583-639. DOI: 10.1111/1467-9868.00353

Gelman, A., Carlin, J. B., Stern, H. S., and Rubin, D. B. “Bayesian Data Analysis.” 2nd Edition, Chapman and Hall. DOI: 10.1002/sim.1856

See Also

decision criteria

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
k <- dim(x)[2]
J <- dim(as.array(unique(y)))[1]
D0 <- 0.25*diag(J - 2)
output <- quantreg_or1(y = y,x = x, B0 = 10*diag(k), D0 = D0,
mcmc = 50, p = 0.25, tune = 1, display = FALSE)
mcmc <- 50
deltastore <- output$delta
burn <- 0.25*mcmc
nsim <- burn + mcmc
postMeanbeta <- output$postMeanbeta
postMeandelta <- output$postMeandelta
beta <- output$beta
deviance <- deviance_or1(y, x, deltastore, burn, nsim,
postMeanbeta, postMeandelta, beta, p = 0.25)

# DIC
#   1300.315
# pd
#   105.0351
# devpostmean
#   1090.245
```

---

deviance_or2 *Deviance Information Criteria for ordinal quantile model with 3 outcomes*

Description

Function for computing the Deviance information criteria for ordinal quantile model with 3 outcomes.

Usage

```
deviance_or2(y, x, gammacp, p, postMeanbeta, postStdbeta,
postMeansigma, postStdsigma, beta, sigma, burn, nsim)
```

Arguments

`y`	observed ordinal outcomes, column vector of dimension $(nx1)$.
`x`	covariate matrix of dimension (nxk) including a column of ones with or without column names.
`gammacp`	row vector of cut-points including -Inf and Inf.
`p`	quantile level or skewness parameter, p in (0,1).
`postMeanbeta`	mean value of β obtained from MCMC draws.
`postStdbeta`	standard deviation of β obtained from MCMC draws.
`postMeansigma`	mean value of σ obtained from MCMC draws.
`postStdsigma`	standard deviation of σ obtained from MCMC draws.
`beta`	MCMC draw of coefficients, dimension is $(kxnsim)$.
`sigma`	MCMC draw of scale factor, dimension is $(nsimx1)$.
`burn`	number of discarded MCMC iterations.
`nsim`	total number of MCMC iterations including the burn-in.

Details

Deviance is $-2*(logLikelihood)$ and has an important role in statistical model comparison because of its relation with Kullback-Leibler information criteria.

Value

Returns a list with components

$$DIC = 2 * avgdeviance - devpostmean$$

$$pd = avgdeviance - devpostmean$$

$$devpostmean = -2 * (logLikelihood)$$

.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Spiegelhalter, D. J., Best, N. G., Carlin, B. P. and Linde, A. (2002). “Bayesian Measures of Model Complexity and Fit.” Journal of the Royal Statistical Society B, Part 4: 583-639. DOI: 10.1111/1467-9868.00353

Gelman, A., Carlin, J. B., Stern, H. S., and Rubin, D. B. “Bayesian Data Analysis.” 2nd Edition, Chapman and Hall. DOI: 10.1002/sim.1856

See Also

decision criteria

Examples

```
set.seed(101)
data("data25j3")
x <- data25j3$x
y <- data25j3$y
k <- dim(x)[2]
output <- quantreg_or2(y = y, x = x, B0 = 10*diag(k),
mcmc = 50, p = 0.25, display = FALSE)
gammacp <- c(-Inf, 0, 3, Inf)
postMeanbeta <- output$postMeanbeta
postStdbeta <- output$postStdbeta
postMeansigma <- output$postMeansigma
postStdsigma <- output$postStdsigma
beta <- output$beta
sigma <- output$sigma
mcmc = 50
burn <- 10
nsim <- burn + mcmc
deviance <- deviance_or2(y, x, gammacp, p = 0.25, postMeanbeta, postStdbeta,
postMeansigma, postStdsigma, beta, sigma, burn, nsim)

# DIC
#   801.8191
# pd
#   6.608594
# devpostmean
#   788.6019
```

---

drawbeta_or1 *Samples β for ordinal quantile model with more than 3 outcomes*

Description

This function samples β from its conditional posterior distribution for ordinal quantile model with more than 3 outcomes i.e. ORI model.

Usage

```
drawbeta_or1(z, x, w, tau2, theta, invB0, invB0b0)
```

Arguments

`z`	dependent variable i.e. ordinal outcome values.
`x`	covariate matrix of dimension (nxk) including a column of ones.
`w`	latent weights, column vector.
`tau2`	2/(p(1-p)).
`theta`	(1-2p)/(p(1-p)).
`invB0`	inverse of prior covariance matrix of normal distribution.
`invB0b0`	prior mean pre-multiplied by invB0.

Details

Function samples a vector of β from a multivariate normal distribution.

Value

Returns a list with components

- `beta`: column vector of β from a multivariate normal distribution.
- `Btilde`: variance parameter for the normal distribution.
- `btilde`: mean parameter for the normal distribution.

References

Rahman, M. A. (2016). "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Casella, G., and George, E. I. (1992). "Explaining the Gibbs Sampler." The American Statistician, 46(3): 167-174. DOI: 10.1080/00031305.1992.10475878

Geman, S., and Geman, D. (1984). "Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images." IEEE Transactions an Pattern Analysis and Machine Intelligence, 6(6): 721-741. DOI: 10.1109/TPAMI.1984.4767596

See Also

Gibbs sampling, normal distribution, mvrnorm, inv

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
p <- 0.25
n <- dim(x)[1]
k <- dim(x)[2]
w <- array( (abs(rnorm(n, mean = 2, sd = 1))), dim = c (n, 1))
theta <- 2.666667
tau2 <- 10.66667
z <- array( (rnorm(n, mean = 0, sd = 1)), dim = c(n, 1))
b0 <- array(0, dim = c(k, 1))
B0 <- diag(k)
invB0 <- matrix(c(
     1, 0, 0,
     0, 1, 0,
     0, 0, 1),
     nrow = 3, ncol = 3, byrow = TRUE)
invB0b0 <- invB0 %*% b0
output <- drawbeta_or1(z, x, w, tau2, theta, invB0, invB0b0)

# output$beta
#   -0.2481837 0.7837995 -3.4680418
```

---

drawbeta_or2 *Samples β for ordinal quantile model with 3 outcomes*

Description

This function samples β from its conditional posterior distribution for ordinal quantile model with 3 outcomes i.e. ORII model.

Usage

```
drawbeta_or2(z, x, sigma, nu, tau2, theta, invB0, invB0b0)
```

Arguments

z	dependent variable i.e. ordinal outcome values.
x	covariate matrix of dimension (nxk) including a column of ones.
sigma	scale factor, a scalar value.
nu	modified scale factor, row vector.
tau2	2/(p(1-p)).
theta	(1-2p)/(p(1-p)).
invB0	inverse of prior covariance matrix of normal distribution.
invB0b0	prior mean pre-multiplied by invB0.

Details

Function samples a vector of β from a multivariate normal distribution.

Value

Returns a list with components

- `beta`: column vector of β from a multivariate normal distribution.
- `Btilde`: variance parameter for the normal distribution.
- `btilde`: mean parameter for the normal distribution.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Casella, G., and George, E. I. (1992). “Explaining the Gibbs Sampler.” The American Statistician, 46(3): 167-174. DOI: 10.1080/00031305.1992.10475878

Geman, S., and Geman, D. (1984). “Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images.” IEEE Transactions an Pattern Analysis and Machine Intelligence, 6(6): 721-741. DOI: 10.1109/TPAMI.1984.4767596

See Also

Gibbs sampling, normal distribution , rgig, inv

Examples

```
set.seed(101)
z <- c(21.01744, 33.54702, 33.09195, -3.677646,
 21.06553, 1.490476, 0.9618205, -6.743081, 21.02186, 0.6950479)
x <- matrix(c(
     1, -0.3010490, 0.8012506,
     1,  1.2764036, 0.4658184,
     1,  0.6595495, 1.7563655,
     1, -1.5024607, -0.8251381,
     1, -0.9733585, 0.2980610,
     1, -0.2869895, -1.0130274,
     1,  0.3101613, -1.6260663,
     1, -0.7736152, -1.4987616,
     1,  0.9961420, 1.2965952,
     1, -1.1372480, 1.7537353),
     nrow = 10, ncol = 3, byrow = TRUE)
sigma <- 1.809417
nu <- c(5, 5, 5, 5, 5, 5, 5, 5, 5, 5)
tau2 <- 10.6667
theta <- 2.6667
invB0 <- matrix(c(
     1, 0, 0,
     0, 1, 0,
     0, 0, 1),
```

```
     nrow = 3, ncol = 3, byrow = TRUE)
invB0b0 <- c(0, 0, 0)

output <- drawbeta_or2(z, x, sigma, nu, tau2, theta, invB0, invB0b0)

# output$beta
#   -0.74441 1.364846 0.7159231
```

---

drawdelta_or1   *Samples δ for ordinal quantile model with more than 3 outcomes*

Description

This function samples the δ using a random-walk Metropolis-Hastings algorithm for ordinal quantile model with more than 3 outcomes.

Usage

```
drawdelta_or1(y, x, beta, delta0, d0, D0, tune, Dhat, p)
```

Arguments

y	observed ordinal outcomes, column vector of dimension $(nx1)$.
x	covariate matrix of dimension (nxk) including a column of ones.
beta	Gibbs draw of coefficients of dimension $(kx1)$.
delta0	initial value for δ.
d0	prior mean of normal distribution.
D0	prior variance for normal distribution to sample δ.
tune	tuning parameter to adjust MH acceptance rate.
Dhat	negative inverse Hessian from maximization of log-likelihood.
p	quantile level or skewness parameter, p in (0,1).

Details

Samples the δ using a random-walk Metropolis-Hastings algorithm.

Value

Returns a list with components

- `deltaReturn`: vector with δ values using MH algorithm.
- `accept`: indicator for acceptance of proposed value of δ.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Chib, S., and Greenberg, E. (1995). “Understanding the Metropolis-Hastings Algorithm.” The American Statistician, 49(4): 327-335. DOI: 10.2307/2684568

Hastings, W. K. (1970). “Monte Carlo Sampling Methods Using Markov Chains and Their Applications.” Biometrika, 57: 1317-1340. DOI: 10.2307/1390766

Jeliazkov, I., Graves, J., and Kutzbach, M. (2008). “Fitting and Comparison of Models for Multivariate Ordinal Outcomes.” Advances in Econometrics: Bayesian Econometrics, 23: 115–156. DOI: 10.1016/S0731-9053(08)23004-5

Jeliazkov, I., and Rahman, M. A. (2012). “Binary and Ordinal Data Analysis in Economics: Modeling and Estimation” in Mathematical Modeling with Multidisciplinary Applications, edited by X.S. Yang, 123-150. John Wiley & Sons Inc, Hoboken, New Jersey. DOI: 10.1002/9781118462706.ch6

See Also

NPflow, Gibbs sampling, mvnpdf

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
p <- 0.25
beta <- c(0.3990094, 0.8168991, 2.8034963)
delta0 <- c(-0.9026915, -2.2488833)
d0 <- matrix(c(0, 0),
                 nrow = 2, ncol = 1, byrow = TRUE)
D0 <- matrix(c(0.25, 0.00, 0.00, 0.25),
                    nrow = 2, ncol = 2, byrow = TRUE)
tune <- 0.1
Dhat <- matrix(c(0.046612180, -0.001954257, -0.001954257, 0.083066204),
             nrow = 2, ncol = 2, byrow = TRUE)
p <- 0.25
output <- drawdelta_or1(y, x, beta, delta0, d0, D0, tune, Dhat, p)

# deltareturn
#   -0.9025802 -2.229514
# accept
#   1
```

drawlatent_or1 — *Samples the latent variable z for ordinal quantile model with more than 3 outcomes*

Description

This function samples the latent variable z from a truncated normal distribution for ordinal quantile model with more than 3 outcomes.

Usage

```
drawlatent_or1(y, x, beta, w, theta, tau2, delta)
```

Arguments

`y`	observed ordinal outcomes, column vector of dimension $(nx1)$.
`x`	covariate matrix of dimension (nxk) including a column of ones.
`beta`	Gibbs draw of coefficients of dimension $(kx1)$.
`w`	latent weights vector.
`theta`	(1-2p)/(p(1-p)).
`tau2`	2/(p(1-p)).
`delta`	row vector of cutpoints including -Inf and Inf.

Details

Function samples the latent variable z from a truncated normal distribution.

Value

column vector of values for latent variable, z.

References

Albert, J., and Chib, S. (1993). "Bayesian Analysis of Binary and Polychotomous Response Data." Journal of the American Statistical Association, 88(422): 669–679. DOI: 10.1080/01621459.1993.10476321

Casella, G., and George, E. I. (1992). "Explaining the Gibbs Sampler." The American Statistician, 46(3): 167-174. DOI: 10.1080/00031305.1992.10475878

Geman, S., and Geman, D. (1984). "Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images." IEEE Transactions an Pattern Analysis and Machine Intelligence, 6(6): 721-741. DOI: 10.1109/TPAMI.1984.4767596

Robert, C. P. (1995). "Simulation of truncated normal variables." Statistics and Computing, 5: 121–125. DOI: 10.1007/BF00143942

See Also

Gibbs sampling, truncated normal distribution, rtruncnorm

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
p <- 0.25
beta <- c(0.3990094, 0.8168991, 2.8034963)
w <- 1.114347
theta <- 2.666667
tau2 <- 10.66667
delta <- c(-0.002570995,  1.044481071)
output <- drawlatent_or1(y, x, beta, w, theta, tau2, delta)

# output
#   0.6261896 3.129285 2.659578 8.680291
#   13.22584 2.545938 1.507739 2.167358
#   15.03059 -3.963201 9.237466 -1.813652
#   2.718623 -3.515609 8.352259 -0.3880043
#   -0.8917078 12.81702 -0.2009296 1.069133 ... soon
```

---

drawlatent_or2 — *Samples the latent variable z for ordinal quantile model with 3 outcomes*

Description

This function samples the latent variable z from a truncated normal distribution for ordinal quantile model with 3 outcomes.

Usage

```
drawlatent_or2(y, x, beta, sigma, nu, theta, tau2, gammacp)
```

Arguments

y	observed ordinal outcomes, column vector of dimension $(nx1)$.
x	covariate matrix of dimension (nxk) including a column of ones.
beta	column vector of coefficients of dimension $(kx1)$.
sigma	scale factor, a scalar value.
nu	modified scale factor, row vector.
theta	(1-2p)/(p(1-p)).
tau2	2/(p(1-p)).
gammacp	row vector of cut-points including -Inf and Inf.

Details

Function samples the latent variable z from a truncated normal distribution.

Value

Returns a column vector of values for latent variable z.

References

Albert, J., and Chib, S. (1993). "Bayesian Analysis of Binary and Polychotomous Response Data." Journal of the American Statistical Association, 88(422): 669–679. DOI: 10.1080/01621459.1993.10476321

Casella, G., and George, E. I. (1992). "Explaining the Gibbs Sampler." The American Statistician, 46(3): 167-174. DOI: 10.1080/00031305.1992.10475878

Geman, S., and Geman, D. (1984). "Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images." IEEE Transactions an Pattern Analysis and Machine Intelligence, 6(6): 721-741. DOI: 10.1109/TPAMI.1984.4767596

Robert, C. P. (1995). "Simulation of truncated normal variables." Statistics and Computing, 5: 121–125. DOI: 10.1007/BF00143942

See Also

Gibbs sampling, truncated normal distribution, rtruncnorm

Examples

```
set.seed(101)
data("data25j3")
x <- data25j3$x
y <- data25j3$y
beta <- c(1.810504, 1.850332, 6.181163)
sigma <- 0.9684741
nu <- c(5, 5, 5, 5, 5, 5, 5, 5, 5, 5)
theta <- 2.6667
tau2 <- 10.6667
gammacp <- c(-Inf, 0, 3, Inf)
output <- drawlatent_or2(y, x, beta, sigma, nu,
theta, tau2, gammacp)

# output
#   1.257096 10.46297 4.138694
#   28.06432 4.179275 19.21582
#   11.17549 13.79059 28.3650 .. soon
```

drawnu_or2 *Samples the scale factor ν for ordinal quantile model with 3 outcomes*

Description

This function samples the ν from a generalized inverse Gaussian (GIG) distribution for ordinal quantile model with 3 outcomes.

Usage

```
drawnu_or2(z, x, beta, sigma, tau2, theta, lambda)
```

Arguments

`z`	Gibbs draw of latent response variable, a column vector.
`x`	covariate matrix of dimension (nxk) including a column of ones.
`beta`	Gibbs draw of coefficients of dimension $(kx1)$.
`sigma`	scale factor, a scalar.
`tau2`	2/(p(1-p)).
`theta`	(1-2p)/(p(1-p)).
`lambda`	index parameter of GIG distribution which is equal to 0.5.

Details

Function samples the ν from a GIG distribution.

Value

Returns a row vector of the ν from GIG distribution.

References

Rahman, M. A. (2016), "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1), 1-24. DOI: 10.1214/15-BA939

Devroye, L. (2014). "Random variate generation for the generalized inverse Gaussian distribution." Statistics and Computing, 24(2): 239–246. DOI: 10.1007/s11222-012-9367-z

See Also

GIGrvg, Gibbs sampling, rgig

Examples

```
set.seed(101)
z <- c(21.01744, 33.54702, 33.09195, -3.677646,
 21.06553, 1.490476, 0.9618205, -6.743081, 21.02186, 0.6950479)
x <- matrix(c(
     1, -0.3010490, 0.8012506,
     1,  1.2764036, 0.4658184,
     1,  0.6595495, 1.7563655,
     1, -1.5024607, -0.8251381,
     1, -0.9733585, 0.2980610,
     1, -0.2869895, -1.0130274,
     1,  0.3101613, -1.6260663,
     1, -0.7736152, -1.4987616,
     1, 0.9961420, 1.2965952,
     1, -1.1372480, 1.7537353),
     nrow = 10, ncol = 3, byrow = TRUE)
beta <- c(-0.74441, 1.364846, 0.7159231)
sigma <- 3.749524
tau2 <- 10.6667
theta <- 2.6667
lambda <- 0.5
output <- drawnu_or2(z, x, beta, sigma, tau2, theta, lambda)

# output
#   5.177456 4.042261 8.950365
#   1.578122 6.968687 1.031987
#   4.13306 0.4681557 5.109653
#   0.1725333
```

`drawsigma_or2` *Samples the σ for ordinal quantile model with 3 outcomes*

Description

This function samples the σ from an inverse-gamma distribution for ordinal quantile model with 3 outcomes.

Usage

```
drawsigma_or2(z, x, beta, nu, tau2, theta, n0, d0)
```

Arguments

`z`	Gibbs draw of latent response variable, a column vector.
`x`	covariate matrix of dimension (nxk) including a column of ones.
`beta`	Gibbs draw of coefficients of dimension $(kx1)$.
`nu`	modified scale factor, row vector.

`tau2`	2/(p(1-p)).
`theta`	(1-2p)/(p(1-p)).
`n0`	prior hyper-parameter for σ.
`d0`	prior hyper-parameter for σ.

Details

Function samples the σ from an inverse gamma distribution.

Value

Returns a list with components

- `sigma`: column vector of the σ from an inverse gamma distribution.
- `dtilde`: scale parameter for the inverse gamma distribution.

References

Albert, J., and Chib, S. (1993). "Bayesian Analysis of Binary and Polychotomous Response Data." Journal of the American Statistical Association, 88(422): 669–679. DOI: 10.1080/01621459.1993.10476321

Casella, G., and George, E. I. (1992). "Explaining the Gibbs Sampler." The American Statistician, 46(3): 167-174. DOI: 10.1080/00031305.1992.10475878

Geman, S., and Geman, D. (1984). "Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images." IEEE Transactions an Pattern Analysis and Machine Intelligence, 6(6): 721-741. DOI: 10.1109/TPAMI.1984.4767596

See Also

rgamma, Gibbs sampling

Examples

```
set.seed(101)
z <- c(21.01744, 33.54702, 33.09195, -3.677646,
 21.06553, 1.490476, 0.9618205, -6.743081, 21.02186, 0.6950479)
x <- matrix(c(
     1, -0.3010490, 0.8012506,
     1,  1.2764036, 0.4658184,
     1,  0.6595495, 1.7563655,
     1, -1.5024607, -0.8251381,
     1, -0.9733585, 0.2980610,
     1, -0.2869895, -1.0130274,
     1,  0.3101613, -1.6260663,
     1, -0.7736152, -1.4987616,
     1,  0.9961420, 1.2965952,
     1, -1.1372480, 1.7537353),
     nrow = 10, ncol = 3, byrow = TRUE)
beta <- c(-0.74441, 1.364846, 0.7159231)
nu <- c(5, 5, 5, 5, 5, 5, 5, 5, 5, 5)
tau2 <- 10.6667
```

```
theta <- 2.6667
n0 <- 5
d0 <- 8
output <- drawsigma_or2(z, x, beta, nu, tau2, theta, n0, d0)

# output$sigma
#   3.749524
```

---

draww_or1 *Samples the latent weight w for ordinal quantile model with more than 3 outcomes*

Description

This function samples the latent weight w from a generalized inverse-Gaussian distribution (GIG) for ordinal quantile model with more than 3 outcomes.

Usage

```
draww_or1(z, x, beta, tau2, theta, lambda)
```

Arguments

z	Gibbs draw of latent response variable, a column vector.
x	covariate matrix of dimension (nxk) including a column of ones.
beta	Gibbs draw of coefficients of dimension $(kx1)$.
tau2	2/(p(1-p)).
theta	(1-2p)/(p(1-p)).
lambda	index parameter of GIG distribution which is equal to 0.5

Details

Function samples a vector of the latent weight w from a GIG distribution.

Value

column vector of w from a GIG distribution.

References

Albert, J., and Chib, S. (1993). “Bayesian Analysis of Binary and Polychotomous Response Data.” Journal of the American Statistical Association, 88(422): 669–679. DOI: 10.1080/01621459.1993.10476321

Casella, G., and George, E. I. (1992). “Explaining the Gibbs Sampler.” The American Statistician, 46(3): 167-174. DOI: 10.1080/00031305.1992.10475878

Geman, S., and Geman, D. (1984). “Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images.” IEEE Transactions an Pattern Analysis and Machine Intelligence, 6(6): 721-741. DOI: 10.1109/TPAMI.1984.4767596

See Also

GIGrvg, Gibbs sampling, rgig

Examples

```
set.seed(101)
z <- c(0.9812363, -1.09788, -0.9650175, 8.396556,
 1.39465, -0.8711435, -0.5836833, -2.792464,
 0.1540086, -2.590724, 0.06169976, -1.823058,
 0.06559151, 0.1612763, 0.161311, 4.908488,
 0.6512113, 0.1560708, -0.883636, -0.5531435)
x <- matrix(c(
     1, 1.4747905363, 0.167095186,
     1, -0.3817326861, 0.041879526,
     1, -0.1723095575, -1.414863777,
     1, 0.8266428137, 0.399722073,
     1, 0.0514888733, -0.105132425,
     1, -0.3159992662, -0.902003846,
     1, -0.4490888878, -0.070475600,
     1, -0.3671705251, -0.633396477,
     1, 1.7655601639, -0.702621934,
     1, -2.4543678120, -0.524068780,
     1,  0.3625025618,  0.698377504,
     1, -1.0339179063,  0.155746376,
     1,  1.2927374692, -0.155186911,
     1, -0.9125108094, -0.030513775,
     1,  0.8761233001,  0.988171587,
     1,  1.7379728231,  1.180760114,
     1,  0.7820635770, -0.338141095,
     1, -1.0212853209, -0.113765067,
     1,  0.6311364051, -0.061883874,
     1,  0.6756039688,  0.664490143),
     nrow = 20, ncol = 3, byrow = TRUE)
beta <- c(-1.583533, 1.407158, 2.259338)
tau2 <- 10.66667
theta <- 2.666667
lambda <- 0.5
output <- draww_or1(z, x, beta, tau2, theta, lambda)

# output
#   0.16135732
#   0.39333080
#   0.80187227
#   2.27442898
#   0.90358310
#   0.99886987
#   0.41515947 ... soon
```

`Educational_Attainment` *The data consists of information on educational attainment and other variables for 3,923 individuals and is taken from the National Longitudinal Study of Youth (NLSY, 1979) survey.*

Description

The data consists of information on educational attainment and other variables for 3,923 individuals and is taken from the National Longitudinal Study of Youth (NLSY, 1979) survey.

Usage

```
data(Educational_Attainment)
```

Details

The data is taken from the National Longitudinal Study of Youth (NLSY, 1979) survey and corresponds to 3,923 individuals. The objective is to study the effect of family background, individual and school level variable on the quantiles of educational attainment. The dependent variable i.e. the educational degree, has four categories given as less than high school, high school degree, some college or associate's degree and college or graduate degree. The independent variables include intercept, square root of family income, mother's education, father's education, mother's working status, gender, race, and whether the youth lived in an urban area at the age o, and indicator variables to control for age-cohort effects.

Value

Returns data with components

- `mother_work`: Indicator for working female at age of 14.
- `urban`: Indicator for the youth living in urban are at age of 14.
- `south`: Indicator for the youth living in South at age of 14.
- `father_educ`: Years of individual's father education.
- `mother_educ`: Years of individual's mother education.
- `fam_income`: Family income of the household in $1000.
- `female`: Indicator for individual's gender.
- `black`: Indicator for black race.
- `age_cohort_2`: Indicator for age of 15.
- `age_cohort_3`: Indicator for age of 16.
- `age_cohort_4`: Indicator for age of 17.
- `dep_edu_level`: matrix of ordinal outcomes.

References

Rahman, M. A. (2016). "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Jeliazkov, I., Graves, J., and Kutzbach, M. (2008). "Fitting and Comparison of Models for Multivariate Ordinal Outcomes." Advances in Econometrics: Bayesian Econometrics, 23: 115–156. DOI: 10.1016/S0731-9053(08)23004-5

Jeliazkov, I., and Rahman, M. A. (2012). "Binary and Ordinal Data Analysis in Economics: Modeling and Estimation" in Mathematical Modeling with Multidisciplinary Applications, edited by X.S. Yang, 123-150. John Wiley & Sons Inc, Hoboken, New Jersey. DOI: 10.1002/9781118462706.ch6

See Also

NLSY, Survey Process.

`infactor_or1` *Inefficiency factor for ordinal quantile model with more than 3 outcomes*

Description

This function calculates the inefficiency factor from the MCMC draws of (β, δ) for ordinal quantile model with more than 3 outcomes. The inefficiency factor is calculated using the batch-means method.

Usage

```
infactor_or1(x, beta, delta, autocorrelationCutoff)
```

Arguments

`x`	covariate matrix of dimension (nxk) including a column of ones with or without column names.
`beta`	Gibbs draw of coefficients of dimension $(kxnsim)$.
`delta`	Gibbs draw of cut-points.
`autocorrelationCutoff`	cut-off to identify the number of lags.

Details

Calculates the inefficiency factor of (β, δ) using the batch-means method.

Value

Returns a list with components

- `inefficiencyDelta`: vector with inefficiency factor for each δ.
- `inefficiencyBeta`: vector with inefficiency factor for each β.

References

Greenberg, E. (2012). “Introduction to Bayesian Econometrics.” Cambridge University Press, Cambridge. DOI: 10.1017/CBO9780511808920

See Also

pracma, acf

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
k <- dim(x)[2]
J <- dim(as.array(unique(y)))[1]
D0 <- 0.25*diag(J - 2)
output <- quantreg_or1(y = y,x = x, B0 = 10*diag(k), D0 = D0,
mcmc = 50, p = 0.25, tune = 1, display = FALSE)
beta <- output$beta
delta <- output$delta
inefficiency <- infactor_or1(x, beta, delta, 0.5)

# Summary of Inefficiency Factor:

#            Inefficiency
# beta_0       0.9162
# beta_1       3.3121
# beta_2       3.1145
# delta_1      3.9862
# delta_2      3.1477
```

---

infactor_or2 — *Inefficiency factor for ordinal quantile model with 3 outcomes*

Description

This function calculates the inefficiency factor from the MCMC draws of (β, σ) for ordinal quantile model with 3 outcomes. The inefficiency factor is calculated using the batch-means method.

Usage

```
infactor_or2(x, beta, sigma, autocorrelationCutoff)
```

Arguments

x — covariate matrix of dimension (nxk) including a column of ones with or without column names.

beta — Gibbs draw of coefficients of dimension $(kxnsim)$.

sigma — Gibbs draw of scale factor.

autocorrelationCutoff — cut-off to identify the number of lags.

Details

Calculates the inefficiency factor of (β, σ) using the batch-means method.

Value

Returns a list with components

- inefficiencyBeta: vector with inefficiency factor for each β.
- inefficiencySigma: vector with inefficiency factor for each σ.

References

Greenberg, E. (2012). "Introduction to Bayesian Econometrics." Cambridge University Press, Cambridge. DOI: 10.1017/CBO9780511808920

See Also

pracma, acf

Examples

```
set.seed(101)
data("data25j3")
x <- data25j3$x
y <- data25j3$y
k <- dim(x)[2]
output <- quantreg_or2(y = y, x = x, B0 = 10*diag(k),
mcmc = 50, p = 0.25, display = FALSE)
beta <- output$beta
sigma <- output$sigma

inefficiency <- infactor_or2(x, beta, sigma, 0.5)

# Summary of Inefficiency Factor:
#             Inefficiency
# beta_0        2.0011
# beta_1        1.6946
# beta_2        1.4633
# sigma         2.6590
```

logMargLikelihood_or1 *Marginal likelihood for ordinal quantile model with more than 3 outcomes*

Description

This function computes the logarithm of marginal likelihood for ordinal quantile model with more than 3 outcomes using MCMC output from the complete and reduced runs.

Usage

```
logMargLikelihood_or1(y, x, b0, B0, d0, D0, postMeanbeta,
postMeandelta, beta, delta, tune, Dhat, p)
```

Arguments

y	observed ordinal outcomes, column vector of dimension $(nx1)$.
x	covariate matrix of dimension (nxk) including a column of ones with or without column names.
b0	prior mean for normal distribution to sample β.
B0	prior variance for normal distribution to sample β
d0	prior mean for normal distribution to sample δ.
D0	prior variance for normal distribution to sample δ.
postMeanbeta	a vector with mean of sampled β for each covariate.
postMeandelta	a vector with mean of sampled δ for each cut-point.
beta	a storage matrix with all sampled values for β.
delta	a storage matrix with all sampled values for δ.
tune	tuning parameter to adjust MH acceptance rate.
Dhat	negative inverse Hessian from maximization of log-likelihood.
p	quantile level or skewness parameter, p in (0,1).

Details

This function computes the logarithm of marginal likelihood for ordinal quantile model with more than 3 outcomes using the MCMC outputs.

Value

Returns a scalar for logarithm of marginal likelihood

References

Rahman, M. A. (2016). "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Chib, S., and Greenberg, E. (1995). "Understanding the Metropolis-Hastings Algorithm." The American Statistician, 49(4): 327-335. DOI: 10.2307/2684568

Chib, S. (1995). "Marginal likelihood from the Gibbs output." Journal of the American Statistical Association, 90(432):1313–1321, 1995. DOI: 10.1080/01621459.1995.10476635

Chib, S., and Jeliazkov, I. (2001). "Marginal likelihood from the Metropolis-Hastings output." Journal of the American Statistical Association, 96(453):270–281, 2001. DOI: 10.1198/016214501750332848

Greenberg, E. (2012). "Introduction to Bayesian Econometrics." Cambridge University Press, Cambridge. DOI: 10.1017/CBO9780511808920

See Also

mvnpdf, dnorm, Gibbs sampling, Metropolis-Hastings algorithm

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
k <- dim(x)[2]
J <- dim(as.array(unique(y)))[1]
D0 <- 0.25*diag(J - 2)
output <- quantreg_or1(y = y,x = x, B0 = 10*diag(k), D0 = D0,
mcmc = 50, p = 0.25, tune = 1, display = FALSE)
# output$logMargLikelihood
#   -551.42
```

`logMargLikelihood_or2` *Marginal likelihood for ordinal quantile model with 3 outcomes*

Description

This function computes the logarithm of marginal likelihood for ordinal quantile model with 3 outcomes using Gibbs output from the complete and reduced runs.

Usage

```
logMargLikelihood_or2(y, x, b0, B0, n0, d0, postMeanbeta, postMeansigma,
btildeStore, BtildeStore, gamma, p)
```

Arguments

y	observed ordinal outcomes, column vector of dimension $(nx1)$.
x	covariate matrix of dimension (nxk) including a column of ones with or without column names.
b0	prior mean for normal distribution to sample β.
B0	prior variance for normal distribution to sample β
n0	prior for shape parameter to sample σ from inverse gamma distribution.
d0	prior for scale parameter to sample σ from inverse gamma distribution.
postMeanbeta	a vector with mean of sampled β for each covariate.
postMeansigma	a vector with mean of sampled σ.
btildeStore	a storage matrix for posterior mean of β.
BtildeStore	a storage matrix for posterior variance of β.
gamma	one and only cut-point other than 0.
p	quantile level or skewness parameter, p in (0,1).

Details

Function computes the logarithm of marginal likelihood for ordinal model with 3 outcomes using a Gibbs sampling procedure.

Value

Returns a scalar for logarithm of marginal likelihood

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Chib, S. (1995). “Marginal likelihood from the Gibbs output.” Journal of the American Statistical Association, 90(432):1313–1321, 1995. DOI: 10.1080/01621459.1995.10476635

Greenberg, E. (2012). “Introduction to Bayesian Econometrics.” Cambridge University Press, Cambridge. DOI: 10.1017/CBO9780511808920

See Also

dinvgamma, mvnpdf, dnorm, Gibbs sampling

Examples

```
set.seed(101)
data("data25j3")
x <- data25j3$x
y <- data25j3$y
k <- dim(x)[2]
output <- quantreg_or2(y = y, x = x, B0 = 10*diag(k),
mcmc = 50, p = 0.25, display = FALSE)
```

```
# output$logMargLikelihood
#   -404.57
```

Policy_Opinion *The data consists of public opinion on raising federal income taxes on the rich and a host of other variables for 1,164 individuals and is taken from the 2010-2012 American National Election Studies (ANES) on the Evaluation of Government and Society Study I (EGSS 1)*

Description

The data consists of public opinion on raising federal income taxes on the rich and a host of other variables for 1,164 individuals and is taken from the 2010-2012 American National Election Studies (ANES) on the Evaluation of Government and Society Study I (EGSS 1)

Usage

```
data(Policy_Opinion)
```

Details

The data consists of 1,164 observations taken from the 2010-2012 American National Election Studies (ANES) on the Evaluations of Government and Society Study 1 (EGSS 1). The objective is to analyze public opinion on the proposal to raise federal income taxes for couples (individuals) earning more than $250,000 ($200,000) per year. The responses were recorded as oppose, neither favor nor oppose, or favor the tax increase and forms the dependent variable in the study. The independent variables include indicator variables (or dummy) for employment, income above $75,000, bachelor's and post-bachelor's degree, computer ownership, cellphone ownership, and white race.

Value

Returns data with components

- `Intercept`: column of ones.
- `AgeCat`: Indicator for age Category.
- `IncomeCat`: Indicator for household income > $75,000.
- `Bachelors`: Individual's highest degree in Bachelors.
- `Post.Bachelors`: Indicator for highest degree in Masters, Professional or Doctorate.
- `numComputers`: Indicator for computer ownership by individual or household.
- `CellPhone`: Indicator for cellphone ownership by individual or household.
- `White`: Indicator for white race.
- `y`: matrix of ordinal outcomes.

References

Rahman, M. A. (2016). "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Jeliazkov, I., Graves, J., and Kutzbach, M. (2008). "Fitting and Comparison of Models for Multivariate Ordinal Outcomes." Advances in Econometrics: Bayesian Econometrics, 23: 115–156. DOI: 10.1016/S0731-9053(08)23004-5

See Also

ANES, Tax Policy

`qrminfundtheorem` *Minimize the negative of log-likelihood*

Description

This function minimizes the negative of the log-likelihood for ordinal quantile model with respect to cut-points δ using the fundamental theorem of calculus.

Usage

```
qrminfundtheorem(deltaIn, y, x, beta, cri0, cri1, stepsize, maxiter, h, dh, sw, p)
```

Arguments

`deltaIn`	initialization of cut-points.
`y`	observed ordinal outcomes, column vector of dimension $(nx1)$.
`x`	covariate matrix of dimension (nxk) including a column of ones.
`beta`	column vector of coefficients of dimension $(kx1)$.
`cri0`	initial criterion, $cri0 = 1$.
`cri1`	criterion lies between (0.001 to 0.0001).
`stepsize`	learning rate lies between (0.1, 1).
`maxiter`	maximum number of iteration.
`h`	change in value of each δ, holding other δ constant for first derivatives.
`dh`	change in each value of δ, holding other δ constant for second derivaties.
`sw`	iteration to switch from BHHH to inv(-H) algorithm.
`p`	quantile level or skewness parameter, p in (0,1).

Details

First derivative from first principle

$$dy/dx = [f(x+h) - f(x-h)]/2h$$

Second derivative from first principle

$$f'(x-h) = (f(x) - f(x-h))/h$$

$$f''(x) = [(f(x+h) - f(x))/h - (f(x) - f(x-h))/h]/h$$
$$= [(f(x+h) + f(x-h) - 2f(x))]/h^2$$

cross partial derivatives

$$f(x) = [f(x+dh, y) - f(x-dh, y)]/2dh$$

$$f(x,y) = [(f(x+dh, y+dh) - f(x+dh, y-dh))/2dh - (f(x-dh, y+dh) - f(x-dh, y-dh))/2dh]/2dh$$
$$= 0.25 * [(f(x+dh, y+dh) - f(x+dh, y-dh)) - (f(x-dh, y+dh) - f(x-dh, y-dh))]/dh2$$

Value

Returns a list with components

- `deltamin`: vector with cutpoints that minimize the log-likelihood function.
- `negsum`: scalar with sum of log-likelihood values.
- `logl`: vector with log-likelihood values.
- `G`: gradient vector, (nxk) matrix with i-th row as the score for the i-th unit.
- `H`: represents Hessian matrix.

References

Rahman, M. A. (2016). "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

See Also

differential calculus, functional maximization, mldivide

Examples

```
set.seed(101)
deltaIn <- c(-0.002570995,  1.044481071)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
p <- 0.25
beta <- c(0.3990094, 0.8168991, 2.8034963)
cri0     <- 1
```

```
cri1     <- 0.001
stepsize <- 1
maxiter  <- 10
h        <- 0.002
dh       <- 0.0002
sw       <- 20
output <- qrminfundtheorem(deltaIn, y, x, beta, cri0, cri1, stepsize, maxiter, h, dh, sw, p)

# deltamin
#   0.8266967 0.3635708
# negsum
#   645.4911
# logl
#    -0.7136999
#    -1.5340787
#    -1.1072447
#    -1.4423124
#    -1.3944677
#    -0.7941271
#    -1.6544072
#    -0.3246632
#    -1.8582422
#    -0.9220822
#    -2.1117739 .. soon
# G
#    0.803892784  0.00000000
#   -0.420190546  0.72908381
#   -0.421776117  0.72908341
#   -0.421776117 -0.60184063
#   -0.421776117 -0.60184063
#    0.151489598  0.86175120
#    0.296995920  0.96329114
#   -0.421776117  0.72908341
#   -0.340103190 -0.48530164
#    0.000000000  0.00000000
#   -0.421776117 -0.60184063.. soon
# H
#   -338.21243  -41.10775
#   -41.10775 -106.32758
```

`qrnegLogLikensum_or1` *Negative log-likelihood for ordinal quantile model with more than 3 outcomes*

Description

Function for calculating the negative log-likelihood for ordinal quantile model with more than 3 outcomes.

Usage

```
qrnegLogLikensum_or1(deltaIn, y, x, beta, p)
```

Arguments

deltaIn	initialization of cut-points.
y	observed ordinal outcomes, column vector of dimension $(nx1)$.
x	covariate matrix of dimension (nxk) including a column of ones.
beta	column vector of coefficients of dimension $(kx1)$.
p	quantile level or skewness parameter, p in (0,1).

Details

Computes the negative of the log-likelihood function for ordinal quantile regression model with more than 3 outcomes.

Value

Returns a list with components

- `nlogl`: vector with likelihood values.
- `negsumlogl`: scalar with value of negative log-likelihood.

References

Rahman, M. A. (2016). "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

See Also

likelihood maximization

Examples

```
set.seed(101)
deltaIn <- c(-0.002570995, 1.044481071)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
p <- 0.25
beta <- c(0.3990094, 0.8168991, 2.8034963)
output <- qrnegLogLikensum_or1(deltaIn, y, x, beta, p)

# nlogl
#   0.7424858
#   1.1649645
#   2.1344390
#   0.9881085
#   2.7677386
```

```
#   0.8229129
#   0.8854911
#   0.3534490
#   1.8582422
#   0.9508680 .. soon

# negsumlogl
#   663.5475
```

`qrnegLogLike_or2` *Negative log-likelihood for ordinal quantile model with 3 outcomes*

Description

This function computes the negative of the log-likelihood for ordinal quantile model with 3 outcomes.

Usage

```
qrnegLogLike_or2(y, x, gammacp, beta, sigma, p)
```

Arguments

`y`	observed ordinal outcomes, column vector of dimension $(nx1)$.
`x`	covariate matrix of dimension (nxk) including a column of ones with or without column names.
`gammacp`	row vector of cutpoints including -Inf and Inf.
`beta`	column vector of coefficients of dimension $(kx1)$.
`sigma`	scale factor, a scalar.
`p`	quantile level or skewness parameter, p in (0,1).

Details

Computes the negative of the log-likelihood for ordinal quantile model with 3 outcomes where the error is assumed to follow an asymmetric Laplace distribution.

Value

Returns the negative log-likelihood value.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

See Also

likelihood maximization

Examples

```
set.seed(101)
data("data25j3")
x <- data25j3$x
y <- data25j3$y
p <- 0.25
gammacp <- c(-Inf, 0, 3, Inf)
beta <- c(1.810504, 1.850332, 6.18116)
sigma <- 0.9684741
output <- qrnegLogLike_or2(y, x, gammacp, beta, sigma, p)

# output
#   902.4045
```

---

quantreg_or1 *Bayesian quantile regression for ordinal quantile model with more than 3 outcomes*

Description

This function estimates Bayesian quantile regression for ordinal quantile model with more than 3 outcomes and reports the posterior mean, posterior standard deviation, and 95 percent posterior credible intervals of (β, δ).

Usage

```
quantreg_or1(y, x, b0, B0, d0, D0, mcmc, p, tune, display)
```

Arguments

y	observed ordinal outcomes, column vector of dimension $(nx1)$.
x	covariate matrix of dimension (nxk) including a column of ones with or without column names.
b0	prior mean for normal distribution to sample β, default is 0.
B0	prior variance for normal distribution to sample β.
d0	prior mean of normal distribution to sample δ, default is 0.
D0	prior variance for normal distribution to sample δ.
mcmc	number of MCMC iterations, post burn-in.
p	quantile level or skewness parameter, p in (0,1).
tune	tuning parameter to adjust MH acceptance rate.
display	whether to print the final output or not, default is TRUE.

Details

Function implements the Bayesian quantile regression for ordinal model with more than 3 outcomes using a combination of Gibbs sampling and Metropolis-Hastings algorithm.

Function initializes prior and then iteratively samples β, δ and latent variable z. Burn-in is taken as $0.25 * mcmc$ and $nsim = burn\text{-}in + mcmc$.

Value

Returns a list with components:

- `postMeanbeta`: vector with mean of sampled β for each covariate.
- `postMeandelta`: vector with mean of sampled δ for each cut point.
- `postStdbeta`: vector with standard deviation of sampled β for each covariate.
- `postStddelta`: vector with standard deviation of sampled δ for each cut point.
- `gamma`: vector of cut points including Inf and -Inf.
- `catt`
- `acceptancerate`: scalar to judge the acceptance rate of samples.
- `allQuantDIC`: results of the DIC criteria.
- `logMargLikelihood`: scalar value for log marginal likelihood.
- `beta`: matrix with all sampled values for β.
- `delta`: matrix with all sampled values for δ.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Yu, K., and Moyeed, R. A. (2001). “Bayesian Quantile Regression.” Statistics and Probability Letters, 54(4): 437–447. DOI: 10.12691/ajams-6-6-4

Casella, G., and George, E. I. (1992). “Explaining the Gibbs Sampler.” The American Statistician, 46(3): 167-174. DOI: 10.1080/00031305.1992.10475878

Geman, S., and Geman, D. (1984). “Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images.” IEEE Transactions an Pattern Analysis and Machine Intelligence, 6(6): 721-741. DOI:10.1109/TPAMI.1984.4767596

Chib, S., and Greenberg, E. (1995). “Understanding the Metropolis-Hastings Algorithm.” The American Statistician, 49(4): 327-335. DOI: 10.2307/2684568

Hastings, W. K. (1970). “Monte Carlo Sampling Methods Using Markov Chains and Their Applications.” Biometrika, 57: 1317-1340. DOI: 10.2307/1390766

See Also

tcltk, rnorm, qnorm, Gibbs sampler, Metropolis-Hastings algorithm

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
k <- dim(x)[2]
J <- dim(as.array(unique(y)))[1]
D0 <- 0.25*diag(J - 2)
output <- quantreg_or1(y = y,x = x, B0 = 10*diag(k), D0 = D0,
mcmc = 50, p = 0.25, tune = 1)


# Number of burn-in draws: 12.5
# Number of retained draws: 50
# Summary of MCMC draws:


#             Post Mean  Post Std   Upper Credible Lower Credible
# beta_0       -2.6851   0.3427        -2.0229        -3.2861
# beta_1        3.4947   0.5927         4.4195         2.3914
# beta_2        4.1840   0.8009         5.5109         2.8934
# delta_1       0.2870   0.3163         0.6512        -0.3379
# delta_2       0.4889   0.2324         0.7524        -0.0214

# MH acceptance rate: 36
# Log of Marginal Likelihood: -551.42
# DIC: 1300.32
```

---

quantreg_or2 — *Bayesian quantile regression for ordinal quantile model with 3 outcomes*

Description

This function estimates Bayesian quantile regression for ordinal quantile model with 3 outcomes and reports the posterior mean, posterior standard deviation, and 95 percent posterior credible intervals of (β, σ).

Usage

```
quantreg_or2(y, x, b0, B0 , n0, d0, gamma, mcmc, p, display)
```

Arguments

y	observed ordinal outcomes, column vector of dimension $(nx1)$.
x	covariate matrix of dimension (nxk) including a column of ones with or without column names.

`b0`	prior mean for normal distribution to sample β, default is 0.
`B0`	prior variance for normal distribution to sample β
`n0`	prior for shape parameter to sample σ from inverse gamma distribution, default is 5.
`d0`	prior for scale parameter to sample σ from inverse gamma distribution, default is 8.
`gamma`	one and only cut-point other than 0.
`mcmc`	number of MCMC iterations, post burn-in.
`p`	quantile level or skewness parameter, p in (0,1).
`display`	whether to print the final output or not, default is TRUE.

Details

Function implements the Bayesian quantile regression for ordinal quantile model with 3 outcomes using a Gibbs sampling procedure.

Function initializes prior and then iteratively samples β, σ and latent variable z. Burn-in is taken as $0.25 * mcmc$ and $nsim = burn\text{-}in + mcmc$.

Value

Returns a list with components

- `postMeanbeta`: vector with mean of sampled β for each covariate.
- `postMeansigma`: vector with mean of sampled σ.
- `postStdbeta`: vector with standard deviation of sampled β for each covariate.
- `postStdsigma`: vector with standard deviation of sampled σ.
- `allQuantDIC`: results of the DIC criteria.
- `logMargLikelihood`: scalar value for log marginal likelihood.
- `beta`: matrix with all sampled values for β.
- `sigma`: matrix with all sampled values for σ.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

Yu, K., and Moyeed, R. A. (2001). “Bayesian Quantile Regression.” Statistics and Probability Letters, 54(4): 437–447. DOI: 10.12691/ajams-6-6-4

Casella, G., and George, E. I. (1992). “Explaining the Gibbs Sampler.” The American Statistician, 46(3): 167-174. DOI: 10.1080/00031305.1992.10475878

Geman, S., and Geman, D. (1984). “Stochastic Relaxation, Gibbs Distributions, and the Bayesian Restoration of Images.” IEEE Transactions an Pattern Analysis and Machine Intelligence, 6(6): 721-741. DOI: 10.1109/TPAMI.1984.4767596

See Also

tcltk, rnorm, qnorm, Gibbs sampling

Examples

```
set.seed(101)
data("data25j3")
x <- data25j3$x
y <- data25j3$y
k <- dim(x)[2]
output <- quantreg_or2(y = y, x = x, B0 = 10*diag(k),
mcmc = 50, p = 0.25)

# Number of burn-in draws : 12.5
# Number of retained draws : 50
# Summary of MCMC draws :

#             Post Mean Post Std Upper Credible Lower Credible
#    beta_0   -4.5185   0.9837        -3.1726        -6.2000
#    beta_1    6.1825   0.9166         7.6179         4.8619
#    beta_2    5.2984   0.9653         6.9954         4.1619
#    sigma     1.0879   0.2073         1.5670         0.8436

# Log of Marginal Likelihood: -404.57
# DIC: 801.82
```

---

rndald — *Generates random numbers from an asymmetric Laplace distribution*

Description

This function generates a vector of random numbers from an asymmetric Laplace distribution with quantile p.

Usage

```
rndald(sigma, p, n)
```

Arguments

sigma	scale factor, a scalar.
p	quantile or skewness parameter, p in (0,1).
n	number of observations

Details

Generates a vector of random numbers from an asymmetric Laplace distribution, as a mixture of normal–exponential distributions.

Value

Returns a vector $(nx1)$ of random numbers using an AL(0, σ, p)

References

Kozumi, H., and Kobayashi, G. (2011). "Gibbs Sampling Methods for Bayesian Quantile Regression." Journal of Statistical Computation and Simulation, 81(11): 1565–1578. DOI: 10.1080/00949655.2010.496117

Yu, K., and Zhang, J. (2005). "A Three-Parameter Asymmetric Laplace Distribution." Communications in Statistics - Theory and Methods, 34(9-10), 1867-1879. DOI: 10.1080/03610920500199018

See Also

asymmetric Laplace distribution

Examples

```
set.seed(101)
sigma <- 2.503306
p <- 0.25
n <- 1
output <- rndald(sigma, p, n)

# output
#   1.07328
```

---

traceplot_or1 *Trace plots for ordinal quantile model with more than 3 outcomes*

Description

This function generates trace plots of MCMC samples for (β, δ) in the quantile regression model with more than 3 outcomes.

Usage

```
traceplot_or1(beta, delta, burn)
```

Arguments

beta	Gibbs draw of β vector of dimension $(kxnsim)$.
delta	Gibbs draw of δ.
burn	number of discarded MCMC iterations.

Details

Trace plot is a visual depiction of the values generated from the markov chain versus the iteration number.

Value

Returns trace plots for each element of β and δ.

References

Rahman, M. A. (2016). "Bayesian Quantile Regression for Ordinal Models." Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

See Also

MCMC simulations

Examples

```
set.seed(101)
data("data25j4")
x <- data25j4$x
y <- data25j4$y
k <- dim(x)[2]
J <- dim(as.array(unique(y)))[1]
D0 <- 0.25*diag(J - 2)
output <- quantreg_or1(y = y,x = x, B0 = 10*diag(k), D0 = D0,
mcmc = 50, p = 0.25, tune = 1, display = FALSE)
mcmc <- 50
beta <- output$beta
delta <- output$delta
traceplot_or1(beta, delta, round(0.25*mcmc))
```

---

traceplot_or2 *Trace plots for ordinal quantile model with 3 outcomes*

Description

This function generates trace plots of MCMC samples for (β, σ) in the quantile regression model with 3 outcomes.

Usage

```
traceplot_or2(beta, sigma, burn)
```

Arguments

`beta`	Gibbs draw of β vector of dimension $(kxnsim)$.
`sigma`	Gibbs draw of scale parameter, σ.
`burn`	number of discarded MCMC iterations.

Details

Trace plot is a visual depiction of the values generated from the markov chain versus the iteration number.

Value

Returns trace plots for each element of β and σ.

References

Rahman, M. A. (2016). “Bayesian Quantile Regression for Ordinal Models.” Bayesian Analysis, 11(1): 1-24. DOI: 10.1214/15-BA939

See Also

MCMC simulations

Examples

```
set.seed(101)
data("data25j3")
x <- data25j3$x
y <- data25j3$y
k <- dim(x)[2]
output <- quantreg_or2(y = y,x = x, B0 = 10*diag(k),
mcmc = 50, p = 0.25, display = FALSE)
mcmc <- 50
beta <- output$beta
sigma <- output$sigma
traceplot_or2(beta, sigma, round(0.25*mcmc))
```

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