Package ‘cquad’

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Type Package

Title Conditional Maximum Likelihood for Quadratic Exponential Models for Binary Panel Data

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Description Estimation, based on conditional maximum likelihood, of the quadratic exponential model proposed by Bartolucci, F. & Nigro, V. (2010, Econometrica) <DOI:10.3982/ECTA7531> and of a simplified and a modified version of this model. The quadratic exponential model is suitable for the analysis of binary longitudinal data when state dependence (further to the effect of the covariates and a time-fixed individual intercept) has to be taken into account. Therefore, this is an alternative to the dynamic logit model having the advantage of easily allowing conditional inference in order to eliminate the individual intercepts and then getting consistent estimates of the parameters of main interest (for the covariates and the lagged response). The simplified version of this model does not distinguish, as the original model does, between the last time occasion and the previous occasions. The modified version formulates in a different way the interaction terms and it may be used to test in a easy way state dependence as shown in Bartolucci, F., Nigro, V. & Pigini, C. (2018, Econometric Reviews) <DOI:10.1080/07474938.2015.1060039>. The package also includes estimation of the dynamic logit model by a pseudo conditional estimator based on the quadratic exponential model, as proposed by Bartolucci, F. & Nigro, V. (2012, Journal of Econometrics) <DOI:10.1016/j.jeconom.2012.03.004>. For large time dimensions of the panel, the computation of the proposed models involves a recursive function adapted from Krailo M. D., & Pike M. C. (1984, Journal of the Royal Statistical Society. Series C (Applied Statistics)).

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Description

Estimation, based on conditional maximum likelihood, of the quadratic exponential model proposed by Bartolucci & Nigro (2010) and of a simplified and a modified version of this model. The quadratic exponential model is suitable for the analysis of binary longitudinal data when state dependence (further to the effect of the covariates and a time-fixed individual intercept) has to be taken into account. Therefore, this is an alternative to the dynamic logit model having the advantage of easily allowing conditional inference in order to eliminate the individual intercepts and then getting consistent estimates of the parameters of main interest (for the covariates and the lagged response). The simplified version of this model does not distinguish, as the original model does, between the last time occasion and the previous occasions. The modified version formulates in a different way the interaction terms and it may be used to test in a easy way state dependence as shown in Bartolucci, Nigro & Pigini (2018). The package also includes estimation of the dynamic logit model by a pseudo conditional estimator based on the quadratic exponential model, as proposed by Bartolucci & Nigro (2012).

Details

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References


Examples

```r
# example based on simulated data
data(data_sim)
data_sim = data_sim[1:500,]  # to speed up the example, remove otherwise
# static model
out1 = cquad(y~X1+X2, data_sim)
# dynamic model
out2 = cquad(y~X1+X2, data_sim, dyn=TRUE)
```

Description

Fit by conditional maximum likelihood each of the models in cquad package.

Usage

```r
cquad(formula, data, index = NULL, model = c("basic","equal","extended","pseudo"),
w = rep(1, n), dyn = FALSE, Ttol=10)
```
**Arguments**

- **formula**: formula with the same syntax as in plm package
- **data**: data.frame or pdata.frame
- **index**: to denote panel structure as in plm package
- **model**: type of model = "basic", "equal", "extended", "pseudo"
- **w**: vector of weights (optional)
- **dyn**: TRUE if in the dynamic version; FALSE for the static version (by default)
- **Ttol**: Treshold individual observations that activates the recursive algorithm (default=10)

**Value**

- **formula**: formula defining the model
- **lk**: conditional log-likelihood value
- **coefficients**: estimate of the regression parameters
- **vcov**: asymptotic variance-covariance matrix for the parameter estimates
- **scv**: matrix of individual scores
- **J**: Hessian of the log-likelihood function
- **se**: standard errors
- **ser**: robust standard errors
- **Tv**: number of time occasions for each unit

**Author(s)**

Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Ancona "Politecnica delle Marche"), Francesco Valentini (University of Ancona "Politecnica delle Marche")

**Examples**

```r
# example based on simulated data
data(data_sim)
data_sim = data_sim[1:500,]  # to speed up the example, remove otherwise
# basic (static) model
out1 = cquad(y~X1+X2,data_sim)
summary(out1)
# basic (dynamic) model
out2 = cquad(y~X1+X2,data_sim,dyn=TRUE)
summary(out2)
# equal model
out3 = cquad(y~X1+X2,data_sim,model="equal")
summary(out3)
# extended model
out4 = cquad(y~X1+X2,data_sim,model="extended")
summary(out4)
# psuedo CML for dynamic model
out5 = cquad(y~X1+X2,data_sim,model="pseudo")
summary(out5)
```
cquad_basic

Conditional maximum likelihood estimation of the basic quadratic exponential model

Description

Fit by conditional maximum likelihood a simplified version of the model for binary logitudinal data proposed by Bartolucci & Nigro (2010); see also Cox (1972).

Usage

cquad_basic(id, yv, X = NULL, be = NULL, w = rep(1, n), dyn = FALSE, Ttol=10)

Arguments

id list of the reference unit of each observation
yv corresponding vector of response variables
X corresponding matrix of covariates (optional)
be initial vector of parameters (optional)
w vector of weights (optional)
dyn TRUE if in the dynamic version; FALSE for the static version (by default)
Ttol Treshold individual observations that activates the recursive algorithm (default=10)

Value

formula formula defining the model
lk conditional log-likelihood value
coefficients estimate of the regression parameters (including for the lag-response)
vcov asymptotic variance-covariance matrix for the parameter estimates
scv matrix of individual scores
J Hessian of the log-likelihood function
se standard errors
ser robust standard errors
Tv number of time occasions for each unit

Author(s)

Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Ancona "Politecnica delle Marche"), Francesco Valentini (University of Ancona "Politecnica delle Marche")
References


Examples

```r
# example based on simulated data
data(data_sim)
data_sim = data_sim[1:500,]  # to speed up the example, remove otherwise
id = data_sim$id; yv = data_sim$y; X = cbind(X1=data_sim$X1,X2=data_sim$X2)
# static model
out1 = cquad_basic(id,yv,X,Ttol=10)
summary(out1)
# dynamic model
out2 = cquad_basic(id,yv,X,dyn=TRUE,Ttol=10)
summary(out2)
```

cquad_equ

*Conditional maximum likelihood estimation for the modified version of the quadratic exponential model (to test for state dependence)*

Description

Fit by conditional maximum likelihood a modified version of the model for binary longitudinal data proposed by Bartolucci & Nigro (2010), in which the interaction terms have an extended form. This modified version is used to test for state dependence as described in Bartolucci et al. (2018).

Usage

```r
cquad_equ(id, yv, X = NULL, be = NULL, w = rep(1, n), Ttol=10)
```

Arguments

- `id` list of the reference unit of each observation
- `yv` corresponding vector of response variables
- `X` corresponding matrix of covariates (optional)
- `be` initial vector of parameters (optional)
- `w` vector of weights (optional)
- `Ttol` Treshold individual observations that activates the recursive algorithm (default=10)
**cquad_ext**

**Value**
- `formula`: formula defining the model
- `lk`: conditional log-likelihood value
- `coefficients`: estimate of the regression parameters (including for the lag-response)
- `vcov`: asymptotic variance-covariance matrix for the parameter estimates
- `scv`: matrix of individual scores
- `J`: Hessian of the log-likelihood function
- `se`: standard errors
- `ser`: robust standard errors
- `Tv`: number of time occasions for each unit

**Author(s)**
Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Perugia), Francesco Valentini (University of Ancona “Politecnica delle Marche”)

**References**

**Examples**

```r
# example based on simulated data
data(data_sim)
data_sim = data_sim[1:500,]  # to speed up the example, remove otherwise
id = data_sim$id; yv = data_sim$y; X = cbind(X1=data_sim$X1, X2=data_sim$X2)
out = cquad_equ(id, yv, X, Ttol=10)
```

---

**Description**
Fit by conditional maximum likelihood the model for binary longitudinal data proposed by Bartolucci & Nigro (2010).

**Usage**
```
cquad_ext(id, yv, X = NULL, be = NULL, w = rep(1, n), Ttol=10)
```
Arguments

id list of the reference unit of each observation
yv corresponding vector of response variables
X corresponding matrix of covariates (optional)
be initial vector of parameters (optional)
w vector of weights (optional)
Ttol Treshold individual observations that activates the recursive algorithm (default=10)

Value

formula formula defining the model
lk conditional log-likelihood value
coefficients estimate of the regression parameters (including for the lag-response)
vcov asymptotic variance-covariance matrix for the parameter estimates
scv matrix of individual scores
J Hessian of the log-likelihood function
se standard errors
ser robust standard errors
Tv number of time occasions for each unit

Author(s)

Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Ancona "Politecnica delle Marche"), Francesco Valentini (University of Ancona "Politecnica delle Marche")

References


Examples

```r
# example based on simulated data
data(data_sim)
data_sim = data_sim[1:500,] # to speed up the example, remove otherwise
id = data_sim$id; yv = data_sim$y; X = cbind(X1=data_sim$X1,X2=data_sim$X2)
# static model
out = cquad_ext(id,yv,X,Ttol=10)
summary(out)
```
Description

Estimate the dynamic logit model for binary longitudinal data by the pseudo conditional maximum likelihood method proposed by Bartolucci & Nigro (2012).

Usage

cquad_pseudo(id, yv, X = NULL, be = NULL, w = rep(1,n), Ttol=10)

Arguments

id list of the reference unit of each observation
yv corresponding vector of response variables
X corresponding matrix of covariates (optional)
be initial vector of parameters (optional)
w vector of weights (optional)
Ttol Threshold individual observations that activates the recursive algorithm (default=10)

Value

formula formula defining the model
lk conditional log-likelihood value
coefficients estimate of the regression parameters (including for the lag-response)
vcov asymptotic variance-covariance matrix for the parameter estimates
scv matrix of individual scores
J Hessian of the log-likelihood function
se standard errors
se2 robust standard errors that also take into account the first step
tv number of time occasions for each unit

Author(s)

Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Ancona "Politecnica delle Marche"), Francesco Valentini (University of Ancona "Politecnica delle Marche")

References

### Examples

```r
## Not run:
# example based on simulated data
data(data_sim)
data_sim = data_sim[1:500,]  # to speed up the example, remove otherwise
id = data_sim$id; y = data_sim$y; X = cbind(X1=data_sim$X1,X2=data_sim$X2)
# estimate dynamic logit model
out = cquad_pseudo(id,y,X, Ttol=10)
summary(out)

## End(Not run)
```

---

### data_sim

**Simulated dataset**

---

### Description

It contains a dataset simulated from the dynamic logit model.

### Usage

```r
data(data_sim)
```

### Format

The observations are for 1000 sample units at 5 five time occasions:

- **id**: list of the reference unit of each observation
- **time**: number of the time occasion
- **X1**: first covariate
- **X2**: second covariate
- **y**: response

### Examples

```r
data(data_sim)
head(data_sim)
```
print.cquad

Description
Print output for class cquad and output provided by cquad_basic, cquad_equ, cquad_ext, cquad_pseudo

Usage
## S3 method for class 'cquad'
print(x, ...)

Arguments
- x: output of class cquad
- ...: further arguments passed to or from other methods

Author(s)
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quasi_sym

Recursive computation of the conditional likelihood for the Quadratic Exponential Model proposed in Bartolucci & Nigro (2010)

Description
Recursively compute the denominator of the individual conditional likelihood function for the Quadratic Exponential Model, adapted from Krailo & Pike (1984).

Usage
quasi_sym(eta, s, dyn=FALSE, y0=NULL)

Arguments
- eta: individual vector of products between covariate and parameters
- s: total score of the individual
- dyn: TRUE if in the dynamic version; FALSE for the static version (by default)
- y0: Individual initial observation for dynamic models
quasi_sym_equ

Value

- \( f \): value of the denominator
- \( d_1 \): first derivative of the recursive function
- \( d_1 \): a component of the score function
- \( D_2 \): second derivative of the recursive function
- \( D_{12} \): a component of the Hessian matrix

Author(s)

Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Ancona "Politecnica delle Marche"), Francesco Valentini (University of Ancona "Politecnica delle Marche")

References


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**quasi_sym_equ**  
*Recursive computation of the conditional likelihood for the Modified Quadratic Exponential Model proposed in Bartolucci et al. (2018)*

---

Description

Recursively compute the denominator of the individual conditional likelihood function for the Modified Quadratic Exponential Model recursively, adapted from Krailo & Pike (1984).

Usage

```r
quasi_sym_equ(eta, s, y0=NULL)
```

Arguments

- `eta`: individual vector of products between covariate and parameters
- `s`: total score of the individual
- `y0`: Individual initial observation for dynamic models

Value

- \( f \): value of the denominator
- \( d_1 \): first derivative of the recursive function
- \( d_1 \): a component of the score function
- \( D_2 \): second derivative of the recursive function
- \( D_{12} \): a component of the Hessian matrix
**quasi_sym_pseudo**

**Author(s)**
Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Ancona "Politecnica delle Marche"), Francesco Valentini (University of Ancona "Politecnica delle Marche")

**References**


**Description**

Recursively compute the denominator of the individual conditional likelihood function for the pseudo conditional maximum likelihood method proposed by Bartolucci & Nigro (2012), adapted from Krailo & Pike (1984).

**Usage**

`quasi_sym_pseudo(eta,qi,s,y0=NULL)`

**Arguments**

- `eta` individual vector of products between covariate and parameters
- `s` total score of the individual
- `qi` Vector of quantities from first step estimation
- `y0` Individual initial observation for dynamic models

**Value**

- `f` value of the denominator
- `d1` first derivative of the recursive function
- `d11` a component of the score function
- `D2` second derivative of the recursive function
- `D12` a component for the Hessian matrix
sim_panel_logit

Author(s)
Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Ancona "Politecnica delle Marche"), Francesco Valentini (University of Ancona "Politecnica delle Marche")

References

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dsim_panel_logit

Simulate data from the dynamic logit model

**Description**
Simulate data from the dynamic logit model given a set of covariates and a vector of parameters.

**Usage**
sim_panel_logit(id, al, x = NULL, eta, dyn = FALSE)

**Arguments**
- `id`: list of the reference unit of each observation
- `al`: list of individual specific effects
- `x`: corresponding matrix of covariates (optional)
- `eta`: vector of parameters
- `dyn`: TRUE if in the dynamic version; FALSE for the static version (by default)

**Value**
- `yv`: simulated vector of binary response variables
- `pv`: vector of probabilities of "success"

**Author(s)**
Francesco Bartolucci (University of Perugia), Claudia Pigini (University of Ancona "Politecnica delle Marche")
### Examples

```r
# simulate data from the static logit model
n = 1000; TT = 5  # sample size, number of time occasions
id = (1:n)%x%rep(1,TT)  # vector of indices
al = rnorm(n)  # simulate alpha
X = matrix(rnorm(2*n*TT),n*TT,2)  # simulate two covariates
eta1 = c(1,1)  # vector of parameters
out = sim_panel_logit(id,al,X,eta1)
y1 = out$yv

# simulate data from the dynamic logit model
eta2 = c(1,-1,2)  # vector of parameters including state dependence
out = sim_panel_logit(id,al,X,eta2,dyn=TRUE)
y2 = out$yv
```

---

**sq**

*Generate binary sequences*

---

### Description

Generate binary sequences of a certain length and with a certain sum.

### Usage

```r
sq(J, s = NULL)
```

### Arguments

- **J**: length of the binary sequences
- **s**: sum of the binary sequences (optional)

### Value

- **M**: Matrix of binary configurations

### Author(s)

Francesco Bartolucci (University of Perugia)

### Examples

```r
# generate all sequence of 5 binary variables
sq(5)
# generate all sequence of 5 binary variables, with sum equal 2
sq(5,2)
```
Summary for class cquad

Description

Summarize the output for class cquad provided by cquad_basic, cquad_equ, cquad_ext, cquad_pseudo

Usage

```r
# S3 method for class 'cquad'
summary(object, ...)
```

Arguments

- `object`: output of class cquad
- `...`: further arguments passed to or from other methods

Author(s)

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