Package 'BigVAR'

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Type Package

Title Dimension Reduction Methods for Multivariate Time Series

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Description Estimates VAR and VARX models with structured Lasso Penalties.

Depends R (>= 3.1.0), methods

Imports MASS, zoo, lattice, Rcpp,

License GPL (>=2)

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URL http://www.github.com/wbnicholson/BigVAR

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NeedsCompilation yes

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R topics documented:

A *Generator for Simulated Multivariate Time Series*

Description

Coefficient matrix for a stationary simulated multivariate time series

Details

Example generator matrix adapted from Table 3.2 of Gredenhoff and Karlsson (1997)

Author(s)

Will Nicholson

References

Gredenhoff, Mikael, and Sune Karlsson. "Lag-length selection in VAR-models using equal and unequal lag-length procedures." Computational Statistics 14.2 (1999): 171-187.

BigVAR *Dimension Reduction Methods for Multivariate Time Series.*

Description

BigVAR implements the HVAR and VARX-L frameworks which allow for the estimation of vector autoregressions and vector autoregressions with exogenous variables using structured convex penalties. This package originated as a 2014 Google "Summer of Code" Project. The development version of this package is hosted on github: http://www.github.com/wbnicholson/BigVAR.

Details

To use the facilities of this package, starting with an $T \times k + m$ multivariate time series (in which T denotes the length of the series, k the number of endogenous or "model") and run `constructModel` to create an object of class `BigVAR`. `cv.BigVAR` creates an object of class `BigVAR.results`, which chooses an optimal penalty parameter based on minimizing h-step ahead forecasts on a specified cross-validation period over a grid of values as well as comparisons against AIC, BIC, unconditional mean, and a random walk. There are plot functions for both BigVAR (`plot.BigVAR`) and BigVAR.results (`plot`) as well as a predict function for BigVAR.results (`predict`).

Author(s)

Will Nicholson <wbn8@cornell.edu>,

References

Lutkepohl "New Introduction to Multivariate Time Series", William B Nicholson, Jacob Bien, and David S Matteson. "High Dimensional Forecasting via Interpretable Vector Autoregression." arXiv preprint arXiv:1412.5250, 2016. William B Nicholson, David S. Matteson, and Jacob Bien (2015), "VARX-L Structured regularization for large vector autoregressions with exogenous variables," arXiv preprint arXiv:1508.07497, 2016.. William B Nicholson, David S. Matteson, and Jacob Bien (2016), "BigVAR: Dimension Reduction Reduction Methods for Multivariate Time Series," http://www.wbnicholson.com/BigVAR.pdf.

See Also

`constructModel`, `cv.BigVAR`, `BigVAR.results`, `plot`, `predict`

Examples

```
# Fit a Basic VAR-L(3,4) on simulated data
data(Y)
T1=floor(nrow(Y)/3)
T2=floor(2*nrow(Y)/3)
m1=constructModel(Y,p=4,struct="Basic",gran=c(50,10),verbose=FALSE,T1=T1,T2=T2)
plot(m1)
results=cv.BigVAR(m1)
plot(results)
predict(results,n.ahead=1)
```

BigVAR-class *BigVAR Object Class*

Description

An object class to be used with cv.BigVAR

Details

To construct an object of class BigVAR, use the function `constructModel`

Slots

`Data` a $T \times k$ multivariate time Series

`lagmax` Maximal lag order for modeled series

`Structure` Penalty Structure

`Relaxed` Indicator for relaxed VAR

`Granularity` Granularity of Penalty Grid

`horizon` Desired Forecast Horizon

`crossval` Cross-Validation Procedure

`Minnesota` Minnesota Prior Indicator

`verbose` Indicator for Verbose output

`dates` dates extracted from an xts object

`ic` Indicator for including AIC and BIC benchmarks

`VARX` VARX Model Specifications

`T1` Index of time series in which to start cross validation

`T2` Index of times series in which to start forecast evaluation

`ONESE` Indicator for "One Standard Error Heuristic"

`ownlambdas` Indicator for user-supplied lambdas

`tf` Indicator for transfer function

`alpha` Grid of candidate alpha values (applies only to Sparse VARX-L models)

`recursive` Indicator as to whether recursive multi-step forecasts are used (applies only to multiple horizon VAR models)

See Also

`constructModel`

`BigVAR.est` *BigVAR Estimation*

Description

Fit a BigVAR object with a structured penalty (VARX-L or HVAR).

Usage

```
BigVAR.est(object)
```

Arguments

`object`	BigVAR object created from `ConstructModel`

Details

Fits HVAR or VARX-L model on a BigVAR object. Does not perform cross-validation. This method allows the user to construct their own penalty parameter selection procedure.

Value

An array of $k \times kp \times n$ or $k \times kp + ms \times n$ coefficient matrices; one for each of the n values of lambda.

See Also

constructModel, BigVAR.results,cv.BigVAR

Examples

```
data(Y)
Y=Y[1:100,]
#construct a Basic VAR-L
Model1=constructModel(Y,p=4,struct="Basic",gran=c(50,10))
BigVAR.est(Model1)
```

BigVAR.results *BigVAR.results This class contains the results from cv.BigVAR.*

Description

It inherits the class BigVAR, but contains substantially more information.

Fields

`InSampMSFE` In-sample MSFE from optimal value of lambda

`LambdaGrid` Grid of candidate lambda values

`index` Rank of optimal lambda value

`OptimalLambda` Value of lambda that minimizes MSFE

`OOSMSFE` Average Out of sample MSFE of BigVAR model with optimal lambda

`seoosfmsfe` Standard error of out of sample MSFE of BigVAR model with optimal lambda

`MeanMSFE` Average out of sample MSFE of unconditional mean forecast

`MeanSD` Standard error of out of sample MSFE of unconditional mean forecast

`RWMSFE` Average out of sample MSFE of random walk forecast

`RWSD` Standard error of out of sample MSFE of random walk forecast

`AICMSFE` Average out of sample MSFE of AIC forecast

`AICSD` Standard error of out of sample MSFE of AIC forecast

`BICMSFE` Average out of sample MSFE of BIC forecast

`BICSD` Standard error of out of sample MSFE of BIC forecast

`betaPred` The final estimated $k \times kp + ms + 1$ coefficient matrix, to be used for prediction

`Zvals` The final lagged values of `Y`, to be used for prediction

`resids` residuals obtained from betaPred

`Data` a $T \times k$ or $T \times k + m$ multivariate time Series

`lagmax` Maximal lag order

`Structure` Penalty structure

`Relaxed` Indicator for relaxed VAR

`Granularity` Granularity of penalty grid

`horizon` Desired forecast horizon

`crossval` Cross-Validation procedure

`alpha` additional penalty parameter for Sparse Lag Group or Sparse Own/Other methods. Will contain either the heuristic choice of $1/(k+1)$ or the value selected by cross validation if the argument `dual` is set to `TRUE`

`VARXI` VARX Indicator

`Minnesota` Minnesota Prior Indicator

`verbose` verbose indicator

`dual` indicator as to whether dual cross validation was conducted

`contemp` indicator if contemporaneous exogenous predictors are used

Note

One can also access any object of class BigVAR from BigVAR.results

Author(s)

Will Nicholson

`constructModel` *Construct an object of class BigVAR*

Description

Construct an object of class BigVAR

Usage

```
constructModel(Y, p, struct, gran, RVAR = FALSE, h = 1, cv = "Rolling",
  MN = FALSE, verbose = TRUE, IC = TRUE, VARX = list(),
  T1 = floor(nrow(Y)/3), T2 = floor(2 * nrow(Y)/3), ONESE = FALSE,
  ownlambdas = FALSE, alpha = as.double(NULL), recursive = FALSE)
```

Arguments

Y	$T \times k$ multivariate time series or Y $T \times (k+m)$ endogenous and exogenous series, respectively
p	Predetermined maximal lag order (for modeled series)
struct	The choice of penalty structure (see details).
gran	vector of penalty parameter specifications.
RVAR	True or False: whether to refit based upon the support selected using the Relaxed-VAR procedure
h	Desired forecast horizon
cv	Cross-validation approach, either "Rolling" for rolling cross-validation or "LOO" for leave-one-out cross-validation.
MN	Minnesota Prior Indicator
verbose	Verbose output while estimating
IC	True or False: whether to include AIC and BIC benchmarks
VARX	List containing VARX model specifications.
T1	Index of time series in which to start cross validation
T2	Index of times series in which to start forecast evaluation
ONESE	True or False: whether to use the "One Standard Error Heuristic"
ownlambdas	True or False: Indicator for user-supplied penalty parameters
alpha	grid of candidate parameters for the alpha in the Sparse Lag and Sparse Own/Other VARX-L
recursive	True or False: Indicator as to whether iterative multi-step predictions are desired in the VAR context if the forecast horizon is greater than 1

Details

The choices for "struct" are as follows

- "Basic" (Basic VARX-L)
- "Lag" (Lag Group VARX-L)
- "SparseLag" (Lag Sparse Group VARX-L)
- "OwnOther" (Own/Other Group VARX-L)
- "SparseOO" (Own/Other Sparse Group VARX-L)
- "EFX" (Endogenous First VARX-L)
- "HVARC" (Componentwise HVAR)
- "HVAROO" (Own/Other HVAR)
- "HVARELEM" (Elementwise HVAR)
- "Tapered" (Lag weighted Lasso VAR)

The first number in the vector "gran" specifies how deep to construct the penalty grid and the second specifies how many penalty parameters to use If ownlambas is set to TRUE, gran should contain the user-supplied penalty parameters.

VARX specifications consist of a list with entry k denoting the series that are to be modeled and entry s to denote the maximal lag order for exogenous series.

The argument alpha is ignored unless the structure choice is "SparseLag" or "Lag." By default "alpha" is set to NULL and will be initialized as 1/(k+1) in cv.BigVAR and BigVAR.est. Any user supplied values must be between 0 and 1.

Note

The specifications "Basic", "Lag," "SparseLag," "SparseOO," and "OwnOther" can accommodate both VAR and VARX models. EFX only applies to VARX models. "HVARC," "HVAROO," "HVARELEM," and "Tapered" can only be used with VAR models.

References

William B Nicholson, Jacob Bien, and David S Matteson. "High Dimensional Forecasting via Interpretable Vector Autoregression." arXiv preprint arXiv:1412.5250, 2016. William B Nicholson, David S. Matteson, and Jacob Bien (2015), "VARX-L Structured regularization for large vector autoregressions with exogenous variables," arXiv preprint arXiv:1508.07497, 2016. William B Nicholson, David S. Matteson, and Jacob Bien (2016), "BigVAR: Dimension Reduction Reduction Methods for Multivariate Time Series," http://www.wbnicholson.com/BigVAR.pdf.

See Also

cv.BigVAR,BigVAR.est

Examples

```
library(BigVAR)
# VARX Example
# Create a Basic VARX-L with k=2, m=1, s=2, p=4
VARX=list()
VARX$k=2 # indicates that the first two series are modeled
VARX$s=2 # sets 2 as the maximal lag order for exogenous series
data(Y)
T1=floor(nrow(Y)/3)
T2=floor(2*nrow(Y)/3)
Model1=constructModel(Y,p=4,struct="Basic",gran=c(50,10),verbose=FALSE,VARX=VARX,T1=T1,T2=T2)
```

---

cv.BigVAR *Cross Validation for BigVAR*

Description

Cross Validation for BigVAR

Usage

```
cv.BigVAR(object)
```

Arguments

object	BigVAR object created from ConstructModel

Details

The main function of the BigVAR package. Performs cross validation to select penalty parameters over a training sample (as the minimizer of in-sample MSFE), then evaluates them over a test set. Compares against sample mean, random walk, AIC, and BIC benchmarks. Creates an object of class BigVAR.results

Value

An object of class BigVAR.results.

See Also

constructModel, BigVAR.results,BigVAR.est

Examples

```
data(Y)
# Fit a Basic VARX-L with rolling cross validation
Model1=constructModel(Y,p=4,struct="Basic",gran=c(50,10))
results=cv.BigVAR(Model1)
```

MultVarSim *Simulate a VAR*

Description

Simulate a VAR

Usage

```
MultVarSim(k, A1, p, Sigma, T)
```

Arguments

k	Number of Series
A1	Either a $k \times k$ coefficient matrix or a $kp \times kp$ matrix created using VarptoVar1MC.
p	Maximum Lag Order
Sigma	Residual Covariance Matrix of dimension $k \times k$
T	Number of simulations

Value

Returns a $T \times k$ of realizations from a VAR.

References

Lutkepohl, "A New Introduction to Multiple Time Series Analysis"

See Also

VarptoVar1MC

Examples

```
k=3;p=6
B=matrix(0,nrow=k,ncol=p*k)
A1<- matrix(c(.4,-.02,.01,-.02,.3,.02,.01,.04,.3),ncol=3,nrow=3)
A2 <- matrix(c(.2,0,0,0,.3,0,0,0,.13),ncol=3,nrow=3)
B[,1:k]=A1
B[,(4*k+1):(5*k)]=A2
A <- VarptoVar1MC(B,p,k)
Y <-MultVarSim(k,A,p,.1*diag(k),100)
```

---

plot *Plot an object of class BigVAR.results*

Description

Plot an object of class BigVAR.results

Usage

```
## S4 method for signature 'BigVAR.results'
plot(x, y = NULL, ...)
```

Arguments

x	BigVAR.results object created from cv.BigVAR
y	NULL
...	additional arguments

Details

Plots the in sample MSFE of all values of lambda with the optimal value highlighted.

plot.BigVAR *Plot a BigVAR object*

Description

Plot a BigVAR object

Usage

```
## S4 method for signature 'BigVAR'
plot(x, y = NULL, ...)
```

Arguments

x	BigVAR object created from ConstructModel
y	NULL
...	additional plot arguments

Details

Uses plot.zoo to plot each individual series of Y on a single plot

Value

NA, side effect is graph

See Also

constructModel

predict *Forecast using a BigVAR.results object*

Description

Forecast using a BigVAR.results object

Usage

```
predict(object,...)
```

Arguments

object	BigVAR.results object from cv.BigVAR
...	additional arguments affecting the predictions produced (e.g. n.ahead)

Details

Provides n.ahead step forecasts using the model produced by cv.BigVAR.

See Also

cv.BigVAR

Examples

```
data(Y)
Y=Y[1:100,]
Model1=constructModel(Y,p=4,struct="Basic",gran=c(50,10),verbose=FALSE)
results=cv.BigVAR(Model1)
predict(results,n.ahead=1)
```

---

show *Default show method for an object of class BigVAR.results*

Description

Default show method for an object of class BigVAR.results

Usage

```
## S4 method for signature 'BigVAR.results'
show(object)
```

Arguments

object	BigVAR.results object created from cv.BigVAR

Details

prints forecast results and additional diagnostic information as well as comparisons with mean, random walk, and AIC, and BIC benchmarks

See Also

cv.BigVAR,BigVAR.results

show.BigVAR *Default show method for an object of class BigVAR*

Description

Default show method for an object of class BigVAR

Usage

```
## S4 method for signature 'BigVAR'
show(object)
```

Arguments

object	BigVAR object created from ConstructModel

Value

Displays the following information about the BigVAR object:

- Prints the first 5 rows of Y
- Penalty Structure
- Relaxed Least Squares Indicator
- Maximum lag order
- VARX Specifications (if applicable)
- Start, end of cross validation period

See Also

constructModel

SparsityPlot.BigVAR.results *Sparsity Plot of a BigVAR.results object*

Description

Sparsity Plot of a BigVAR.results object

Usage

```
SparsityPlot.BigVAR.results(object)
```

Arguments

object	BigVAR.results object

Details

Uses levelplot from the lattice package to plot the magnitude of each coefficient in the last coefficient estimated by cv.BigVAR.

Value

NA, side effect is graph

See Also

cv.BigVAR, BigVAR.results

Examples

```
data(Y)
Y <- Y[1:100,]
Model1 <- constructModel(Y,p=4,struct="Basic",gran=c(50,10),verbose=FALSE)
SparsityPlot.BigVAR.results(cv.BigVAR(Model1))
```

VarptoVar1MC *Converts a VAR coefficient matrix of order p to multiple companion form*

Description

Converts a VAR coefficient matrix of order p to multiple companion form

Usage

```
VarptoVar1MC(B, p, k)
```

Arguments

B	a $k \times kp$ coefficient matrix
p	Lag order
k	Number of Series

Value

Returns a $kp \times kp$ coefficient matrix representing all coefficient matrices contained in Ai as a VAR(1).

References

See page 15 of Lutkepohl, "A New Introduction to Multiple Time Series Analysis"

See Also

MultVarSim

Examples

```
k=3;p=6
B=matrix(0,nrow=k,ncol=p*k)
A1<- matrix(c(.4,-.02,.01,-.02,.3,.02,.01,.04,.3),ncol=3,nrow=3)
A2 <- matrix(c(.2,0,0,0,.3,0,0,0,.13),ncol=3,nrow=3)
B[,1:k]=A1
B[,(4*k+1):(5*k)]=A2
A <- VarptoVar1MC(B,p,k)
```

VARXFit *Fit a VAR or VARX model by least squares*

Description

Fit a VAR or VARX model by least squares

Usage

```
VARXFit(Y, p, IC, VARX = NULL)
```

Arguments

Y	a $t \times k$ multivariate time series
p	maximum lag order
IC	Information criterion indicator, if set to NULL, it will fit a least squares VAR(X) of orders p and s. Otherwise, if set to "AIC" or "BIC" it return the model with lag orders that minimize the given IC.
VARX	a list of VARX specifications (as in constructModel (or NULL)

Details

This function uses a modified form of the least squares technique proposed by Neumaier and Schneider (2001). It fits a least squares VAR or VARX via a QR decomposition that does not require explicit matrix inversion. This results in improved computational performance as well as numerical stability over the conventional least squares approach.

Value

Returns a list with four entries:

- "Bhat"Estimated $k \times kp + ms$ coefficient matrix
- "SigmaUEstimated $k \times k$ residual covariance matrix
- "phat"Selected lag order for VAR component
- "shat"Selected lag order for VARX component

References

Neumaier, Arnold, and Tapio Schneider. "Estimation of parameters and eigenmodes of multivariate autoregressive models." ACM Transactions on Mathematical Software (TOMS) 27.1 (2001): 27-57.

See Also

constructModel, cv.BigVAR

Examples

```
data(Y)
# fit a VAR_3(3)
mod <- VARXFit(Y,3,NULL,NULL)
# fit a VAR_3 with p= 6 and lag selected according to AIC
modAIC <- VARXFit(Y,6,"AIC",NULL)
# Fit a VARX_{2,1} with p=6, s=4 and lags selected by BIC
modXBIC <- VARXFit(Y,6,"BIC",list(k=2,s=4))
```

VARXForecastEval *Evaluate forecasts from a VAR or VARX with lag orders selected by AIC/BIC*

Description

Evaluate forecasts from a VAR or VARX with lag orders selected by AIC/BIC

Usage

```
VARXForecastEval(Y, X, p, s, T1, T2, IC, h, iterated = FALSE)
```

Arguments

Y	a $T \times k$ multivariate time series
X	a $T \times m$ multivariate time series of unmodeled exogenous variables
p	maximum lag order for endogenous series
s	maximum lag order for exogenous series

T1	start of forecast evaluation period.
T2	end of forecast evaluation period
IC	specifies whether to select lag order according to "AIC" or "BIC"
h	desired forecast horizon
iterated	indicator as to whether to use iterated or direct multistep forecasts (if applicable, VAR context only)

Details

This function evaluates the one-step ahead forecasts of a VAR or VARX fit by least squares over an evaluation period. At every point in time, lag orders for the endogenous and exogenous series are selected according to AIC or BIC. This function is run automatically when cv.BigVAR is called unless ic is set to FALSE in constructModel.

Value

Returns the one-step ahead MSFE over the evaluation period.

References

Neumaier, Arnold, and Tapio Schneider. "Estimation of parameters and eigenmodes of multivariate autoregressive models." ACM Transactions on Mathematical Software (TOMS) 27.1 (2001): 27-57.

See Also

VARXFit,constructModel, cv.BigVAR

Examples

```
data(Y)

# Evaluate the performance of a VAR with lags selected by BIC.
p <- 4
T1 <- floor(nrow(Y))/3
T2 <- floor(2*nrow(Y))/3
# Matrix of zeros for X
X <- matrix(0,nrow=nrow(Y),ncol=ncol(Y))
BICMSFE <- VARXForecastEval(Y,X,p,0,T1,T2,"BIC",1)
```

Y *Simulated Multivariate Time Series*

Description

Realization of a simulated multivariate time series

Details

100×3 multivariate time series distributed according to the generator matrix A.

Author(s)

Will Nicholson

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