

# Package ‘MultiATSM’

April 15, 2022

**Type** Package

**Title** Multicountry Term Structure of Interest Rates Models

**Version** 0.2.1

**Date** 2022-04-14

**Author** Rubens Moura

**Maintainer** Rubens Moura <rubens.gtmoura@gmail.com>

**Description** Estimation routines for several classes of affine term structure of interest rates models. All the models are based on the single-country unspanned macroeconomic risk framework from Joslin, Priebisch, and Singleton (2014) <doi:10.1111/jofi.12131>. Multicountry extensions such as the ones of Jotikasthira, Le, and Lundblad (2015) <doi:10.1016/j.jfineco.2014.09.004> and Candelon and Moura (2021) <<http://hdl.handle.net/2078.1/249985>> are also available.

**License** GPL-2 | GPL-3

**Encoding** UTF-8

**RoxygenNote** 7.1.1

**Imports** zoo, pracma, wrapr, hablar, ggplot2

**Suggests** readxl, readr, magic, Jmisc, functional, cowplot, powerplus, reshape2, sjmisc, stringr, knitr, rmarkdown, bookdown, kableExtra, neldermead, magrittr

**Depends** R (>= 3.5.0)

**VignetteBuilder** knitr

**NeedsCompilation** no

**Repository** CRAN

**Date/Publication** 2022-04-14 22:22:29 UTC

## R topics documented:

A0N_MLEdensity_WOE__jointQ_Bootstrap . . . . .	4
A0N_MLEdensity_WOE__jointQ_sepSigma_Bootstrap . . . . .	6
A0N_MLEdensity_WOE__sepQ_Bootstrap . . . . .	8

A0N__computeBnAn_jointQ . . . . .	10
A0N__computeBnAn_sepQ . . . . .	11
aux2true . . . . .	12
Bootstrap . . . . .	13
BootstrapBoundsSet . . . . .	14
bound2x . . . . .	15
BR_jps_out . . . . .	16
BUnspannedAdapJoint . . . . .	16
BUnspannedAdapSep . . . . .	17
BUnspannedAdapSep_BS . . . . .	17
contain . . . . .	18
DatabasePrep . . . . .	19
DataForEstimation . . . . .	20
DataSet_BS . . . . .	21
df_dx . . . . .	22
FactorsGVAR . . . . .	23
FEVDandGFEVDbs_jointQ . . . . .	23
FEVDandGFEVDbs_jointQ_Ortho . . . . .	24
FEVDandGFEVDbs_sepQ . . . . .	25
FEVDgraphsJLLOrtho . . . . .	25
FEVDgraphsJoint . . . . .	26
FEVDgraphsSep . . . . .	27
FEVDjoint . . . . .	28
FEVDjointOrthoJLL . . . . .	28
FEVDjointOrthoJLL_BS . . . . .	29
FEVDjoint_BS . . . . .	29
FEVDsep . . . . .	30
FEVDsep_BS . . . . .	31
FitgraphsJoint . . . . .	31
FitgraphsSep . . . . .	32
FMN__Rotate . . . . .	33
ForecastYields . . . . .	34
ForecastYieldsJointQ . . . . .	35
ForecastYieldsSepQ . . . . .	36
Functionf . . . . .	37
Functionf_Boot . . . . .	37
f_with_vectorized_parameters . . . . .	38
GaussianDensity . . . . .	40
getpara . . . . .	40
getx . . . . .	41
GFEVDgraphsJLLOrtho . . . . .	42
GFEVDgraphsJoint . . . . .	42
GFEVDgraphsSep . . . . .	43
GFEVDjoint . . . . .	44
GFEVDjointOrthoJLL . . . . .	45
GFEVDjointOrthoJLL_BS . . . . .	45
GFEVDjoint_BS . . . . .	46
GFEVDsep . . . . .	47

GFEVDsep_BS . . . . .	48
GIRFgraphsJLLOrtho . . . . .	48
GIRFgraphsJoint . . . . .	49
GIRFgraphsSep . . . . .	50
GIRFjoint . . . . .	50
GIRFjointOrthoJLL . . . . .	51
GIRFjointOrthoJLL_BS . . . . .	52
GIRFjoint_BS . . . . .	53
GIRFSep . . . . .	53
GIRFSep_BS . . . . .	54
GraphicalOutputs . . . . .	55
GVAR . . . . .	55
IdxAllSpanned . . . . .	57
IdxSpanned . . . . .	57
InputsForMLEdensity . . . . .	58
InputsForMLEdensity_BS . . . . .	60
InputsForOutputs . . . . .	61
IRFandGIRFbs_jointQ . . . . .	63
IRFandGIRFbs_jointQ_Ortho . . . . .	64
IRFandGIRFbs_sepQ . . . . .	65
IRFgraphsJLLOrtho . . . . .	65
IRFgraphsJoint . . . . .	66
IRFgraphsSep . . . . .	67
IRFjoint . . . . .	68
IRFjointOrthoJLL . . . . .	68
IRFjointOrthoJLL_BS . . . . .	69
IRFjoint_BS . . . . .	69
IRFsep . . . . .	70
IRFsep_BS . . . . .	71
JLL . . . . .	71
K1XQStationary . . . . .	73
killa . . . . .	73
LabelsSpanned . . . . .	74
LabelsStar . . . . .	74
LabFac . . . . .	74
Maturities . . . . .	75
MLEdensity_jointQ . . . . .	76
MLEdensity_jointQ_sepSigma . . . . .	77
MLEdensity_sepQ . . . . .	79
ModelPara . . . . .	81
MultiATSM . . . . .	81
NumOutputs . . . . .	82
NumOutputs_Bootstrap . . . . .	83
Optimization . . . . .	83
Optimization_Boot . . . . .	85
OutputConstructionJoint . . . . .	87
OutputConstructionJoint_BS . . . . .	87
OutputConstructionSep . . . . .	88

OutputConstructionSep_BS . . . . .	89
ParaLabels . . . . .	90
pca_weights_one_country . . . . .	90
PdynamicsSet_BS . . . . .	91
pos2x . . . . .	92
Reg_K1Q . . . . .	92
Reg_OLSconstrained . . . . .	93
RemoveNA . . . . .	94
RiskFactors . . . . .	94
RiskFactorsGraphs . . . . .	95
RiskFactorsPrep . . . . .	95
RMSEjoint . . . . .	96
RMSEsep . . . . .	96
SpannedFactorsjointQ . . . . .	97
SpannedFactorsSepQ . . . . .	97
Spanned_Factors . . . . .	98
sqrtm_robust . . . . .	98
StarFactors . . . . .	99
TradeFlows . . . . .	100
Transition_Matrix . . . . .	100
true2aux . . . . .	101
update_para . . . . .	102
VAR . . . . .	104
VarianceExplainedJoint . . . . .	104
VarianceExplainedSep . . . . .	105
x2bound . . . . .	106
x2pos . . . . .	106
Yields . . . . .	107
YieldsFitJoint . . . . .	107
YieldsFitsep . . . . .	108

**Index****109**


---

A0N\_MLEdensity\_WOE\_\_jointQ\_Bootstrap

*Compute the maximum likelihood function (joint Q models) - Bootstrap version*

---

**Description**

Compute the maximum likelihood function (joint Q models) - Bootstrap version

**Usage**

```

A0N_MLEdensity_WOE__jointQ_Bootstrap(
  K1XQ,
  r0,
  SSZ,
  K0Z,
  K1Z,
  se,
  Gy.0,
  mat,
  Y,
  Z,
  P,
  Wpca,
  We,
  WpcaFull,
  dt,
  Economies,
  FactorLabels,
  ModelType,
  residBS,
  MaxEigen,
  GVARinputs,
  JLLinputs,
  nargout
)

```

**Arguments**

K1XQ	risk-neutral feedback matrix (NxN)
r0	long-run interest rate (scalar)
SSZ	variance-covariance matrix (KxK)
K0Z	intercept from the P-dynamics (Kx1)
K1Z	feedback matrix from the P-dynamics (KxK)
se	Variance of the portfolio of yields observed with error (scalar)
Gy.0	matrix of contemporaneous terms from the P-dynamics (KxK)
mat	vector of maturities (in years) of yields used in estimation (J x 1)
Y	matrix of yields used in estimation (J x T)
Z	complete set of spanned and unspanned factors (KxT)
P	complete set of spanned factors (NxT)
Wpca	matrix of weights of the portfolios observed without errors (NxJ)
We	matrix of weights of the portfolios observed with errors ((J-N)xJ)
WpcaFull	composite matrix of weights the portfolios observed with and without errors

dt	time interval unit of the model (scalar). For instance, if data is (i) monthly, dt <- 12; (ii) quarterly, dt <- 4; (iii) yearly, dt <- 1.
Economies	a string-vector containing the names of the economies which are part of the economic system
FactorLabels	string-list based which contains the labels of all the variables present in the model
ModelType	feasible options are (i) "VAR jointQ", (ii) "GVAR jointQ" or (iii) "JLL jointSigma"
residBS	index of the re-ordered bootstrap residuals
MaxEigen	largest eigenvalue under the P-dynamics
GVARinputs	if the model chosen is the "GVAR sepQ", "GVARinputs" should be specified (see "GVAR" function )
JLLinputs	if the model chosen is the "JLL jointSigma". "JLLinputs" should be specified (see "JLL" function)
nargout	if nargout== 1: provides only the values of the likelihood; if nargout== 2: complete ATSM outputs

## References

This function is modified version of the "A0N\_MLEdensity\_WOE" function by Le and Singleton (2018).

"A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>

---

A0N\_MLEdensity\_WOE\_\_jointQ\_sepSigma\_Bootstrap

*Compute the maximum likelihood function ("joint Q" models for separate Sigma estimation) - Bootstrap version*

---

## Description

Compute the maximum likelihood function ("joint Q" models for separate Sigma estimation) - Bootstrap version

## Usage

```
A0N_MLEdensity_WOE__jointQ_sepSigma_Bootstrap(
    K1XQ,
    r0,
    SSZ,
    K0Z,
    K1Z,
    se,
    Gy.0,
    mat,
```

```

Y,
Z,
P,
Wpca,
We,
WpcaFull,
dt,
Economies,
FactorLabels,
ModelType,
residBS,
MaxEigen,
GVARinputs,
JLLinputs,
nargout
)

```

### Arguments

K1XQ	risk-neutral feedback matrix (NxN)
r0	long-run interest rate (scalar)
SSZ	variance-covariance matrix (KxK)
K0Z	intercept from the P-dynamics (Kx1)
K1Z	feedback matrix from the P-dynamics (KxK)
se	Variance of the portfolio of yields observed with error (scalar)
Gy.0	matrix of contemporaneous terms from the P-dynamics (KxK)
mat	vector of maturities (in years) of yields used in estimation (J x 1)
Y	matrix of yields used in estimation (J x T)
Z	complete set of spanned and unspanned factors (KxT)
P	complete set of spanned factors (NxT)
Wpca	matrix of weights of the portfolios observed without errors (NxJ)
We	matrix of weights of the portfolios observed with errors ((J-N)xJ)
WpcaFull	composite matrix of weights the portfolios observed with and without errors
dt	time interval unit of the model (scalar). For instance, if data is (i) monthly, dt <- 12; (ii) quarterly, dt <- 4; (iii) yearly, dt <- 1.
Economies	a string-vector containing the names of the economies which are part of the economic system
FactorLabels	string-list based which contains the labels of all the variables present in the model
ModelType	feasible options are (i) "JLL original" or (ii) "JLL NoDomUnit"
residBS	indexes of the re-ordered bootstrap residuals
MaxEigen	largest eigenvalue under the P-dynamics

GVARinputs	if the model chosen is the "GVAR sepQ", "GVARinputs" must be specified (see "GVAR" function )
JLLinputs	if the model chosen is the "JLL jointSigma", "JLLinputs" must be specified (see "JLL" function)
nargout	if nargout== 1: provides only the values of the likelihood; if nargout== 2: complete ATSM outputs

## References

This function is modified version of the "A0N\_MLEdensity\_WOE" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

A0N\_MLEdensity\_WOE\_\_sepQ\_Bootstrap

*Compute the maximum likelihood function ("sep Q" models) - Bootstrap version*

---

## Description

Compute the maximum likelihood function ("sep Q" models) - Bootstrap version

## Usage

```
A0N_MLEdensity_WOE__sepQ_Bootstrap(
    K1XQ,
    r0,
    SSZ,
    K0Z,
    K1Z,
    se,
    Gy.0,
    mat,
    Y,
    Z,
    P,
    Wpca,
    We,
    WpcaFull,
    dt,
    Economy,
    FactorLabels,
    ModelType,
    residBS,
```



```

    MaxEigen,
    GVARinputs,
    nargout
)

```

### Arguments

K1XQ	risk-neutral feedback matrix (N×N)
r0	long-run interest rate (scalar)
SSZ	variance-covariance matrix (K×K)
K0Z	intercept from the P-dynamics (K×1)
K1Z	feedback matrix from the P-dynamics (K×K)
se	Variance of the portfolio of yields observed with error (scalar)
Gy.0	matrix of contemporaneous terms from the P-dynamics (K×K)
mat	vector of maturities (in years) of yields used in estimation (J × 1)
Y	matrix of yields used in estimation (J × T)
Z	complete set of spanned and unspanned factors (K×T)
P	complete set of spanned factors (N×T)
Wpca	matrix of weights of the portfolios observed without errors (N×J)
We	matrix of weights of the portfolios observed with errors ((J-N)×J)
WpcaFull	composite matrix of weights the portfolios observed with and without errors
dt	time interval unit of the model (scalar). For instance, if data is (i) monthly, dt <- 12; (ii) quarterly, dt <- 4; (iii) yearly, dt <- 1.
Economy	Name of the economies under study
FactorLabels	string-list based which contains the labels of all the variables present in the model
ModelType	Feasible options are: (i) "JPS", (ii) "JPS jointP" or (iii) "GVAR sepQ"
residBS	index of the re-ordered bootstrap residuals
MaxEigen	largest eigenvalue under the P-dynamics
GVARinputs	if the model chosen is the "GVAR sepQ", "GVARinputs" should be specified (see "GVAR" function)
nargout	if nargout== 1: provides only the values of the likelihood; if nargout== 2: complete ATSM outputs

### References

This function is modified version of the "A0N\_MLEdensity\_WOE" function by Le and Singleton (2018).

"A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>

---

A0N\_\_computeBnAn\_jointQ

*Compute the cross-section loadings of yields of a canonical A0\_N model ("joint Q" models)*

---

### Description

Compute the cross-section loadings of yields of a canonical A0\_N model ("joint Q" models)

### Usage

A0N\_\_computeBnAn\_jointQ(mat, K1XQ, dx, r0, SSX, Economies)

### Arguments

mat	vector of maturities (J x 1). Maturities are in multiples of the discrete interval used in the model
K1XQ	risk neutral feedback matrix (N x N)
dx	state loadings for the one-period rate (1xN). Default is a vector of ones
r0	the long run risk neutral mean of the short rate (scalar)
SSX	the covariance matrix of the errors (N x N)
Economies	Set of economies that are part of the economic system (vector of text)

### Value

List containing:

- Intercept (Jx1)
- slope (JxN)
- the betan (JX1, part of the intercepts unrelated to the long run risk neutral mean r0) coefficients of a canonical A\_0(N).

### References

This function is an extended version of the "A0N\_\_computeBnAn" function by Le and Singleton (2018).

"A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>

---

A0N\_\_computeBnAn\_sepQ *Compute the cross-section loadings of yields of a canonical A0\_N model ("sep Q" models)*

---

### Description

Compute the cross-section loadings of yields of a canonical A0\_N model ("sep Q" models)

### Usage

A0N\_\_computeBnAn\_sepQ(mat, K1XQ, dx, r0, SSX)

### Arguments

mat	vector of maturities (J x 1). Maturities are in multiples of the discrete interval used in the model
K1XQ	risk neutral feedback matrix (N x N)
dx	state loadings for the one-period rate (1xN). Default is a vector of ones
r0	the long run risk neutral mean of the short rate (scalar)
SSX	the covariance matrix of the errors (N x N)

### Value

List containing:

- Intercept (Jx1)
- slope (JxN)
- the betan (JX1, part of the intercepts unrelated to the long run risk neutral mean r0) coefficients of a canonical A\_0(N).

### References

- This function is based on the "A0N\_\_computeBnAn" function by Le and Singleton (2018). "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>
- Dai and Singleton (2000). "Specification Analysis of Affine Term Structure Models" (The Journal of Finance)

---

aux2true	<i>Map auxiliary (unconstrained) parameters a to constrained parameters b</i>
----------	---

---

### Description

Map auxiliary (unconstrained) parameters a to constrained parameters b

### Usage

```
aux2true(
  a,
  ctype,
  lb,
  ub,
  FactorLabels,
  Economies,
  JLLinputs = NULL,
  GVARinputs = NULL,
  nargout
)
```

### Arguments

a	unconstrained auxiliary parameter
ctype	One of the following options: <ul style="list-style-type: none"> <li>• 'Jordan'</li> <li>• 'Jordan; stationary'</li> <li>• 'Jordan MultiCountry'</li> <li>• 'Jordan MultiCountry; stationary'</li> <li>• 'psd';</li> <li>• 'BlockDiag'</li> <li>• 'bounded'</li> <li>• 'diag'</li> <li>• 'JLLstructure'</li> </ul>
lb	lower bounds of b (if option 'bounded' is chosen)
ub	upper bounds of b (if option 'bounded' is chosen)
FactorLabels	string-list based which contains the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system
JLLinputs	Inputs used in the estimation of the JLL-based models
GVARinputs	Inputs used in the estimation of the GVAR-based models
nargout	"nargout <- 1" returns a constrained scalar or matrix "nargout <- 2" returns a list of parameters

## References

This function is a modified version of the "aux2true" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

Bootstrap	<i>Generates the bootstrap-related outputs</i>
-----------	--

---

## Description

Generates the bootstrap-related outputs

## Usage

```
Bootstrap(
    ModelType,
    ModelParaPE,
    NumOutPE,
    mat,
    Economies,
    InputsForOutputs,
    FactorLabels,
    DataFrequency,
    vararginPE,
    JLLinputs = NULL,
    GVARinputs = NULL
)
```

## Arguments

ModelType	string-vector containing the label of the model to be estimated
ModelParaPE	point estimate from the model parameters (see the outputs of the "Optimization" function)
NumOutPE	point estimate from the numerical outputs (see the outputs of the "NumOutputs" function)
mat	vector of maturities (in years) used in the estimation
Economies	string-vector containing the names of the economies which are part of the economic system
InputsForOutputs	list containing the desired inputs for the construction of IRFs, GIRFs, FEVDs, and GFEVDs.
FactorLabels	string-list based which contains the labels of all the variables present in the model

DataFrequency	character-based vector: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"
vararginPE	list containing starting values and constraints (see arguments of the "Optimization" function)
JLLinputs	list of necessary inputs for the estimation of JLL-based models (see "JLL" function)
GVARinputs	list of necessary inputs for the estimation of GVAR-based models (see "GVAR" function)

### Value

list containing the following elements:

- list of model parameters for one each one the draws;
- list of numerical outputs (IRFs, GIRFs, FEVDs, GFEVDs) for each one of the draws;
- Confidence bands for the chosen level of significance.

### References

This function is a modified and extended version of the "VARirbound" function from "A toolbox for VAR analysis" by Ambrogio Cesa-Bianchi (<https://github.com/ambropo/VAR-Toolbox>)

### Examples

# See examples in the vignette file of this package (Section 4).

---

BootstrapBoundsSet      *Builds the confidence bounds and graphs (Bootstrap set)*

---

### Description

Builds the confidence bounds and graphs (Bootstrap set)

### Usage

```
BootstrapBoundsSet(
  ModelType,
  ModelBootstrap,
  NumOutPE,
  InputsForOutputs,
  Economies
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelBootstrap	list containing the complete set of model parameters after the bootstrap estimation procedure
NumOutPE	point estimate from the numerical outputs (see the outputs of the "NumOutputs" function)
InputsForOutputs	list containing the desired inputs for the construction of IRFs, GIRFs, FEVDs, and GFEVDs
Economies	string-vector containing the names of the economies which are part of the economic system

---

bound2x	<i>Transform a number bounded between a lower bound and upper bound to x by:</i>
---------	--

---

**Description**

Transform a number bounded between a lower bound and upper bound to x by:

**Usage**

bound2x(y, lb, ub)

**Arguments**

y	Number to be transformed (scalar)
lb	lower bound (scalar)
ub	upper bound (scalar)

**References**

This function is based on the "bound2x" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

BR_jps_out	<i>Replications of the JPS (2014) outputs by Bauer and Rudebusch (2017)</i>
------------	---

---

**Description**

Unspanned macro risk model outputs by Bauer and Rudebusch (2017)

**Usage**

```
data("BR_jps_gro_R3")
```

**Format**

Unspanned macro risk model outputs by Bauer and Rudebusch (2017)

**est.llk** summary list of log-likelihood estimations

**M.o** time series of unspanned factors

**pars** additional summary list of log-likelihood estimations

**W** Weight matrix that results from principal components analysis

**Y** time series of bond yields

**N** total number of risk factor of the model (spanned and unspanned)

**R** total number of spanned factor of the model

**References**

Bauer, M. and Rudebusch, G. "Resolving the Spanning Puzzle in Macro-Finance Term Structure Models"

---

BUnspannedAdapJoint	<i>Transform B_spanned into B_unspanned for jointQ models</i>
---------------------	---

---

**Description**

Transform B\_spanned into B\_unspanned for jointQ models

**Usage**

```
BUnspannedAdapJoint(G, M, N, C, J, BSpanned)
```



**Arguments**

G	number of global unspanned factors
M	number of domestic unspanned factors
N	number of domestic spanned factors
C	number of economies of the economic system
J	number of country-specific observed bond yields
BSpanded	B that accomodates only the map to the spanned factors only

---

BUnspannedAdapSep	<i>Transform B_spanded into B_unspanned for sepQ models</i>
-------------------	---

---

**Description**

Transform B\_spanded into B\_unspanned for sepQ models

**Usage**

BUnspannedAdapSep(G, M, ModelPara, Economies, Economy, ModelType)

**Arguments**

G	number of global unspanned factors
M	number of domestic unspanned factors per country
ModelPara	list of model parameter estimates (See the "Optimization" function)
Economies	complet set of economies of the economic system
Economy	specific economy under study
ModelType	a string-vector containing the label of the model to be estimated

---

BUnspannedAdapSep_BS	<i>Obtain the full form of B unspanned for "sep Q" models within the bootstrap setting</i>
----------------------	--

---

**Description**

Obtain the full form of B unspanned for "sep Q" models within the bootstrap setting

**Usage**

BUnspannedAdapSep\_BS(G, M, ModelParaBoot, Economies, Economy, ModelType, tt)

**Arguments**

G	number of global unspanned factors
M	number of country-specific domestic unspanned factors
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
Economies	string-vector containing the names of the economies which are part of the economic system
Economy	string-vector containing the names of the economy under study
ModelType	string-vector containing the label of the model to be estimated
tt	number of the bootstrap draw

---

 contain

---

*Check whether one element is a subset of another element*


---

**Description**

Check whether one element is a subset of another element

**Usage**

```
contain(s1, s2)
```

**Arguments**

s1	smaller subset
s2	complete set

**References**

This function is based on the "contain" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

DatabasePrep

*Prepare the GVARFactors database*


---

**Description**

Prepare the GVARFactors database

**Usage**

```
DatabasePrep(
  t_First,
  t_Last,
  Economies,
  N,
  FactorLabels,
  ModelType,
  Wgvar = NULL,
  DataPathMacro = NULL,
  DataPathYields = NULL
)
```

**Arguments**

t_First	sample starting date (yyyy-mm-dd)
t_Last	sample last date (yyyy-mm-dd)
Economies	string-vector containing the names of the economies which are part of the economic system
N	number of country-specific spanned factor (scalar)
FactorLabels	list containing the factor labels
ModelType	string-vector containing the label of the model to be estimated
Wgvar	GVAR transition matrix (Cx $C$ ), if GVAR type model is chosen; default is set to NULL.
DataPathMacro	path of the Excel file containing the macroeconomic data (if any). The default is linked to the Excel file available in the package.
DataPathYields	path of the Excel file containing the yields data (if any). The default is linked to the Excel file available in the package.

**Value**

List of the risk factor set used in the estimation of the GVAR model

List containing the risk factor set used in the estimation of the GVAR-based models

**Examples**

```

DomVar <- c("Eco_Act", "Inflation")
GlobalVar <- c("GBC", "CPI_OECD")
t0 <- "2006-09-01"
tF <- "2019-01-01"
Economies <- c("China", "Brazil", "Mexico", "Uruguay", "Russia")
N <- 3
ModelType <- "JPS jointQ"
FactorLabels <- LabFac(N, DomVar, GlobalVar, Economies, ModelType)

GVARFactors <- DatabasePrep(t0, tF, Economies, N, FactorLabels, ModelType)

```

---

DataForEstimation	<i>Retrieve data from Excel and build the database used in the model estimation</i>
-------------------	---

---

**Description**

Retrieve data from Excel and build the database used in the model estimation

**Usage**

```

DataForEstimation(
  t0,
  tF,
  Economies,
  N,
  FactorLabels,
  ModelType,
  DataFrequency,
  DataPathMacro = NULL,
  DataPathYields = NULL,
  Wgvar = NULL
)

```

**Arguments**

t0	Sample starting date (yyyy-mm-dd)
tF	Sample last date (yyyy-mm-dd)
Economies	string-vector containing the names of the economies which are part of the economic system
N	Number of country-specific spanned factor (scalar)
FactorLabels	String-list based which contains the labels of all the variables present in the model

ModelType	String-vector containing the label of the model to be estimated
DataFrequency	Character-based-vector. Available options are: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"
DataPathMacro	Path of the Excel file conating the macroeconomic data (if any). The default is linked to the excel file present in the package.
DataPathYields	Path of the Excel file conating the yields data (if any). The default is linked to the excel file present in the package.
Wgvar	GVAR transition matrix, if GVAR type model is chosen; default is set to NULL.

### Value

A list containing the

1. time series of the complete set of bond yields (matrix, JxT or CJxT);
2. time series of the complete set risk factors (matrix, KxT);
3. 'GVARFactors': list of all variables that are used in the estimation of the VARX (see e.g. 'CM\_Factors\_GVAR' file). If the estimated model type is not GVAR-based, then returns NULL.

### Examples

```
DomVar <- c("Eco_Act", "Inflation")
GlobalVar <- c("GBC", "CPI_OECD")
t0 <- "2006-09-01"
tF <- "2019-01-01"
Economies <- c("China", "Brazil", "Mexico", "Uruguay", "Russia")
N <- 2
ModelType <- "JPS"
FactorLabels <- LabFac(N, DomVar, GlobalVar, Economies, ModelType)
DataFrequency <- "Monthly"

DataModel <- DataForEstimation(t0, tF, Economies, N, FactorLabels, ModelType, DataFrequency)
```

---

DataSet\_BS

*Prepare the factor set for GVAR models (Bootstrap version)*

---

### Description

Prepare the factor set for GVAR models (Bootstrap version)

### Usage

```
DataSet_BS(ModelType, RiskFactors, Wgvar, Economies, FactorLabels)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
RiskFactors	Complete set of risk factors (KxT)
Wgvar	transition matrix from GVAR models (CxC)
Economies	string-vector containing the names of the economies which are part of the economic system
FactorLabels	string-list based which contains the labels of all the variables present in the model

---

df__dx	<i>Computes numerical first order derivative of f(x)</i>
--------	--

---

**Description**

Computes numerical first order derivative of f(x)

**Usage**

```
df__dx(f, x)
```

**Arguments**

f	function which contains vector (J x T) valued function handle
x	parameter values

**Value**

transformed matrix (MN x JT)

**References**

This function is based on the "df\_\_dx" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

FactorsGVAR

*Data: Risk Factors for the GVAR - Candelon and Moura (2021)*

---

### Description

Risk factors data used in the GVAR models - Candelon and Moura (2021)

### Usage

```
data("CM_Factors_GVAR")
```

### Format

list containing the variables used in the GVAR models

### References

Candelon, B. and Moura, R. "A Multi-Country Model of the Term Structures of Interest Rates with a GVAR".

---

FEVDandGFEVDbs\_jointQ *Creates the confidence bounds and the graphs of FEVDs and GFEVDs after bootstrap ("joint Q" models)*

---

### Description

Creates the confidence bounds and the graphs of FEVDs and GFEVDs after bootstrap ("joint Q" models)

### Usage

```
FEVDandGFEVDbs_jointQ(  
  ModelType,  
  ModelBootstrap,  
  NumOutPE,  
  InputsForOutputs,  
  Economies,  
  PathsGraphs  
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelBootstrap	list containing the complete set of model parameters after bootstrap estimation procedure
NumOutPE	list of model parameter point estimates
InputsForOutputs	list conataining the desired inputs for the construction of the outputs of interest
Economies	string-vector containing the names of the economies which are part of the economic system
PathsGraphs	path of the folder in which the graphs will be saved

---

FEVDandGFEVDbs\_jointQ\_Ortho

*Creates the confidence bounds and the graphs of FEVDs and GFEVDs after bootstrap (JLL-based models)*

---

**Description**

Creates the confidence bounds and the graphs of FEVDs and GFEVDs after bootstrap (JLL-based models)

**Usage**

```
FEVDandGFEVDbs_jointQ_Ortho(
  ModelType,
  ModelBootstrap,
  NumOutPE,
  InputsForOutputs,
  Economies,
  PathsGraphs
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelBootstrap	list containing the complete set of model parameters after bootstrap estimation procedure
NumOutPE	list of model parameter point estimates
InputsForOutputs	list conataining the desired inputs for the construction of the outputs of interest
Economies	a string-vector containing the names of the economies which are part of the economic system
PathsGraphs	path of the folder in which the graphs will be saved



---

FEVDandGFEVDbs_sepQ	<i>Creates the confidence bounds and the graphs of FEVDs and GFEVDs after bootstrap ("sep Q" models)</i>
---------------------	--

---

**Description**

Creates the confidence bounds and the graphs of FEVDs and GFEVDs after bootstrap ("sep Q" models)

**Usage**

```
FEVDandGFEVDbs_sepQ(  
  ModelType,  
  ModelBootstrap,  
  NumOutPE,  
  InputsForOutputs,  
  Economies,  
  PathsGraphs  
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelBootstrap	list containing the complete set of model parameters after bootstrap estimation procedure
NumOutPE	list of model parameter point estimates
InputsForOutputs	list containing the desired inputs for the construction of the outputs of interest
Economies	string-vector containing the names of the economies which are part of the economic system
PathsGraphs	path of the folder in which the graphs will be saved

---

FEVDgraphsJLLOrtho	<i>FEVDs graphs for orthogonalized risk factors of JLL-based models</i>
--------------------	---

---

**Description**

FEVDs graphs for orthogonalized risk factors of JLL-based models

**Usage**

```
FEVDgraphsJLLOrtho(
  ModelType,
  NumOut,
  WishPdynamicgraphs,
  WishYieldsgraphs,
  FEVDhoriz,
  PathsGraphs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPdynamicgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
FEVDhoriz	single numerical vector containing the desired horizon of analysis for the FEVDs
PathsGraphs	Path of the folder in which the graphs will be saved

---

FEVDgraphsJoint	<i>FEVDs graphs for ("joint Q" models)</i>
-----------------	--

---

**Description**

FEVDs graphs for ("joint Q" models)

**Usage**

```
FEVDgraphsJoint(
  ModelType,
  NumOut,
  WishPdynamicgraphs,
  WishYieldsgraphs,
  FEVDhoriz,
  PathsGraphs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPdynamicgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
FEVDhoriz	single numerical vector containing the desired horizon of analysis for the FEVDs
PathsGraphs	Path of the folder in which the graphs will be saved

---

FEVDgraphsSep	<i>FEVDs graphs for ("sep Q" models)</i>
---------------	--

---

**Description**

FEVDs graphs for ("sep Q" models)

**Usage**

```
FEVDgraphsSep(
  ModelType,
  NumOut,
  WishPdynamicgraphs,
  WishYieldgraphs,
  FEVDhoriz,
  PathsGraphs,
  Economies
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPdynamicgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
FEVDhoriz	single numerical vector containing the desired horizon of analysis for the FEVDs
PathsGraphs	Path of the folder in which the graphs will be saved
Economies	a string-vector containing the names of the economies which are part of the economic system

---

FEVDjoint	<i>FEVDs for "joint Q" models</i>
-----------	-----------------------------------

---

**Description**

FEVDs for "joint Q" models

**Usage**

FEVDjoint(ModelType, ModelPara, FEVDhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
FEVDhoriz	single numerical vector conataining the desired horizon of analysis for the FEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**Details**

Structural shocks are identified via Cholesky decomposition

---

FEVDjointOrthogoJLL	<i>Orthogonalized FEVDs for JLL models</i>
---------------------	--

---

**Description**

Orthogonalized FEVDs for JLL models

**Usage**

FEVDjointOrthogoJLL(ModelType, ModelPara, FEVDhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
FEVDhoriz	single numerical vector conataining the desired horizon of analysis for the FEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	a string-vector containing the names of the economies which are part of the economic system

**Details**

Structural shocks are identified via Cholesky decomposition

---

FEVDjointOrthogoJLL\_BS

*FEVDs after bootstrap for JLL-based models*

---

**Description**

FEVDs after bootstrap for JLL-based models

**Usage**

```
FEVDjointOrthogoJLL_BS(
  ModelType,
  ModelParaBoot,
  FEVDhoriz,
  FactorLabels,
  Economies
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
FEVDhoriz	single numerical vector containing the desired horizon of analysis for the FEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

FEVDjoint\_BS

*FEVDs after bootstrap for "joint Q" models*

---

**Description**

FEVDs after bootstrap for "joint Q" models

**Usage**

```
FEVDjoint_BS(ModelType, ModelParaBoot, FEVDhoriz, FactorLabels, Economies)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
FEVDhoriz	single numerical vector containing the desired horizon of analysis for the FEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

FEVDsep

*FEVDs for "sep Q" models*


---

**Description**

FEVDs for "sep Q" models

**Usage**

```
FEVDsep(ModelType, ModelPara, FEVDhoriz, FactorLabels, Economies)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
FEVDhoriz	single numerical vector containing the desired horizon of analysis for the FEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**Details**

Structural shocks are identified via Cholesky decomposition

---

FEVDsep_BS	<i>FEVDs after bootstrap for "sep Q" models</i>
------------	---

---

**Description**

FEVDs after bootstrap for "sep Q" models

**Usage**

```
FEVDsep_BS(ModelType, ModelParaBoot, FEVDhoriz, FactorLabels, Economies)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
FEVDhoriz	single numerical vector containing the desired horizon of analysis for the FEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

FitgraphsJoint	<i>Model fit graphs for ("joint Q" models)</i>
----------------	--

---

**Description**

Model fit graphs for ("joint Q" models)

**Usage**

```
FitgraphsJoint(
  ModelType,
  WishFitgraphs,
  ModelPara,
  NumOut,
  Economies,
  PathsGraphs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
WishFitgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
ModelPara	List of model parameter estimates (See the "Optimization" function)
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
Economies	a string-vector containing the names of the economies which are part of the economic system
PathsGraphs	Path of the folder in which the graphs will be saved

---

FitgraphsSep	<i>Model fit graphs for ("sep Q" models)</i>
--------------	--

---

**Description**

Model fit graphs for ("sep Q" models)

**Usage**

```
FitgraphsSep(
  ModelType,
  WishFitgraphs,
  ModelPara,
  NumOut,
  Economies,
  PathsGraphs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
WishFitgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
ModelPara	List of model parameter estimates (See the "Optimization" function)
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
Economies	a string-vector containing the names of the economies which are part of the economic system
PathsGraphs	Path of the folder in which the graphs will be saved



---

FMN__Rotate	<i>Performs state rotations</i>
-------------	---------------------------------

---

### Description

Performs state rotations

### Usage

FMN\_\_Rotate(y0, U1, U0)

### Arguments

y0	list of model parameters as described below
U1	matrix (N x N)
U0	vector (N x 1). Optional. Default: vector of zeros.

### Details

This function performs a rotation from a model with Z as states to one with  $S = U0 + U1*Z$  as states.

Specifically, each model is characterized by the following inputs organized in a list of variables:

- (i) K0: intercepts (N x 1);
- (ii) K1: feedback matrix (N x N\*p);
- (iii) SS: volatility matrices (N x N\*(M+1))

More specifically, the state Z follows the dynamics:

$Z_t = N(K0 + K1 [Z_{t-1}; Z_{t-2}; \dots], SSi[ , , 1] + \sum_{i=1}^M SSi[ , , i+1])$  where SSi <- array(SS, c(N, N, M+1))

### Value

y1 - list of outputs after the transformation, the structure parallels that of y0

### References

# This function is modified version of the "FMN\_\_Rotate" function by Le and Singleton (2018). "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>

---

ForecastYields	<i>Gather bond yields forecasts for all the model types</i>
----------------	---

---

**Description**

Gather bond yields forecasts for all the model types

**Usage**

```
ForecastYields(
  ModelType,
  ModelPara,
  InputsForOutputs,
  FactorLabels,
  Economies,
  DataFrequency,
  JLLinputs,
  GVARinputs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
InputsForOutputs	list containing the desired horizon of analysis for the IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	a string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system
DataFrequency	text: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"
JLLinputs	list of necessary inputs for the estimation of JLL-based models (see "JLL" function)
GVARinputs	list of necessary inputs for the estimation of GVAR-based models (see "GVAR" function)

**Value**

List containing the following elements

1. Out-of-sample forecasts of bond yields per forecast horizon
2. Out-of-sample forecast errors of bond yields per forecast horizon
3. Root mean square errors per forecast horizon

**Examples**

# See examples in the vignette file of this package (Section 4).

---

ForecastYieldsJointQ *Bond yields forecasts ("joint Q" models)*

---

**Description**

Bond yields forecasts ("joint Q" models)

**Usage**

```
ForecastYieldsJointQ(
  ModelType,
  ModelPara,
  InputsForOutputs,
  FactorLabels,
  Economies,
  DataFrequency,
  JLLinputs,
  GVARinputs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
InputsForOutputs	list containing the desired horizon of analysis for the IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	a string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system
DataFrequency	character-based vector: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"
JLLinputs	list of necessary inputs for the estimation of JLL-based models (see "JLL" function)
GVARinputs	list of necessary inputs for the estimation of GVAR-based models (see "GVAR" function)

---

ForecastYieldsSepQ      *Bond yields forecasts ("sep Q" models)*

---

### Description

Bond yields forecasts ("sep Q" models)

### Usage

```
ForecastYieldsSepQ(
  ModelType,
  ModelPara,
  InputsForOutputs,
  FactorLabels,
  Economies,
  DataFrequency,
  JLLinputs,
  GVARinputs
)
```

### Arguments

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
InputsForOutputs	list containing the desired horizon of analysis for the IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	a string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system
DataFrequency	character-based vector: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"
JLLinputs	list of necessary inputs for the estimation of JLL-based models (see "JLL" function)
GVARinputs	list of necessary inputs for the estimation of GVAR-based models (see "GVAR" function)

---

Functionf                      *Set up the vector-valued objective function (Point estimate)*

---

**Description**

Set up the vector-valued objective function (Point estimate)

**Usage**

Functionf(MLEinputs, Economies, mat, DataFrequency, FactorLabels, ModelType)

**Arguments**

MLEinputs	Set of inputs that are necessary to the log-likelihood function
Economies	string-vector containing the names of the economies which are part of the economic system
mat	vector of maturities (in years) of yields used in estimation (J x 1)
DataFrequency	character-based vector: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"
FactorLabels	string-list based which contains the labels of all the variables present in the model
ModelType	string-vector containing the label of the model to be estimated

**Value**

objective function

**Examples**

```
# See examples in the vignette file of this package (Section 4).
```

---

Functionf\_Boot                      *Set up the vector-valued objective function (Bootstrap)*

---

**Description**

Set up the vector-valued objective function (Bootstrap)

**Usage**

```
Functionf_Boot(
  ModelType,
  MLEinputsBS,
  Economies,
  mat,
  dt,
  FactorLabels,
  residBS,
  MaxEigen,
  JLLinputs,
  GVARinputs
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
MLEinputsBS	Set of inputs that are necessary to the log-likelihood function
Economies	string-vector containing the names of the economies which are part of the economic system
mat	vector of maturities (in years) of yields used in estimation (J x 1)
dt	adjusted yearly frequency of the data
FactorLabels	string-list based which contains the labels of all the variables present in the model
residBS	indexes of the re-ordered bootstrap residuals
MaxEigen	largest eigenvalue under the P-dynamics
JLLinputs	necessary inputs for the estimation of JLL-based models
GVARinputs	necessary inputs for the estimation of GVAR-based models

---

f\_with\_vectorized\_parameters

*Use function f to generate the outputs from a ATSM*

---

**Description**

Use function f to generate the outputs from a ATSM

**Usage**

```
f_with_vectorized_parameters(
  x,
  sizex,
  f,
  con,
```

```

    varargin,
    ModelType,
    FactorLabels,
    Economies,
    JLLinputs,
    GVARinputs,
    nargout
)

```

### Arguments

x	vector containing all the vectorized auxiliary parameters
sizeX	matrix (6x2) containing the size information of all parameters
f	vector-valued objective function (function)
con	if con = 'concentration', then set the value of the parameter whose name contains @ to empty
varargin	variable inputs used in the optimization (see inputs from "optimization" function)
ModelType	string-vector containing the label of the model to be estimated
FactorLabels	string-list based which contains the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system
JLLinputs	Set of necessary inputs used in the estimation of the JLL-based models (see "JLL" function)
GVARinputs	Set of necessary inputs used in the estimation of the GVAR-based models (see "GVAR" function)
nargout	if nargout <- 1, returns only the values of the likelihood function. If nargout <- 2, generates the entire set of outputs

### References

This function is modified version of the "f\_with\_vectorized\_parameters" function by Le and Singleton (2018).

"A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>

---

GaussianDensity      *computes the density function of a gaussian process*

---

**Description**

computes the density function of a gaussian process

**Usage**

GaussianDensity(res, SS, invSS, logabsdetSS)

**Arguments**

res	matrix of residuals (N x T)
SS	covariance matrice or array of covariance matrices (If $\dim(SS) > 3$ , then the model has a stochastic volatility) (N x N) or (N x N x T)
invSS	Inverse of SS (N x N) or (N x N x T) - optional input
logabsdetSS	$\log(\text{abs}( SS ))$ (1 x T) - optional input

**Value**

y - vector of density (1 x T)

**References**

This function is based on the "Gaussian" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

getpara      *Extract the parameter values from varargin*

---

**Description**

Extract the parameter values from varargin

**Usage**

getpara(varargin)

**Arguments**

varargin	All parameter features
----------	------------------------



## References

This function is modified version of the "getpara" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

getx	<i>Obtain the auxiliary values corresponding to each parameter, its size and its name</i>
------	---

---

## Description

Obtain the auxiliary values corresponding to each parameter, its size and its name

## Usage

```
getx(con, varargin, Economies, FactorLabels, JLLinputs = NULL)
```

## Arguments

con	If con = 'concentration' and a parameter's name contains '@', then its auxiliary value is set to empty
varargin	variable inputs used in the optimization (see "optimization" function)
Economies	string-vector containing the names of the economies which are part of the economic system
FactorLabels	list of necessary inputs for the estimation of JLL-based models (see "JLL" function)
JLLinputs	Necessary inputs for the estimation of the JLL-based models

## References

This function is a modified version of the "getx" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling).

---

GFEVDgraphsJLLOrtho     *GFEVDs graphs for orthogonalized risk factors of JLL-based models*

---

### Description

GFEVDs graphs for orthogonalized risk factors of JLL-based models

### Usage

```
GFEVDgraphsJLLOrtho(
  ModelType,
  NumOut,
  WishPdynamicgraphs,
  WishYieldsgraphs,
  GFEVDhoriz,
  PathsGraphs
)
```

### Arguments

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPdynamicgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
GFEVDhoriz	single numerical vector containing the desired horizon of analysis for the GFEVDs
PathsGraphs	Path of the folder in which the graphs will be saved

---

GFEVDgraphsJoint     *GFEVDs graphs for ("joint Q" models)*

---

### Description

GFEVDs graphs for ("joint Q" models)

**Usage**

```
GFEVDgraphsJoint(
  ModelType,
  NumOut,
  WishPdynamicsgraphs,
  WishYieldsgraphs,
  GFEVDhoriz,
  PathsGraphs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPdynamicsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
GFEVDhoriz	single numerical vector conataining the desired horizon of analysis for the GFEVDs
PathsGraphs	Path of the folder in which the graphs will be saved

---

GFEVDgraphsSep	<i>GFEVDs graphs for ("sep Q" models)</i>
----------------	---

---

**Description**

GFEVDs graphs for ("sep Q" models)

**Usage**

```
GFEVDgraphsSep(
  ModelType,
  NumOut,
  WishPdynamicsgraphs,
  WishYieldsgraphs,
  GFEVDhoriz,
  PathsGraphs,
  Economies
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPynamicsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
GFEVDhoriz	single numerical vector conataining the desired horizon of analysis for the GFEVDs
PathsGraphs	Path of the folder in which the graphs will be saved
Economies	a string-vector containing the names of the economies which are part of the economic system

---

GFEVDjoint	<i>GFEVDs for "joint Q" models</i>
------------	------------------------------------

---

**Description**

GFEVDs for "joint Q" models

**Usage**

```
GFEVDjoint(ModelType, ModelPara, GFEVDhoriz, FactorLabels, Economies)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
GFEVDhoriz	single numerical vector conataining the desired horizon of analysis for the GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "fevd" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GFEVDjointOrthoJLL     *Orthogonalized GFEVDs for JLL models*

---

**Description**

Orthogonalized GFEVDs for JLL models

**Usage**

GFEVDjointOrthoJLL(ModelType, ModelPara, GFEVDhoriz, FactorLabels, Economies)

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
GFEVDhoriz	single numerical vector conataining the desired horizon of analysis for the GFEVDs
FactorLabels	a string-list based which contains all the labels of all the variables present in the model
Economies	a string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "fevd" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GFEVDjointOrthoJLL\_BS     *GFEVDs after bootstrap for JLL-based models*

---

**Description**

GFEVDs after bootstrap for JLL-based models

**Usage**

```
GFEVDjointOrthoJLL_BS(
  ModelType,
  ModelParaBoot,
  GFEVDhoriz,
  FactorLabels,
  Economies
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
GFEVDhoriz	single numerical vector containing the desired horizon of analysis for the GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "fevd" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GFEVDjoint\_BS

*GFEVDs after bootstrap for "joint Q" models*


---

**Description**

GFEVDs after bootstrap for "joint Q" models

**Usage**

GFEVDjoint\_BS(ModelType, ModelParaBoot, GFEVDhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	List of model parameter estimates (See the "Optimization" function) after a bootstrap draw
GFEVDhoriz	single numerical vector containing the desired horizon of analysis for the GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

## References

- This function is a modified and extended version of the "fevd" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GFEVDsep

*GFEVDs for "sep Q" models*

---

## Description

GFEVDs for "sep Q" models

## Usage

GFEVDsep(ModelType, ModelPara, GFEVDhoriz, FactorLabels, Economies)

## Arguments

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
GFEVDhoriz	single numerical vector containing the desired horizon of analysis for the GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

## References

- This function is a modified and extended version of the "fevd" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GFEVDsep\_BS                      *GFEVDs after bootstrap for "sep Q" models*

---

**Description**

GFEVDs after bootstrap for "sep Q" models

**Usage**

GFEVDsep\_BS(ModelType, ModelParaBoot, GFEVDhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
GFEVDhoriz	single numerical vector containing the desired horizon of analysis for the GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "fevd" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GIRFgraphsJLLOrtho                      *GIRFs graphs for orthogonalized risk factors of JLL-based models*

---

**Description**

GIRFs graphs for orthogonalized risk factors of JLL-based models

**Usage**

```
GIRFgraphsJLLOrtho(
  ModelType,
  NumOut,
  WishPdynamicsgraphs,
  WishYieldsgraphs,
  GIRFhoriz,
  PathsGraphs
)
```



**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPynamicsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
GIRFhoriz	single numerical vector conataining the desired horizon of analysis for the GIRFs
PathsGraphs	Path of the folder in which the graphs will be saved

---

GIRFgraphsJoint	<i>GIRFs graphs for ("joint Q" models)</i>
-----------------	--

---

**Description**

GIRFs graphs for ("joint Q" models)

**Usage**

```
GIRFgraphsJoint(
  ModelType,
  NumOut,
  WishPynamicsgraphs,
  WishYieldsgraphs,
  GIRFhoriz,
  PathsGraphs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPynamicsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
GIRFhoriz	single numerical vector conataining the desired horizon of analysis for the GIRFs
PathsGraphs	Path of the folder in which the graphs will be saved

---

GIRFgraphsSep                      *GIRFs graphs for ("sep Q" models)*

---

### Description

GIRFs graphs for ("sep Q" models)

### Usage

```
GIRFgraphsSep(
  ModelType,
  NumOut,
  WishPdynamicsgraphs,
  WishYieldsgraphs,
  GIRFhoriz,
  PathsGraphs,
  Economies
)
```

### Arguments

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPdynamicsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
GIRFhoriz	single numerical vector conataining the desired horizon of analysis for the GIRFs
PathsGraphs	Path of the folder in which the graphs will be saved
Economies	a string-vector containing the names of the economies which are part of the economic system

---

GIRFjoint                              *GIRFs for "joint Q" models*

---

### Description

GIRFs for "joint Q" models

### Usage

```
GIRFjoint(ModelType, ModelPara, GIRFhoriz, FactorLabels, Economies)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
GIRFhoriz	single numerical vector conataining the desired horizon of analysis for the GIRFs
FactorLabels	a string-list based which contains all the labels of all the variables present in the model
Economies	a string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "irf" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GIRFjointOrthoJLL      *Orthogonalized GIRFs for JLL models*

---

**Description**

Orthogonalized GIRFs for JLL models

**Usage**

GIRFjointOrthoJLL(ModelType, ModelPara, GIRFhoriz, FactorLabels, Economies)

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
GIRFhoriz	single numerical vector conataining the desired horizon of analysis for the GIRFs
FactorLabels	a string-list based which contains all the labels of all the variables present in the model
Economies	a string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "irf" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GIRFjointOrthoJLL\_BS *GIRFs after bootstrap for JLL-based models*

---

### Description

GIRFs after bootstrap for JLL-based models

### Usage

```
GIRFjointOrthoJLL_BS(
  ModelType,
  ModelParaBoot,
  GIRFhoriz,
  FactorLabels,
  Economies
)
```

### Arguments

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
GIRFhoriz	single numerical vector containing the desired horizon of analysis for the GIRFs
FactorLabels	string-list based which contains the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

### References

- This function is a modified and extended version of the "irf" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GIRFjoint\_BS                      *GIRFs after bootstrap for "joint Q" models*

---

**Description**

GIRFs after bootstrap for "joint Q" models

**Usage**

GIRFjoint\_BS(ModelType, ModelParaBoot, GIRFhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
GIRFhoriz	single numerical vector containing the desired horizon of analysis for the GIRFs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "irf" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GIRFSep                              *GIRFs for "sep Q" models*

---

**Description**

GIRFs for "sep Q" models

**Usage**

GIRFSep(ModelType, ModelPara, GIRFhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
GIRFhoriz	single numerical vector conataining the desired horizon of analysis for the GIRFs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "irf" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GIRFSep\_BS

*GIRFs after bootstrap for "sep Q" models*


---

**Description**

GIRFs after bootstrap for "sep Q" models

**Usage**

GIRFSep\_BS(ModelType, ModelParaBoot, GIRFhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
GIRFhoriz	single numerical vector conataining the desired horizon of analysis for the GIRFs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**References**

- This function is a modified and extended version of the "irf" function from Smith, L.V. and A. Galesi (2014). GVAR Toolbox 2.0, available at <https://sites.google.com/site/gvarmodelling/gvar-toolbox>.
- Pesaran and Shin, 1998. "Generalized impulse response analysis in linear multivariate models" (Economics Letters)

---

GraphicalOutputs	<i>Generate the graphical outputs for the selected models (Point estimate)</i>
------------------	--

---

**Description**

Generate the graphical outputs for the selected models (Point estimate)

**Usage**

```
GraphicalOutputs(
  ModelType,
  ModelPara,
  NumOut,
  InputsForOutputs,
  Economies,
  FactorLabels
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
InputsForOutputs	list containing the desired inputs for the construction of the desired output
Economies	string-vector containing the names of the economies which are part of the economic system
FactorLabels	string-list based which contains the labels of all the variables present in the model

---

GVAR	<i>Estimate a GVAR(1) and a VARX(1,1,1)</i>
------	---

---

**Description**

Estimate a GVAR(1) and a VARX(1,1,1)

**Usage**

```
GVAR(GVARinputs, N)
```

**Arguments**

GVARinputs	<p>List containing the following necessary inputs for the estimation of the GVAR:</p> <ol style="list-style-type: none"> <li>1. Economies: string-vector containing the names of the economies which are part of the economic system</li> <li>2. 'GVARFactors': list of all variables that are used in the estimation of the VARX (see e.g. 'CM_Factors_GVAR' file);</li> <li>3. 'VARXtype': character-vector containing two possibilities: <ul style="list-style-type: none"> <li>• 'unconstrained': model is estimated without any constrained (each equation is estimated individually by OLS);</li> <li>• 'constrained: Spanned Factors': model is estimated taking into account the fact that foreign-pricing-factors do NOT impinge on (i) domestic economic variables and (ii) domestic pricing factors. (equations are estimated by restricted least squares)</li> <li>• 'constrained: ' extended by the name of the risk factor: model is estimated taking into account the fact that the restricted factor is only affected by its own lagged values and the lagged values of its own star variables. (equations are estimated by restricted least squares)</li> </ul> </li> <li>4. 'Wgvar': GVAR transition matrix (C x C) - see the output from 'Transition_Matrix' function</li> </ol>
N	number of country-specific spanned factors (scalar)

**Value**

A list containing

1. parameters of the country-specific VARX(1,1,1)
  - intercept (M+Nx1);
  - phi\_1 (M+N x M+N);
  - phi\_1^star (M+N x M+N);
  - phi\_g (M+N x M+N);
  - Sigma (M+N x G)
2. parameters of the GVAR.
  - F0 (F X 1);
  - F1 (F x F);
  - Sigma\_y (F x F)

**References**

Chudik and Pesaran, (2016). "Theory and Practice of GVAR modelling" (Journal of Economic Surveys)



**Examples**

```

data(CM_Factors_GVAR)

N <- 3

GVARinputs <- list()
GVARinputs$Economies <- c("China", "Brazil", "Mexico", "Uruguay")
GVARinputs$GVARFactors <- FactorsGVAR
GVARinputs$VARXtype <- "unconstrained"
GVARinputs$Wgvar <- matrix( c(0, 0.83, 0.86, 0.38,
                             0.65, 0, 0.13, 0.55,
                             0.32, 0.12, 0, 0.07,
                             0.03, 0.05, 0.01, 0), nrow = 4, ncol = 4)

GVAR(GVARinputs, N)

```

---

IdxAllSpanned

*Find the indexes of the spanned factors*


---

**Description**

Find the indexes of the spanned factors

**Usage**

```
IdxAllSpanned(ModelType, FactorLabels, Economies)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
FactorLabels	string-list based which contains the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

IdxSpanned

*Extract the indexes related to the spanned factors in the variance-covariance matrix*


---

**Description**

Extract the indexes related to the spanned factors in the variance-covariance matrix

**Usage**

```
IdxSpanned(G, M, N, C)
```

**Arguments**

G	number of global unspanned factors (scalar)
M	number of domestic unspanned factors per country (scalar)
N	number of domestic spanned factors per country (scalar)
C	number of countries of the economic system (scalar)

---

InputsForMLEdensity     *Generates several inputs that are necessary to build the likelihood function*

---

**Description**

Generates several inputs that are necessary to build the likelihood function

**Usage**

```
InputsForMLEdensity(
  ModelType,
  Yields,
  PdynamicsFactors,
  FactorLabels,
  mat,
  Economies,
  DataFrequency,
  JLLinputs = NULL,
  GVARinputs = NULL
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
Yields	time series of yields (JxT or CJ x T)
PdynamicsFactors	time series of the risk factors (K x T)
FactorLabels	string-list based which contains the labels of all the variables present in the model
mat	vector of maturities (in years) used in the estimation
Economies	string-vector containing the names of the economies of the system. If the ModelType selected is "JPS", "JPS jointP", "GVAR sepQ", then only one economy can be selected. For the other models, more than one economy must be selected.
DataFrequency	character-based-vector. Available options are: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"

JLLinputs	list of necessary inputs for the estimation of JLL-based models (see "JLL" function)
GVARinputs	list of necessary inputs for the estimation of GVAR-based models (see "GVAR" function)

### Details

To ensure that the risk factors matrix is correctly built for the model "JPS", the global factors should be allocated on the first G rows of this matrix.

### Value

List of necessary inputs for constructing the model's log-likelihood function

### Examples

```
# Example 1:
data(CM_Factors)
data(CM_Yields)

ModelType <- "JPS"
Economies <- "Mexico"
Factors <- RiskFactors
N <- 3
GlobalVar <- c("GBC", "CPI_OECD") # Global Variables
DomVar <- c("Eco_Act", "Inflation") # Domestic Variables
FactorLabels <- LabFac(N, DomVar, GlobalVar, Economies, ModelType)

mat <- c(0.25, 0.5, 1, 3, 5, 10)
DataFrequency <- "Monthly"

i <- length(Economies)
ATSMInputs <- InputsForMLEdensity(ModelType, Yields, Factors, FactorLabels, mat,
                                  Economies, DataFrequency)

# Example 2:
data(CM_Factors)
data(CM_Yields)
data(CM_Factors_GVAR)

ModelType <- "GVAR jointQ"
Economies <- c("China", "Brazil", "Mexico", "Uruguay")
mat <- c(0.25, 0.5, 1, 3, 5, 10)
DataFrequency <- "Monthly"
Factors <- RiskFactors
N <- 3
GlobalVar <- c("GBC", "CPI_OECD") # Global Variables
DomVar <- c("Eco_Act", "Inflation") # Domestic Variables
FactorLabels <- LabFac(N, DomVar, GlobalVar, Economies, ModelType)

GVARinputs <- list()
GVARinputs$Economies <- Economies
```

```

GVARinputs$GVARFactors <- FactorsGVAR
GVARinputs$VARXtype <- "unconstrained"
GVARinputs$Wgvar <- matrix( c(0, 0.83, 0.86, 0.38,
                             0.65, 0, 0.13, 0.55,
                             0.32, 0.12, 0, 0.07,
                             0.03, 0.05, 0.01, 0), nrow = 4, ncol = 4)
ATSMinputs <- InputsForMLEdensity(ModelType, Yields, Factors, FactorLabels, mat, Economies,
                                  DataFrequency, JLLinputs= NULL , GVARinputs)

# Example 3:
if (requireNamespace('neldermead', quietly = TRUE)) {

  data(CM_Factors)
  data(CM_Yields)
  ModelType <- "JLL jointSigma"
  GlobalVar <- c("GBC", "CPI_OECD") # Global Variables
  DomVar <- c("Eco_Act", "Inflation") # Domestic Variables
  N <- 3
  Economies <- c( "China", "Brazil", "Mexico", "Uruguay")
  FactorLabels <- LabFac(N, DomVar, GlobalVar, Economies, ModelType)

  Factors <- RiskFactors
  mat <- c(0.25, 0.5, 1, 3, 5, 10)
  DataFrequency <- "Monthly"
  JLLinputs <- list()
  JLLinputs$Economies <- Economies
  JLLinputs$DomUnit <- "China"
  JLLinputs$WishSigmas <- 1
  JLLinputs$SigmaNonOrtho <- NULL
  JLLinputs$JLLModelType <- ModelType

  ATSMinputs <- InputsForMLEdensity(ModelType, Yields, Factors, FactorLabels, mat, Economies,
                                    DataFrequency, JLLinputs)
} else {
  message("skipping functionality due to missing Suggested dependency")
}

```

---

InputsForMLEdensity\_BS

*Generates several inputs that are necessary to build the likelihood function - Bootstrap version*

---

### **Description**

Generates several inputs that are necessary to build the likelihood function - Bootstrap version

**Usage**

```

InputsForMLEdensity_BS(
  ModelType,
  Y_artificial,
  Z_artificial,
  FactorLabels,
  mat,
  Economies,
  DataFrequency,
  JLLinputs = NULL,
  GVARinputs = NULL
)

```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
Y_artificial	time series of yields (CJ x T or JxT)
Z_artificial	time series of the risk factors (F x T)
FactorLabels	string-list based which contains the labels of all the variables present in the model
mat	vector of maturities (in years) used in the estimation
Economies	string-vector containing the names of the economies of the system. If the ModelType selected is "JPS", "JPS jointP", "GVAR sepQ", then only one economy can be selected. For the other models, more than one economy must be selected.
DataFrequency	character-based-vector. Available options are: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"
JLLinputs	list of necessary inputs for the estimation of JLL-based models (see "JLL" function)
GVARinputs	list of necessary inputs for the estimation of GVAR-based models (see "GVAR" function)

---

InputsForOutputs	<i>Collect the inputs that are used to construct the numerical and the graphical outputs</i>
------------------	--

---

**Description**

Collect the inputs that are used to construct the numerical and the graphical outputs

**Usage**

```

InputsForOutputs(
  ModelType,
  Horiz,
  ListOutputWished,
  OutputLabel,
  WishStationarityQ,
  WishGraphYields = 0,
  WishGraphRiskFactors = 0,
  WishOrthoJLLgraphs = 0,
  WishBootstrap = 0,
  ListBoot = NULL,
  WishForecast = 0,
  ListForecast = NULL
)

```

**Arguments**

ModelType	String-vector containing the label of the model to be estimated
Horiz	Single numerical vector containing the desired horizon of analysis for the outputs
ListOutputWished	List of desired graphical outputs. Available options are: "Fit", "IRF", "FEVD", "GIRF", "GFEVD".
OutputLabel	Name of the output label to be stored
WishStationarityQ	User must set 1 if she wishes to impose the largest eigenvalue under the Q to be strictly smaller than 1, otherwise set 0.
WishGraphYields	Binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise. Default is set as "0".
WishGraphRiskFactors	Binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise. Default is set as "0".
WishOrthoJLLgraphs	Binary variable: set 1, if the user wishes orthogonalized JLL-based graphs to be generated; or set 0, otherwise. Default is set as "0"
WishBootstrap	Binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise. Default is set as "0".
ListBoot	List containing the four following elements: <ol style="list-style-type: none"> <li>"methodBS": Desired bootstrap method among (a) 'bs' (standard residual bootstrap), (b) 'wild' (wild bootstrap), (c) 'block' (block bootstrap);</li> <li>"BlockLength": if block bootstrap is chosen, then the user has to specify the length of the block (single numerical vector);</li> <li>"ndraws": number of draws;</li> </ol>

- 4. "pctg": level of confidence (single numerical vector expressed in basis points)
- WishForecast Binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise. Default is set as "0".
- ListForecast list containing the three following elements:
- 1. "ForHoriz": forecast horizon;
  - 2. "t0Sample": index of the first variable of the information set;
  - 3. "t0Forecast": index of the first forecast cut-off date.

**Value**

List of necessary inputs to generate the graphs of the outputs of the desired model

**Examples**

```

ModelType <- "JPS"
Horiz <- 100
DesiredOutputGraphs <- c("Fit", "GIRF", "GFEVD")
OutputLabel <- "Test"
WishStationarityQ <- 1
WishGraphRiskFac <- 0
WishGraphYields <- 1

```

```

InputsList <- InputsForOutputs(ModelType, Horiz, DesiredOutputGraphs, OutputLabel,
                               WishStationarityQ, WishGraphYields, WishGraphRiskFac)

```

---

IRFandGIRFbs\_jointQ *Creates the confidence bounds and the graphs of IRFs and GIRFs after bootstrap ("joint Q" models)*

---

**Description**

Creates the confidence bounds and the graphs of IRFs and GIRFs after bootstrap ("joint Q" models)

**Usage**

```

IRFandGIRFbs_jointQ(
  ModelType,
  ModelBootstrap,
  NumOutPE,
  InputsForOutputs,
  Economies,
  PathsGraphs
)

```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelBootstrap	list containing the complete set of model parameters after bootstrap estimation procedure
NumOutPE	list of model parameter point estimates
InputsForOutputs	list containing the desired inputs for the construction of the outputs of interest
Economies	string-vector containing the names of the economies which are part of the economic system
PathsGraphs	path of the folder in which the graphs will be saved

---

IRFandGIRFbs\_jointQ\_Ortho

*Creates the confidence bounds and the graphs of IRFs and GIRFs after bootstrap (JLL-based models)*

---

**Description**

Creates the confidence bounds and the graphs of IRFs and GIRFs after bootstrap (JLL-based models)

**Usage**

```
IRFandGIRFbs_jointQ_Ortho(
  ModelType,
  ModelBootstrap,
  NumOutPE,
  InputsForOutputs,
  Economies,
  PathsGraphs
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelBootstrap	list containing the complete set of model parameters after bootstrap estimation procedure
NumOutPE	list of model parameter point estimates
InputsForOutputs	list containing the desired inputs for the construction of the outputs of interest
Economies	string-vector containing the names of the economies which are part of the economic system
PathsGraphs	path of the folder in which the graphs will be saved



---

IRFandGIRFbs_sepQ	<i>Creates the confidence bounds and the graphs of IRFs and GIRFs after bootstrap ("sep Q" models)</i>
-------------------	--

---

### Description

Creates the confidence bounds and the graphs of IRFs and GIRFs after bootstrap ("sep Q" models)

### Usage

```
IRFandGIRFbs_sepQ(  
  ModelType,  
  ModelBootstrap,  
  NumOutPE,  
  InputsForOutputs,  
  Economies,  
  PathsGraphs  
)
```

### Arguments

ModelType	string-vector containing the label of the model to be estimated
ModelBootstrap	list containing the complete set of model parameters after bootstrap estimation procedure
NumOutPE	list of model parameter point estimates
InputsForOutputs	list containing the desired inputs for the construction of the outputs of interest
Economies	string-vector containing the names of the economies which are part of the economic system
PathsGraphs	path of the folder in which the graphs will be saved

---

IRFgraphsJLLOrtho	<i>IRFs graphs for orthogonalized risk factors of JLL-based models</i>
-------------------	--

---

### Description

IRFs graphs for orthogonalized risk factors of JLL-based models

**Usage**

```
IRFgraphsJLLOrtho(
  ModelType,
  NumOut,
  WishPdynamicgraphs,
  WishYieldsgraphs,
  IRFhoriz,
  PathsGraphs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPdynamicgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
IRFhoriz	single numerical vector containing the desired horizon of analysis for the IRFs
PathsGraphs	Path of the folder in which the graphs will be saved

---

IRFgraphsJoint	<i>IRFs graphs for ("joint Q" models)</i>
----------------	---

---

**Description**

IRFs graphs for ("joint Q" models)

**Usage**

```
IRFgraphsJoint(
  ModelType,
  NumOut,
  WishPdynamicgraphs,
  WishYieldsgraphs,
  IRFhoriz,
  PathsGraphs
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPynamicsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
IRFhoriz	single numerical vector conataining the desired horizon of analysis for the IRFs
PathsGraphs	Path of the folder in which the graphs will be saved

---

IRFgraphsSep	<i>IRFs graphs for ("sep Q" models)</i>
--------------	---

---

**Description**

IRFs graphs for ("sep Q" models)

**Usage**

```
IRFgraphsSep(
  ModelType,
  NumOut,
  WishPynamicsgraphs,
  WishYieldsgraphs,
  IRFhoriz,
  PathsGraphs,
  Economies
)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
NumOut	list of computed outputs containing the model fit, IRFs, FEVDs, GIRFs, and GFEVDs
WishPynamicsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
WishYieldsgraphs	binary variable: set 1, if the user wishes graphs to be generated; or set 0, otherwise
IRFhoriz	single numerical vector conataining the desired horizon of analysis for the IRFs
PathsGraphs	Path of the folder in which the graphs will be saved
Economies	a string-vector containing the names of the economies which are part of the economic system

---

IRFjoint	<i>IRFs for "joint Q" models</i>
----------	----------------------------------

---

**Description**

IRFs for "joint Q" models

**Usage**

IRFjoint(ModelType, ModelPara, IRFhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
IRFhoriz	single numerical vector conataining the desired horizon of analysis for the IRFs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**Details**

Structural shocks are identified via Cholesky decomposition

---

IRFjointOrthoJLL	<i>Orthogonalized IRFs for JLL models</i>
------------------	---

---

**Description**

Orthogonalized IRFs for JLL models

**Usage**

IRFjointOrthoJLL(ModelType, ModelPara, IRFhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
IRFhoriz	single numerical vector conataining the desired horizon of analysis for the IRFs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**Details**

Structural shocks are identified via Cholesky decomposition

---

IRFjointOrthoJLL\_BS     *IRFs after bootstrap for JLL-based models*

---

**Description**

IRFs after bootstrap for JLL-based models

**Usage**

```
IRFjointOrthoJLL_BS(  
  ModelType,  
  ModelParaBoot,  
  IRFhoriz,  
  FactorLabels,  
  Economies  
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
IRFhoriz	single numerical vector containing the desired horizon of analysis for the IRFs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

IRFjoint\_BS     *IRFs after bootstrap for "joint Q" models*

---

**Description**

IRFs after bootstrap for "joint Q" models

**Usage**

```
IRFjoint_BS(ModelType, ModelParaBoot, IRFhoriz, FactorLabels, Economies)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
IRFhoriz	single numerical vector containing the desired horizon of analysis for the IRFs
FactorLabels	a string-list based which contains all the labels of all the variables present in the model
Economies	a string-vector containing the names of the economies which are part of the economic system

---

IRFsep	<i>IRFs for "sep Q" models</i>
--------	--------------------------------

---

**Description**

IRFs for "sep Q" models

**Usage**

IRFsep(ModelType, ModelPara, IRFhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (See the "Optimization" function)
IRFhoriz	single numerical vector containing the desired horizon of analysis for the IRFs
FactorLabels	string-list based which contains the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**Details**

Structural shocks are identified via Cholesky decomposition

---

IRFsep_BS	<i>IRFs after bootstrap for "sep Q" models</i>
-----------	--

---

**Description**

IRFs after bootstrap for "sep Q" models

**Usage**

IRFsep\_BS(ModelType, ModelParaBoot, IRFhoriz, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
IRFhoriz	single numerical vector containing the desired horizon of analysis for the IRFs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

JLL	<i>Set of inputs present at JLL's P-dynamics</i>
-----	--

---

**Description**

Set of inputs present at JLL's P-dynamics

**Usage**

JLL(NonOrthoFactors, N, JLLinputs)

**Arguments**

NonOrthoFactors	Risk factors before the orthogonalization (FxT)
N	Number of country-specific spanned factors
JLLinputs	List of necessary inputs to estimate JLL outputs: <ol style="list-style-type: none"> <li>1. Economies: set of economies that are part of the economic system (string-vector)</li> <li>2. "DomUnit": name of the economy which is assigned as the dominant unit. If no dominant unit is assigned, then this variable is defined as "None"</li> </ol>

3. WishSigmas: equal to "1" if one wishes the variance-covariance matrices and the Cholesky factorizations (can take long if they need to be estimated). Set "0", otherwise.
4. SigmaNonOrtho: NULL or some  $K \times K$  matrix from the non-orthogonalized dynamics
5. JLLModelType: available options are "JLL original", "JLL jointSigma" or "JLL NoDomUnit"

### Details

For the models 'JLL original' or "JLL jointSigma" the name of one dominant economy must assigned.

For the model 'JLL NoDomUnit', the name of one dominant economy must be set as "None".

### Value

List of model parameters from both the orthogonalized and non-orthogonalized versions of the JLL's based models

### References

Jotiskhatira, Le and Lundblad (2015). "Why do interest rates in different currencies co-move?" (Journal of Financial Economics)

### Examples

```
if (requireNamespace('neldermead', quietly = TRUE)) {

  data(CM_Factors)
  ZZ <- RiskFactors
  N <- 3

  JLLinputs <- list()
  JLLinputs$Economies <- c("China", "Brazil", "Mexico", "Uruguay")
  JLLinputs$DomUnit <- "China"
  JLLinputs$WishSigmas <- 1
  JLLinputs$SigmaNonOrtho <- NULL
  JLLinputs$JLLModelType <- "JLL original"
  JLL(ZZ, N, JLLinputs)

#} else {
  message("skipping functionality due to missing Suggested dependency")
}
```



---

K1XQStationary	<i>Impose stationarity under the Q-measure</i>
----------------	--

---

**Description**

Impose stationarity under the Q-measure

**Usage**

```
K1XQStationary(StationaryEigenvalues)
```

**Arguments**

StationaryEigenvalues

Binary variable: set "1" if the user whises the largest eigenvalue to be strictly smaller than 1. Set "0", otherwise

**Value**

list

**Examples**

```
stat <- 1 # Takes values 1 and 0  
K1XQStationary(stat)
```

---

killa	<i>Eliminates the @</i>
-------	-------------------------

---

**Description**

Eliminates the @

**Usage**

```
killa(s)
```

**Arguments**

s text vector containing the feature of the variable

**References**

This function is a modified version of the "kill" function by Le and Singleton (2018). "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling).

---

LabelsSpanned	<i>Generate the labels of the spanned factors</i>
---------------	---

---

**Description**

Generate the labels of the spanned factors

**Usage**

LabelsSpanned(N)

**Arguments**

N	number of spanned factors
---	---------------------------

---

LabelsStar	<i>Generate the labels of the star variables</i>
------------	--

---

**Description**

Generate the labels of the star variables

**Usage**

LabelsStar(FactorLabels)

**Arguments**

FactorLabels	Factor labels
--------------	---------------

---

LabFac	<i>Generates the labels factors</i>
--------	-------------------------------------

---

**Description**

Generates the labels factors

**Usage**

LabFac(N, DomVar, GlobalVar, Economies, ModelType)

**Arguments**

N	number of spanned factors per country (scalar)
DomVar	character-vector containing the names of the domestic variables
GlobalVar	character-vector containing the names of the global variables
Economies	string-vector containing the names of the economies which are part of the economic system
ModelType	string-vector containing the label of the model to be estimated

**Value**

List containing the country-specific risk factor labels

**Examples**

```
N <- 2
DomVar <- c("inflation", "Economic growth")
GlobalVar <- "Commodity Prices"
Economies <- c("U.S.", "Canada", "Germany", "Japan")
ModelType <- "JPS"

VarLabels <- LabFac(N, DomVar, GlobalVar, Economies, ModelType)
```

---

Maturities

---

*Create a vector of numerical maturities in years*


---

**Description**

Create a vector of numerical maturities in years

**Usage**

```
Maturities(DataYields, Economies, UnitYields)
```

**Arguments**

DataYields	matrix containing all yields of the system (JxT,if the model is single-country-based or CJxT if the model is multy-country-based)
Economies	vector containing names of all the economies of the system
UnitYields	(i) "Month": if maturity of yields are expressed in months or (ii) "Year": if maturity of yields are expressed in years

**Value**

Vector containing all observed maturities expressed in years

**Examples**

```
data('CM_Yields')
Economies <- c("China", "Brazil", "Mexico", "Uruguay")
Maturities(Yields, Economies, "Month")
```

---

MLEdensity\_jointQ      *Compute the maximum likelihood function ("joint Q" models)*

---

**Description**

Compute the maximum likelihood function ("joint Q" models)

**Usage**

```
MLEdensity_jointQ(
  K1XQ,
  r0,
  SSZ,
  K0Z,
  K1Z,
  se,
  Gy.0,
  mat,
  Y,
  Z,
  P,
  Wpca,
  We,
  WpcaFull,
  dt,
  Economies,
  FactorLabels,
  ModelType,
  GVARinputs,
  JLLinputs,
  nargout
)
```

**Arguments**

K1XQ	risk-neutral feedback matrix (N×N)
r0	long-run interest rate (scalar)
SSZ	variance-covariance matrix (K×K)
K0Z	intercept from the P-dynamics (K×1)
K1Z	feedback matrix from the P-dynamics (K×K)

se	Variance of the portfolio of yields observed with error (scalar)
Gy.0	matrix of contemporaneous terms from the P-dynamics (KxK)
mat	vector of maturities (in years) of yields used in estimation (J x 1)
Y	matrix of yields used in estimation (J x T)
Z	complete set of spanned and unspanned factors (KxT)
P	complete set of spanned factors (NxT)
Wpca	matrix of weights of the portfolios observed without errors (NxJ)
We	matrix of weights of the portfolios observed with errors ((J-N)xJ)
WpcaFull	composite matrix of weights the portfolios observed with and without errors
dt	time interval unit of the model (scalar). For instance, if data is (i) monthly, dt <- 12; (ii) quarterly, dt <- 4; (iii) yearly, dt <- 1.
Economies	set of economies that are part of the economic system (vector of text)
FactorLabels	string-list based which contains the labels of all the variables present in the model
ModelType	feasible options are (i) "VAR jointQ", (ii) "GVAR jointQ" or (iii) "JLL jointSigma"
GVARinputs	if the model chosen is the "GVAR sepQ", the "GVARinputs" should be specified (see "GVAR" function)
JLLinputs	if the model chosen is the "JLL jointSigma". "JLLinputs" should contain (i) DomUnit, (ii) WishSigmas, (iii) SigmaNonOrtho, (iv) JLLModelType (See JLL function)
nargout	if nargout== 1: provides only the values of the likelihood; if nargout== 2: complete ATSM outputs

## References

This function is an extended version of the "AON\_MLEdensity\_WOE" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

MLEdensity\_jointQ\_sepSigma

*Compute the maximum likelihood function ("joint Q" models for separate Sigma estimation)*

---

## Description

Compute the maximum likelihood function ("joint Q" models for separate Sigma estimation)

**Usage**

```
MLEdensity_jointQ_sepSigma(
  K1XQ,
  r0,
  SSZ,
  K0Z,
  K1Z,
  se,
  Gy.0,
  mat,
  Y,
  Z,
  P,
  Wpca,
  We,
  WpcaFull,
  dt,
  Economies,
  FactorLabels,
  ModelType,
  JLLinputs,
  nargout
)
```

**Arguments**

K1XQ	risk-neutral feedback matrix (NxN)
r0	long-run interest rate (scalar)
SSZ	variance-covariance matrix (KxK)
K0Z	intercept from the P-dynamics (Kx1)
K1Z	feedback matrix from the P-dynamics (KxK)
se	Variance of the portfolio of yields observed with error (scalar)
Gy.0	matrix of contemporaneous terms from the P-dynamics (KxK)
mat	vector of maturities (in years) of yields used in estimation (J x 1)
Y	matrix of yields used in estimation (J x T)
Z	complete set of spanned and unspanned factors (KxT)
P	complete set of spanned factors (NxT)
Wpca	matrix of weights of the portfolios observed without errors (NxJ)
We	matrix of weights of the portfolios observed with errors ((J-N)xJ)
WpcaFull	composite matrix of weights the portfolios observed with and without errors
dt	time interval unit of the model (scalar). For instance, if data is (i) monthly, dt <- 12; (ii) quarterly, dt <- 4; (iii) yearly, dt <- 1.
Economies	Set of economies that are part of the economic system (vector of text)

FactorLabels	string-list based which contains the labels of all the variables present in the model
ModelType	feasible options are (i) "JLL original" or (ii) "JLL NoDomUnit"
JLLinputs	if the model chosen is the "JLL jointSigma", "JLLinputs" should be specified (see "JLL" function)
nargout	if nargout== 1: provides only the values of the likelihood; if nargout== 2: complete ATSM outputs

## References

This function is an extended version of the "AON\_MLEdensity\_WOE" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>

---

MLEdensity_sepQ	<i>Compute the maximum likelihood function ("sep Q" models)</i>
-----------------	---

---

## Description

Compute the maximum likelihood function ("sep Q" models)

## Usage

```
MLEdensity_sepQ(
    K1XQ,
    r0,
    SSZ,
    K0Z,
    K1Z,
    se,
    Gy.0,
    mat,
    Y,
    Z,
    P,
    Wpca,
    We,
    WpcaFull,
    dt,
    Economy,
    FactorLabels,
    ModelType,
    GVARinputs = NULL,
    nargout
)
```

**Arguments**

K1XQ	risk-neutral feedback matrix (N×N)
r0	long-run interest rate (scalar)
SSZ	variance-covariance matrix (K×K)
K0Z	intercept from the P-dynamics (K×1)
K1Z	feedback matrix from the P-dynamics (K×K)
se	Variance of the portfolio of yields observed with error (scalar)
Gy.0	matrix of contemporaneous terms from the P-dynamics (K×K)
mat	vector of maturities (in years) of yields used in estimation (J x 1)
Y	matrix of yields used in estimation (J x T)
Z	complete set of spanned and unspanned factors (K×T)
P	complete set of spanned factors (N×T)
Wpca	matrix of weights of the portfolios observed without errors (N×J)
We	matrix of weights of the portfolios observed with errors ((J-N)×J)
WpcaFull	composite matrix of weights the portfolios observed with and without errors
dt	time interval unit of the model (scalar). For instance, if data is (i) monthly, dt <- 12; (ii) quarterly, dt <- 4; (iii) yearly, dt <- 1.
Economy	name of the economy under study
FactorLabels	string-list based which contains the labels of all the variables present in the model
ModelType	Feasible options are: (i) "JPS", (ii) "JPS jointP" or (iii) "GVAR sepQ"
GVARinputs	if the model chosen is the "GVAR sepQ", the "GVARinputs" should be specified (see "GVAR" function)
nargout	if nargout== 1: provides only the values of the likelihood; if nargout== 2: complete ATSM outputs

**References**

This function is modified version of the "A0N\_MLEdensity\_WOE" function by Le and Singleton (2018).

"A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>



---

ModelPara	<i>Replications of the JPS (2014) outputs by the MultiATSM package</i>
-----------	--

---

**Description**

Unspanned macro risk model outputs by the MultiATSM package

**Usage**

```
data("JPSrep")
```

**Format**

list of inputs and outputs

**inputs** general model inputs

**ests** model parameters estimates (JPS form)

**llk** log-likelihood of the observations

**rot** model parameters estimates (rotation form)

---

MultiATSM	<i>ATSM Package</i>
-----------	---------------------

---

**Description**

Estimation of several classes of affine term structure of interest rates models.

**Author(s)**

Rubens Moura <rubens.gtmoura@gmail.com>

---

NumOutputs	<i>Construct the model numerical outputs (model fit, IRFs, GIRFs, FEVDs, and GFEVDs)</i>
------------	--

---

**Description**

Construct the model numerical outputs (model fit, IRFs, GIRFs, FEVDs, and GFEVDs)

**Usage**

```
NumOutputs(ModelType, ModelPara, InputsForOutputs, FactorLabels, Economies)
```

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
InputsForOutputs	list conataining the desired horizon of analysis for the model fit, IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	a string-list based which contains all the labels of all the variables present in the model
Economies	a string-vector containing the names of the economies which are part of the economic system

**Value**

List of the model numerical outputs, namely

1. Model fit of bond yields
2. IRFs
3. FEVDs
4. GIRFs
5. GFEVDs

**Examples**

```
# See examples in the vignette file of this package (Section 4).
```

---

NumOutputs\_Bootstrap    *Numerical outputs (IRFs, GIRFs, FEVD, and GFEVD) for bootstrap*

---

### Description

Numerical outputs (IRFs, GIRFs, FEVD, and GFEVD) for bootstrap

### Usage

```
NumOutputs_Bootstrap(  
  ModelType,  
  ModelParaBoot,  
  InputsForOutputs,  
  FactorLabels,  
  Economies  
)
```

### Arguments

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
InputsForOutputs	list containing the desired inputs for the construction of the model fit, IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

Optimization    *Perform the minimization of mean(f)*

---

### Description

Perform the minimization of mean(f)

### Usage

```
Optimization(  
  f,  
  tol,  
  varargin,  
  FactorLabels,
```

```

Economies,
ModelType,
JLLinputs = NULL,
GVARinputs = NULL
)

```

### Arguments

<code>f</code>	vector-valued objective function (function)
<code>tol</code>	convergence tolerance (scalar). For ML estimation, a reasonable value is <code>tol &lt;- 1e-4</code>
<code>varargin</code>	list containing starting values and constraints: for each input argument <code>K</code> (of <code>f</code> ), we need four inputs that look like: <ol style="list-style-type: none"> <li>1. a starting value: <code>K0</code></li> <li>2. a variable label ('<code>K0</code>') followed by a ':' followed by a type of constraint. The constraint can be: <ul style="list-style-type: none"> <li>• 'bounded': bounded matrix;</li> <li>• 'Jordan' or 'Jordan MultiCountry': a matrix of Jordan type;</li> <li>• 'psd': psd matrix;</li> <li>• 'stationary': largest eigenvalue of the risk-neutral feedback matrix is strictly smaller than 1;</li> <li>• 'diag' or 'BlockDiag': a diagonal or block diagonal matrix.</li> <li>• 'JLLstructure': to impose the zero-restrictions on the variance-covariance matrix along the lines of the JLL models</li> </ul> </li> <li>3. a lower bound <code>lb</code> (<code>lb &lt;- NULL</code> -&gt; no lower bound)</li> <li>4. an upper bound <code>ub</code> (<code>ub &lt;- NULL</code> -&gt; no upper bound)</li> <li>5. Specification of the optimization settings: <ul style="list-style-type: none"> <li>• 'iter off': hide the printouts of the numerical optimization routines;</li> <li>• 'fminunc only': only uses <code>fminunc</code> for the optimization;</li> <li>• 'fminsearch only': only uses <code>fminsearch</code> for the optimization.</li> </ul> </li> </ol>
<code>FactorLabels</code>	string-list based which contains the labels of all the variables present in the model
<code>Economies</code>	string-vector containing the names of the economies which are part of the economic system
<code>ModelType</code>	string-vector containing the label of the model to be estimated
<code>JLLinputs</code>	inputs used in the estimation of the JLL-based models; Default is set to <code>NULL</code>
<code>GVARinputs</code>	inputs used in the estimation of the GVAR-based models; Default is set to <code>NULL</code>

### Details

If a variable name starts with a '@', it means that that parameter will be analytically concentrated out in the specification of `f`. In this case, no starting value is needed for this particular parameter (an empty matrix can be provided as a starting value).

**Value**

- (i) out: list of second output produced by f (the first output of f must be the objective value to be minimized).
- (ii) x: list containing parameter estimates

**References**

This function is based on the "LS\_\_opt" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

**Examples**

```
#' # See examples in the vignette file of this package (Section 4).
```

---

Optimization_Boot	<i>Perform the minimization of mean(f) (adapted for the bootstrap setting)</i>
-------------------	--

---

**Description**

Perform the minimization of mean(f) (adapted for the bootstrap setting)

**Usage**

```
Optimization_Boot(  
  f,  
  tol,  
  varargin,  
  FactorLabels,  
  Economies,  
  ModelType,  
  JLLinputs = NULL,  
  GVARinputs = NULL  
)
```

**Arguments**

- |          |  |
|----------|--|
| f        | vector-valued objective function (function)  |
| tol      | convergence tolerance (scalar). For ML estimation, a reasonable value is $tol < 1e-4$  |
| varargin | list containing starting values and constraints: for each input argument K (of f), we need four inputs that look like: <ol style="list-style-type: none"> <li>1. a starting value: K0</li> </ol> |

2. a variable label ('K0') followed by a ':' followed by a type of constraint. The constraint can be:
  - 'bounded': bounded matrix;
  - 'Jordan' or 'Jordan MultiCountry': a matrix of Jordan type;
  - 'psd': psd matrix;
  - 'stationary': largest eigenvalue of the risk-neutral feedback matrix is strictly smaller than 1;
  - 'diag' or 'BlockDiag': a diagonal or block diagonal matrix.
  - 'JLLstructure': to impose the zero-restrictions on the variance-covariance matrix along the lines of the JLL models
3. a lower bound lb (lb <- NULL -> no lower bound)
4. an upper bound ub (ub <- NULL -> no upper bound)
5. Specification of the optimization settings:
  - 'iter off': hide the printouts of the numerical optimization routines;
  - 'fminunc only': only uses fminunc for the optimization;
  - 'fminsearch only': only uses fminsearch for the optimization.

FactorLabels	string-list based which contains the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system
ModelType	string-vector containing the label of the model to be estimated
JLLinputs	inputs used in the estimation of the JLL-based models; Default is set to NULL
GVARinputs	inputs used in the estimation of the GVAR-based models; Default is set to NULL

### Details

If a variable name starts with a '@', it means that that parameter will be analytically concentrated out in the specification of  $f$ . In this case, no starting value is needed for this particular parameter. An empty matrix can be provided as a starting value

### Value

- (i) out: list of second output produced by  $f$  (the first output of  $f$  must be the objective value to be minimized)
- (ii) x: list containing parameter estimates

### References

This function is based on the "LS\_\_opt" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

OutputConstructionJoint

*Numerical outputs (variance explained, model fit, IRFs, GIRFs, FEVDs, and GFEVDs) for "joint Q" models*

---

### Description

Numerical outputs (variance explained, model fit, IRFs, GIRFs, FEVDs, and GFEVDs) for "joint Q" models

### Usage

```
OutputConstructionJoint(
  ModelType,
  ModelPara,
  InputsForOutputs,
  FactorLabels,
  Economies
)
```

### Arguments

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
InputsForOutputs	list containing the desired horizon of analysis for the model fit, IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

OutputConstructionJoint\_BS

*Gathers all the model numerical outputs after bootstrap for "joint Q" models*

---

### Description

Gathers all the model numerical outputs after bootstrap for "joint Q" models

**Usage**

```
OutputConstructionJoint_BS(
  ModelType,
  ModelParaBoot,
  InputsForOutputs,
  FactorLabels,
  Economies
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
InputsForOutputs	list containing the desired inputs for the construction of IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

OutputConstructionSep *Numerical outputs (variance explained, model fit, IRFs, GIRFs, FEVDs, and GFEVDs) for "sep Q" models*

---

**Description**

Numerical outputs (variance explained, model fit, IRFs, GIRFs, FEVDs, and GFEVDs) for "sep Q" models

**Usage**

```
OutputConstructionSep(
  ModelType,
  ModelPara,
  InputsForOutputs,
  FactorLabels,
  Economies
)
```



**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (See the "Optimization" function)
InputsForOutputs	list conataining the desired horizon of analysis for the model fit, IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

OutputConstructionSep\_BS

*Gathers all the model numerical ouputs after bootstrap for "sep Q" models*

---

**Description**

Gathers all the model numerical ouputs after bootstrap for "sep Q" models

**Usage**

```
OutputConstructionSep_BS(  
  ModelType,  
  ModelParaBoot,  
  InputsForOutputs,  
  FactorLabels,  
  Economies  
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelParaBoot	list of model parameter estimates (see the "Optimization" function) after a bootstrap draw
InputsForOutputs	list conataining the desired inputs for the cunstruction of the model fit, IRFs, GIRFs, FEVDs, and GFEVDs
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

ParaLabels	<i>Create the variable labels used in the estimation</i>
------------	--

---

**Description**

Create the variable labels used in the estimation

**Usage**

```
ParaLabels(ModelType, WishStationarityQ)
```

**Arguments**

**ModelType** a string-vector containing the label of the model to be estimated

**WishStationarityQ**  
User must set "1" is she whises to impose the largest eigenvalue under the Q to be strictly smaller than 1. Otherwise set "0"

**Value**

list containing the features of the parameters that will be used in the estimation

**Examples**

```
ModelType <- "GVAR jointQ"
WishStationarityQ <- 1
ParaLabels(ModelType, WishStationarityQ)
```

---

pca_weights_one_country	<i>Weigth matrix from principal components (matrix of eigenvectors)</i>
-------------------------	---

---

**Description**

Weigth matrix from principal components (matrix of eigenvectors)

**Usage**

```
pca_weights_one_country(Y, Economy)
```

**Arguments**

**Y** matrix dimension (J x T), where J - the number of maturities and T - time series length

**Economy** string-vector containg the name of one economy

**Value**

matrix (J x J)

**Examples**

```
data("CM_Yields")
pca_weights_one_country(Yields, Economy= "Brazil")
```

---

PdynamicsSet_BS	<i>Compute some key parameters from the P-dynamics (Bootstrap set)</i>
-----------------	--

---

**Description**

Compute some key parameters from the P-dynamics (Bootstrap set)

**Usage**

```
PdynamicsSet_BS(  
  ModelType,  
  AllFactorsUnderP,  
  FactorLabels,  
  Economies,  
  JLLinputs = NULL,  
  GVARinputs = NULL  
)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
AllFactorsUnderP	complete set of factors that may be used in the estimation of P (KxT)
FactorLabels	string-list based which contains the labels of all the variables present in the model (see "LabFac" function)
Economies	string-vector containing the names of the economies which are part of the economic system
JLLinputs	List containing the necessary inputs for the estimation of the JLL-based models (see "JLL" function). Default is set to NULL.
GVARinputs	List containing the necessary inputs for the estimation of the GVAR-based models (see "GVAR" function). Default is set to NULL.

---

 pos2x

*Transform a positive number y to back to x by:*


---

**Description**

Transform a positive number y to back to x by:

**Usage**

pos2x(y)

**Arguments**

y                    scalar

**References**

This function is based on the "pos2x" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

 Reg\_K1Q

*Estimate the risk-neutral feedback matrix K1Q using linear regressions*


---

**Description**

Estimate the risk-neutral feedback matrix K1Q using linear regressions

**Usage**

Reg\_K1Q(Y, mat, Z, dt, type)

**Arguments**

Y                    matrix of yields used in estimation (J x T)  
 mat                vector of maturities (in years) of yields used in estimation (J x 1)  
 Z                    pricing factors (can be yields-based or non-yields/macro variables) (N x T)  
 dt                  time unit of the model (scalar). For instance, if data is (i) monthly, dt <- 12; (ii) quarterly, dt <- 4; (iii) yearly, dt <- 1.  
 type                'Jordan' -> K1Q will be of the Jordan type

**Value**

Risk neutral feedback matrix K1Q.

**References**

This function is based on the "Reg\_K1Q" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

**Examples**

```
data(CM_Yields)

Y_China <- Yields[1:6,]
Z_China <- Spanned_Factors(Y_China, Economies ="China", N=3)
mat <-c(0.25 , 0.5 , 1, 3, 5, 10)
dt <- 1/12
type <- 'Jordan'
Reg_K1Q(Y_China, mat, Z_China, dt, type)
```

---

Reg\_OLSconstrained     *Restricted OLS regression*

---

**Description**

Restricted OLS regression

**Usage**

```
Reg_OLSconstrained(Y, X, Bcon, G)
```

**Arguments**

Y	left hand side variables (M x T)
X	regressors (i.e. N-1 variables + the intercept) (N x T)
Bcon	constraints matrix (M x N). If Bcon(i,j) = nan -> B(i,j) is a free parameter
G	weighting matrix (psd) - (M x M). Default is set to be identity

**Details**

# Estimate of B is obtained by minimizing the objective:  
 $\sum_t (Y_t - B X_t)' G^{-1} (Y_t - B X_t)$   
 subject to the constraint that  $B = Bcon$  for all non-nan entries of Bcon

**Value**

matrix of coefficient (M x N)

**References**

This function is based on the "Reg\_\_OLSconstrained" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

RemoveNA	<i>Exclude series that contain NAs</i>
----------	--

---

**Description**

Exclude series that contain NAs

**Usage**

```
RemoveNA(YieldsData, MacroData, Economies)
```

**Arguments**

YieldsData	List of country-specific bond yields
MacroData	List of country-specific and global economic variables
Economies	string-vector containing the names of the economies which are part of the economic system

**Value**

return the time series data that were not initially composed by NAs.

---

RiskFactors	<i>Data: Risk Factors - Candelon and Moura (2021)</i>
-------------	---

---

**Description**

Risk factors data used in Candelon and Moura (2021)

**Usage**

```
data("CM_Factors")
```

**Format**

matrix containing the risk factors of the models

**References**

Candelon, B. and Moura, R. "A Multi-Country Model of the Term Structures of Interest Rates with a GVAR".

---

RiskFactorsGraphs	<i>Spanned and unspanned factors plot</i>
-------------------	---

---

**Description**

Spanned and unspanned factors plot

**Usage**

```
RiskFactorsGraphs(ModelType, ModelOutputs, Economies, FactorLabels)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelOutputs	list of model parameter estimates (see the "Optimization" function)
Economies	string-vector containing the names of the economies which are part of the economic system
FactorLabels	string-list based which contains the labels of all the variables present in the model

---

RiskFactorsPrep	<i>Builds the complete set of time series of the risk factors (spanned and unspanned)</i>
-----------------	---

---

**Description**

Builds the complete set of time series of the risk factors (spanned and unspanned)

**Usage**

```
RiskFactorsPrep(
  FactorSet,
  Economies,
  FactorLabels,
  Initial_Date,
  Final_Date,
  DataFrequency
)
```

**Arguments**

FactorSet	Factor set list (see e.g. "CM_Factors_GVAR" data file)
Economies	string-vector containing the names of the economies which are part of the economic system
FactorLabels	string-list based which contains the labels of all the variables present in the model
Initial_Date	Sample starting date (yyyy-mm-dd)
Final_Date	Sample last date (yyyy-mm-dd)
DataFrequency	character-based vector: "Daily All Days", "Daily Business Days", "Weekly", "Monthly", "Quarterly", "Annually"

**Value**

Risk factors used in the estimation of the desired ATSM

---

RMSEjoint	<i>Compute the root mean square error ("joint Q" models)</i>
-----------	--

---

**Description**

Compute the root mean square error ("joint Q" models)

**Usage**

RMSEjoint(ForecastOutputs)

**Arguments**

ForecastOutputs	List of country-specific forecasts (see "ForecastYieldsjointQ" function)
-----------------	--

---

RMSEsep	<i>Compute the root mean square error ("sep Q" models)</i>
---------	--

---

**Description**

Compute the root mean square error ("sep Q" models)

**Usage**

RMSEsep(ForecastOutputs)

**Arguments**

ForecastOutputs	List of country-specific forecasts (see "ForecastYieldsSepQ" function)
-----------------	--



---

SpannedFactorsjointQ *Gather all spanned factors ("joint Q" models)*

---

**Description**

Gather all spanned factors ("joint Q" models)

**Usage**

SpannedFactorsjointQ(ModelType, ModelPara, Economies, t0Sample, tlastObserved)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	set of model parameters
Economies	string-vector containing the names of the economies which are part of the economic system
t0Sample	index for the initial sample date
tlastObserved	index for the last observation of the information set

---

SpannedFactorsSepQ *Gather all spanned factors ("sep Q" models)*

---

**Description**

Gather all spanned factors ("sep Q" models)

**Usage**

SpannedFactorsSepQ(ModelType, ModelPara, Economies, t0Sample, tlastObserved)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	set of model parameters
Economies	string-vector containing the names of the economies which are part of the economic system
t0Sample	index for the initial sample date
tlastObserved	index for the last observation of the information set

---

Spanned_Factors	<i>Compute the country-specific spanned factors</i>
-----------------	---

---

**Description**

Compute the country-specific spanned factors

**Usage**

```
Spanned_Factors(Yields, Economies, N)
```

**Arguments**

Yields	matrix (J x T), where J - the number of maturities and T - time series length
Economies	C-dimensional string-vector containing the names of the economies which are part of the economic system
N	scalar: desired number of spanned factors (maximum number allowed is N= J)

**Value**

Matrix containing the N spanned for all the countries of the system (CJ xT)

**Examples**

```
data(CM_Yields)
Economies <- c("China", "Brazil", "Mexico", "Uruguay")
N <- 3
Spanned_Factors(Yields, Economies, N)
```

---

sqrtm_robust	<i>Compute the square root of a matrix</i>
--------------	--

---

**Description**

Compute the square root of a matrix

**Usage**

```
sqrtm_robust(m)
```

**Arguments**

m	squared matrix (KxK)
---	----------------------

**Value**

squared matrix  $x$  ( $K \times K$ ) such that  $x$

**References**

#' This function is a modified version of the "sqrtm\_robust" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

 StarFactors

*Generates the star variables necessary for the GVAR estimation*


---

**Description**

Generates the star variables necessary for the GVAR estimation

**Usage**

```
StarFactors(RiskFactors, Economies, W)
```

**Arguments**

RiskFactors	time series of the risk factors ( $F \times T$ )
Economies	string-vector containing the names of the economies which are part of the economic system
W	GVAR transition matrix ( $C \times C$ )

**Value**

List containing the star factors of each country of the economic system

**Examples**

```
data(CM_Factors)
Economies <- c("China", "Brazil", "Mexico", "Uruguay")
Wgvar <- matrix( c(0, 0.83, 0.86, 0.38, 0.65, 0, 0.13, 0.55,
                  0.32, 0.12, 0, 0.07, 0.03, 0.05, 0.01, 0), nrow = 4, ncol = 4)
rownames(Wgvar) <- Economies
colnames(Wgvar) <- Economies
StarFactors(RiskFactors, Economies, Wgvar)
```

---

TradeFlows

*Data: Trade Flows - Candelon and Moura (2021)*

---

**Description**

Trade Flows data used in Candelon and Moura (2021)

**Usage**

```
data("CM_Trade")
```

**Format**

list containing the bilateral trade flows

**References**

Candelon, B. and Moura, R. "A Multi-Country Model of the Term Structures of Interest Rates with a GVAR".

---

Transition\_Matrix

*Compute the transition matrix required in the estimation of the GVAR model*

---

**Description**

Compute the transition matrix required in the estimation of the GVAR model

**Usage**

```
Transition_Matrix(  
  t_First,  
  t_Last,  
  Economies,  
  type,  
  DataPath = NULL,  
  Data = NULL  
)
```

**Arguments**

t_First	Sample starting date (year)
t_Last	Sample last date (year)
Economies	Vector containing the names of all the economies of the system.
type	Three possibilities: <ul style="list-style-type: none"> <li>• "Full Sample": if one wishes ALL weight matrices of each year from which data is available (it may extrapolate the sample period);</li> <li>• "Sample Mean": if one wishes a SINGLE weight matrix containing the average of weights over of the entire sample period;</li> <li>• Some year in particular (e.g. "1998", "2005" ...).</li> </ul>
DataPath	path of the Excel file containing the data (if any). The default is linked to the Excel file available in the package.
Data	Data for computing the transition matrix. Default is set to NULL.

**Details**

NOTE: if there is missing data for any country of the system for that particularly year, then the transition matrix will include only NAs.

**Value**

matrix or list of matrices

**Examples**

```
data(CM_Trade)

t_First <- "2006"
t_Last <- "2019"
Economies <- c("China", "Brazil", "Mexico", "Uruguay")
type <- "Sample Mean"
Transition_Matrix(t_First, t_Last, Economies, type, DataPath = NULL, Data = TradeFlows)
```

---

true2aux                      *Map constrained parameters b to unconstrained auxiliary parameters a.*

---

**Description**

Map constrained parameters b to unconstrained auxiliary parameters a.

**Usage**

```
true2aux(b, ctype, lb, ub, Economies, FactorLabels, JLLinputs = NULL)
```

**Arguments**

b	Constrained parameter
cstype	character-based vector that describes the constraints. Constraints are: <ul style="list-style-type: none"> <li>• 'Jordan';</li> <li>• 'Jordan; stationary'</li> <li>• 'Jordan MultiCountry'</li> <li>• 'Jordan MultiCountry; stationary'</li> <li>• 'stationary'</li> <li>• 'psd'</li> <li>• 'BlockDiag'</li> <li>• 'bounded'</li> <li>• 'diag'</li> <li>• 'JLLstructure'</li> </ul>
lb	lower bounds of b (for the bounded case). Accomodates a scalar or a matrix.
ub	upper bounds of b (for the bounded case). Accomodates a scalar or a matrix.
Economies	string-vector containing the names of the economies which are part of the economic system
FactorLabels	string-list based which contains the labels of all the variables present in the model
JLLinputs	list of necessary inputs for the estimation of JLL-based models (see "JLL" function)

**Value**

unconstrained auxiliary matrix.

**References**

This function is a modified and extended version of the "true2aux" function by Le and Singleton (2018).

"A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>

---

update_para	<i>converts the vectorized auxiliary parameter vector x to the parameters that go directly into the likelihood function.</i>
-------------	--

---

**Description**

converts the vectorized auxiliary parameter vector x to the parameters that go directly into the likelihood function.

**Usage**

```

update_para(
    x,
    sizex,
    ii,
    con,
    FactorLabels,
    Economies,
    JLLinputs = NULL,
    GVARinputs = NULL,
    varargin
)

```

**Arguments**

x	vector containing all the vectorized auxiliary parameters
sizex	matrix (6x2) containing the size information of all parameters
ii	if empty: converts all the parameters; otherwise converts some specific parameters
con	if con = 'concentration', then set the value of the parameter whose name contains @ to empty
FactorLabels	string-list based which contains the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system
JLLinputs	Set of necessary inputs used in the estimation of the JLL-based models
GVARinputs	Set of necessary inputs used in the estimation of the GVAR-based models
varargin	variable inputs used in the optimization (see "Optimization" function)

**Value**

same form as varargin, except now the parameters are updated with the values provided by the auxiliary x. Importantly, by construction, all the constraints on the underlying parameters are satisfied.

**References**

This function is a modified version of the "update\_para" function by Le and Singleton (2018). "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models." (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at: <https://cepr.org/40029>

---

VAR *Estimates a VAR(1)*

---

**Description**

Estimates a VAR(1)

**Usage**

VAR(RiskFactors, VARtype, Bcon = NULL)

**Arguments**

RiskFactors      matrix containing all the risk factors (K x T)  
 VARtype          string-vector which accommodates two possibilities: 'unconstrained' or 'constrained'  
 Bcon              constraints matrix (K+1 x N) - should contain an intercept. If Bcon(i,j) = nan -> B(i,j) is a free parameter.  
                     Default is set to NULL.

**Value**

intercept, feedback matrix and the variance-covariance matrix of a VAR(1)

**Examples**

```
data("CM_Factors")
#Example 1
VAR(RiskFactors, VARtype= 'unconstrained')
#Example 2
K <- nrow(RiskFactors)
Bcon <-matrix(0, nrow = K, ncol = K+1)
Bcon[,1:3] <- NaN
VAR(RiskFactors, VARtype= 'constrained', Bcon)
```

---

VarianceExplainedJoint

*Percentage explained by the spanned factors of the variations in the set of observed yields for "joint Q" models*

---

**Description**

Percentage explained by the spanned factors of the variations in the set of observed yields for "joint Q" models



**Usage**

VarianceExplainedJoint(ModelType, ModelPara, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

VarianceExplainedSep *Percentage explained by the spanned factors of the variations in the set of observed yields for "sep Q" models*

---

**Description**

Percentage explained by the spanned factors of the variations in the set of observed yields for "sep Q" models

**Usage**

VarianceExplainedSep(ModelType, ModelPara, FactorLabels, Economies)

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (see the "Optimization" function)
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

---

x2bound	<i>Transform x to a number bounded btw lb and ub by:</i>
---------	--

---

**Description**

Transform x to a number bounded btw lb and ub by:

**Usage**

x2bound(x, lb, ub, nargout)

**Arguments**

x	number to be transformed (scalar)
lb	lower bound (scalar)
ub	upper bound (scalar)
nargout	"1" or "2" (scalar)

**References**

This function is based on the "x2bound" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling). Available at:  
<https://cepr.org/40029>

---

x2pos	<i>Transform x to a positive number by: <math>y = \log(e^x + 1)</math></i>
-------	--

---

**Description**

Transform x to a positive number by:  $y = \log(e^x + 1)$

**Usage**

x2pos(x, nargout)

**Arguments**

x	scalar or vector
nargout	1 or 2

**References**

This function is based on the "x2pos" function by Le and Singleton (2018).  
 "A Small Package of Matlab Routines for the Estimation of Some Term Structure Models."  
 (Euro Area Business Cycle Network Training School - Term Structure Modelling) Available at:  
<https://cepr.org/40029>

---

Yields	<i>Data: Yields - Candelon and Moura (2021)</i>
--------	---

---

**Description**

Yields data used in Candelon and Moura (2021)

**Usage**

```
data("CM_Yields")
```

**Format**

matrix containing the Yields of the models

**References**

Candelon, B. and Moura, R. "A Multi-Country Model of the Term Structures of Interest Rates with a GVAR".

---

YieldsFitJoint	<i>Computes two measures of model fit for bond yields</i>
----------------	---

---

**Description**

Computes two measures of model fit for bond yields

**Usage**

```
YieldsFitJoint(ModelType, ModelPara, FactorLabels, Economies)
```

**Arguments**

ModelType	string-vector containing the label of the model to be estimated
ModelPara	list of model parameter estimates (see the "Optimization" function)
FactorLabels	string-list based which contains all the labels of all the variables present in the model
Economies	string-vector containing the names of the economies which are part of the economic system

**Details**

"Model-implied yields" is the measure of fit based exclusively on the risk-neutral parameters, whereas the "Model-Fit" takes into account both the risk-neutral and the physical parameters.

**References**

See, for instance, Jotiskhatira, Le and Lundblad (2015). "Why do interest rates in different currencies co-move?" (Journal of Financial Economics)

---

YieldsFitsep	<i>Computes two measures of model fit for bond yields</i>
--------------	---

---

**Description**

Computes two measures of model fit for bond yields

**Usage**

YieldsFitsep(ModelType, ModelPara, FactorLabels, Economies)

**Arguments**

ModelType	a string-vector containing the label of the model to be estimated
ModelPara	List of model parameter estimates (See the "Optimization" function)
FactorLabels	a string-list based which contains the labels of all the variables present in the model
Economies	a string-vector containing the names of the economies which are part of the economic system

**Details**

"Model-implied yields" is the measure of fit based exclusively on the risk-neutral parameters, whereas the "Model-Fit" takes into account both the risk-neutral and the physical parameters.

**References**

See, for instance, Jotiskhatira, Le and Lundblad (2015). "Why do interest rates in different currencies co-move?" (Journal of Financial Economics)

# Index

- \* **(2014)**
  - BR\_jps\_out, 16
  - ModelPara, 81
- \* **Factors**
  - FactorsGVAR, 23
  - RiskFactors, 94
- \* **Flows**
  - TradeFlows, 100
- \* **GVAR**
  - FactorsGVAR, 23
- \* **JPS**
  - BR\_jps\_out, 16
  - ModelPara, 81
- \* **Risk**
  - FactorsGVAR, 23
  - RiskFactors, 94
- \* **Trade**
  - TradeFlows, 100
- \* **Yields**
  - Yields, 107
- \* **outputs**
  - BR\_jps\_out, 16
  - ModelPara, 81
- A0N\_\_computeBnAn\_jointQ, 10
- A0N\_\_computeBnAn\_sepQ, 11
- A0N\_MLEdensity\_WOE\_\_jointQ\_Bootstrap, 4
- A0N\_MLEdensity\_WOE\_\_jointQ\_sepSigma\_BootstrapFunctionf\_Boot, 6
- A0N\_MLEdensity\_WOE\_\_sepQ\_Bootstrap, 8
- aux2true, 12
- Bootstrap, 13
- BootstrapBoundsSet, 14
- bound2x, 15
- BR\_jps\_out, 16
- BUnspannedAdapJoint, 16
- BUnspannedAdapSep, 17
- BUnspannedAdapSep\_BS, 17
- contain, 18
- DatabasePrep, 19
- DataForEstimation, 20
- DataSet\_BS, 21
- df\_\_dx, 22
- f\_with\_vectorized\_parameters, 38
- FactorsGVAR, 23
- FEVDandGFEVDBs\_jointQ, 23
- FEVDandGFEVDBs\_jointQ\_Ortho, 24
- FEVDandGFEVDBs\_sepQ, 25
- FEVDgraphsJLLOrtho, 25
- FEVDgraphsJoint, 26
- FEVDgraphsSep, 27
- FEVDjoint, 28
- FEVDjoint\_BS, 29
- FEVDjointOrthogoJLL, 28
- FEVDjointOrthogoJLL\_BS, 29
- FEVDsep, 30
- FEVDsep\_BS, 31
- FitgraphsJoint, 31
- FitgraphsSep, 32
- FMN\_\_Rotate, 33
- ForecastYields, 34
- ForecastYieldsJointQ, 35
- ForecastYieldsSepQ, 36
- Functionf, 37
- Functionf\_Boot, 37
- GaussianDensity, 40
- getpara, 40
- getx, 41
- GFEVDgraphsJLLOrtho, 42
- GFEVDgraphsJoint, 42
- GFEVDgraphsSep, 43
- GFEVDjoint, 44
- GFEVDjoint\_BS, 46
- GFEVDjointOrthoJLL, 45
- GFEVDjointOrthoJLL\_BS, 45

- GFEVDsep, [47](#)
- GFEVDsep\_BS, [48](#)
- GIRFgraphsJLLOrtho, [48](#)
- GIRFgraphsJoint, [49](#)
- GIRFgraphsSep, [50](#)
- GIRFjoint, [50](#)
- GIRFjoint\_BS, [53](#)
- GIRFjointOrthoJLL, [51](#)
- GIRFjointOrthoJLL\_BS, [52](#)
- GIRFSep, [53](#)
- GIRFSep\_BS, [54](#)
- GraphicalOutputs, [55](#)
- GVAR, [55](#)
  
- IdxAllSpanned, [57](#)
- IdxSpanned, [57](#)
- InputsForMLEdensity, [58](#)
- InputsForMLEdensity\_BS, [60](#)
- InputsForOutputs, [61](#)
- IRFandGIRFbs\_jointQ, [63](#)
- IRFandGIRFbs\_jointQ\_Ortho, [64](#)
- IRFandGIRFbs\_sepQ, [65](#)
- IRFgraphsJLLOrtho, [65](#)
- IRFgraphsJoint, [66](#)
- IRFgraphsSep, [67](#)
- IRFjoint, [68](#)
- IRFjoint\_BS, [69](#)
- IRFjointOrthoJLL, [68](#)
- IRFjointOrthoJLL\_BS, [69](#)
- IRFsep, [70](#)
- IRFsep\_BS, [71](#)
  
- JLL, [71](#)
  
- K1XQStationary, [73](#)
- killa, [73](#)
  
- LabelsSpanned, [74](#)
- LabelsStar, [74](#)
- LabFac, [74](#)
  
- Maturities, [75](#)
- MLEdensity\_jointQ, [76](#)
- MLEdensity\_jointQ\_sepSigma, [77](#)
- MLEdensity\_sepQ, [79](#)
- ModelPara, [81](#)
- MultiATSM, [81](#)
  
- NumOutputs, [82](#)
- NumOutputs\_Bootstrap, [83](#)
  
- Optimization, [83](#)
- Optimization\_Boot, [85](#)
- OutputConstructionJoint, [87](#)
- OutputConstructionJoint\_BS, [87](#)
- OutputConstructionSep, [88](#)
- OutputConstructionSep\_BS, [89](#)
  
- ParaLabels, [90](#)
- pca\_weights\_one\_country, [90](#)
- PdynamicsSet\_BS, [91](#)
- pos2x, [92](#)
  
- Reg\_OLSconstrained, [93](#)
- Reg\_K1Q, [92](#)
- RemoveNA, [94](#)
- RiskFactors, [94](#)
- RiskFactorsGraphs, [95](#)
- RiskFactorsPrep, [95](#)
- RMSEjoint, [96](#)
- RMSEsep, [96](#)
  
- Spanned\_Factors, [98](#)
- SpannedFactorsjointQ, [97](#)
- SpannedFactorsSepQ, [97](#)
- sqrtm\_robust, [98](#)
- StarFactors, [99](#)
  
- TradeFlows, [100](#)
- Transition\_Matrix, [100](#)
- true2aux, [101](#)
  
- update\_para, [102](#)
  
- VAR, [104](#)
- VarianceExplainedJoint, [104](#)
- VarianceExplainedSep, [105](#)
  
- x2bound, [106](#)
- x2pos, [106](#)
  
- Yields, [107](#)
- YieldsFitJoint, [107](#)
- YieldsFitsep, [108](#)