Package 'genpathmox'

May 5, 2022

Title Pathmox Approach Segmentation Tree Analysis

Version 0.8

Description It provides an interesting solution for handling a high number of segmentation variables in partial least squares structural equation modeling. The package implements the ``Pathmox" algorithm (Lamberti, Sanchez, and Aluja,(2016)<doi:10.1002/asmb.2168>) including the F-coefficient test (Lamberti, Sanchez, and Aluja,(2017)<doi:10.1002/asmb.2270>) to detect the path coefficients responsible for the identified differences). The package also allows running the hybrid multi-group approach (Lamberti (2021) <doi:10.1007/s11135-021-01096-9>).

Depends R (>= 3.5.0), stats, cSEM, diagram, methods, graphics, grDevices

License GPL-3

LazyData true

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RoxygenNote 7.1.1

NeedsCompilation no

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Repository CRAN

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R topics documented:

`bar_impvar` *Bar Plot of a ranking of categorical variables by importance*

Description

`"bar_impvar"` returns a bar plot to visualize the ranking of variables by importance in obtaining the terminal nodes of Pathmox.

Usage

```
bar_impvar(x, cex.names = 1, cex.axis = 1.2, cex.main = 1, ...)
```

Arguments

`x`	An object of the class `"plstree"`
`cex.names`	Expansion factor for axis names (bar labels)
`cex.axis`	Expansion factor for numeric axis labels
`cex.main`	Allows fixing the size of the main. Equal to 1 to default
`...`	Further arguments are ignored

Details

The importance of each variable is determined by adding the F-statistic calculated for the variable in each split node of Pathmox.

Author(s)

Giuseppe Lamberti

References

Lamberti, G. et al. (2016). The Pathmox approach for PLS path modeling segmentation. *Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2168.

Lamberti, G. (2015). *Modeling with Heterogeneity*, PhD Dissertation.

See Also

`summary.plstree`, `print.plstree`, `pls.pathmox`, `bar_terminal`, and `plot.plstree`

Examples

```
 ## Not run:
# Example of PATHMOX approach in customer satisfaction analysis
# (Spanish financial company).
# Model with 5 LVs (4 reflective: Image (IMAG), Value (VAL),
# Satisfaction (SAT), and Loyalty (LOY); and 1 formative construct:
# Quality (QUAL))

# load library and dataset csibank
library(genpathmx)
data("csibank")

# Define the model using the lavaan syntax. Use a set of regression formulas to define
# first the structural model and then the measurement model

CSImodel <- "
# Structural model
VAL  ~ QUAL
SAT  ~ IMAG  + QUAL + VAL
LOY  ~ IMAG + SAT

# Measurement model
# Formative
QUAL <~ qual1 + qual2 + qual3 + qual4 + qual5 + qual6 + qual7

# Reflective
IMAG <~ imag1 + imag2 + imag3 + imag4 + imag5 + imag6
VAL  <~ val1  + val2  + val3  + val4
SAT  =~ sat1  + sat2  + sat3
LOY  =~ loy1  + loy2  + loy3

"

# Check if variables are well specified (they have to be factors
# and/or ordered factors)
str(CSIcatvar)

# Transform age and education into ordered factors
CSIcatvar$Age = factor(CSIcatvar$Age, levels=c("<=25",
                                    "26-35", "36-45", "46-55",
                                    "56-65", ">=66"),ordered=T)

CSIcatvar$Education = factor(CSIcatvar$Education,
                             levels=c("Unfinished","Elementary", "Highschool",
                             "Undergrad", "Graduated"),ordered=T)

# Run Pathmox analysis (Lamberti et al., 2016; 2017)
csi.pathmox = pls.pathmox(
 .model = CSImodel ,
 .data  = csibank,
 .catvar= CSIcatvar,
 .signif = 0.05,
```

```
 .deep=2
)

bar_impvar(csi.pathmox)


## End(Not run)
```

`bar_terminal` *Comparative plot for the Pathmox terminal nodes*

Description

`bar_terminal` returns the path coefficient bar plots of the Pathmox terminal nodes.

Usage

```
bar_terminal(
  x,
  LV,
  bycoef = FALSE,
  cex.names = 1,
  cex.axis = 1.2,
  cex.main = 1,
  ...
)
```

Arguments

`x`	An object of the class `"plstree"`
`LV`	A string indicating the name of the endogenous latent variable. The label must be the same as used to define the structural model in the (lavaan syntax)
`bycoef`	Logical value indicating if the comparison is done by nodes or by path coefficients. By default, `FALSE` means that the comparison is done by nodes
`cex.names`	Expansion factor for axis names (bar labels)
`cex.axis`	Expansion factor for numeric axis labels
`cex.main`	Allows fixing the size of the main. It is equal to 1 to default
`...`	Further arguments are ignored

Details

This function aims to visualize, using bar plots, the path coefficients of the endogenous latent variables associated with the terminal nodes. The user indicates the endogenous latent variable they want to visualize. This is done using the same label as used in the structural model definition. (lavaan syntax). The comparison is done by analyzing the path coefficient values for each node, or

the values estimated in each node for each path coefficient. In the former, the plot also returns the R^2. In the latter, the bar corresponding to the node with the highest path coefficient value shows in a different color. By default the comparison is done by analyzing the path coefficient values for each node.

Author(s)

Giuseppe Lamberti

References

Lamberti, G. et al. (2016). The Pathmox approach for PLS path modeling segmentation. *Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2168.

Lamberti, G. (2015). *Modeling with Heterogeneity*, PhD Dissertation.

See Also

summary.plstree, print.plstree, pls.pathmox, plot.plstree, and bar_impvar

Examples

```
 ## Not run:
# Example of PATHMOX approach in customer satisfaction analysis
# (Spanish financial company).
# Model with 5 LVs (4 reflective: Image (IMAG), Value (VAL),
# Satisfaction (SAT), and Loyalty (LOY); and 1 formative construct:
# Quality (QUAL))

# load library and dataset csibank
library(genpathmx)
data("csibank")

# Define the model using the lavaan syntax. Use a set of regression formulas to define
# first the structural model and then the measurement model

CSImodel <- "
# Structural model
VAL  ~ QUAL
SAT  ~ IMAG  + QUAL + VAL
LOY  ~ IMAG + SAT

# Measurement model
# Formative
QUAL <~ qual1 + qual2 + qual3 + qual4 + qual5 + qual6 + qual7

# Reflective
IMAG <~ imag1 + imag2 + imag3 + imag4 + imag5 + imag6
VAL  <~ val1  + val2  + val3  + val4
SAT  =~ sat1  + sat2  + sat3
LOY  =~ loy1  + loy2  + loy3

"
```

```
# Run pathmox on one single variable
age = csibank[,2]

# Transform age into an ordered factor
age = factor(age, levels=c("<=25", "26-35", "36-45", "46-55",
                                    "56-65", ">=66"),ordered=T)

csi.pathmox.age = pls.pathmox(
 .model = CSImodel ,
 .data  = csibank,
 .catvar= age,
 .signif = 0.05,
 .deep=1
)

# Visualize the bar plot by comparing the nodes
bar_terminal(csi.pathmox.age,LV="SAT")

# Visualize the bar plot by comparing path coefficients
bar_terminal(csi.pathmox.age,LV="SAT",bycoef=TRUE)


## End(Not run)
```

`climate` *climate*

Description

climate

Usage

```
climate
```

Format

climate data refers to the younger emplyees (<=30) of an international bank organizational study. It consists of 35 variables for 669 employees divided into 6 qualitative variables and 31 indicator (or manifest) variables. The 3 categorical variables, reflecting specific employee characteristics as potential observed sources of heterogeneity, gender, job level, and seniority. The 37 indicator (or manifest) variables were loyalty (3 indicators), satisfaction (5 indicators), and the 5 work climate constructs of empowerment (6 indicators), company reputation (5 indicators), pay (4 indicators), work conditions (3 indicators), leadership (5 indicators)

Latent variable description

- `Loyalty`: Employee commitment to the organization

- `Satisfaction`: Employee contentedness with their job and aspects such as kind of work, supervision, etc
- `Empowerment`: Employee perceptions of management vision (vertical or horizontal)
- `Reputation`: Employee perceptions of the company's reputation
- `Leadership`: Employee perceptions of leadership practices such as feedback and appraisal
- `Pay`: Employee perceptions of pay and of its equity
- `Conditions`: Employee perceptions regarding the conditions in which they perform their work

Manifest variables description

- `Emp1`: Recognition of work performed
- `Emp2`: Employee treatment as responsible
- `Emp3`: Teamwork is empowered
- `Emp4`: Autonomy is favored
- `Emp5`: Confidence in performed tasks
- `EMP6`: Creativity and initiative are endorsed
- `Imag1`: Organization's reputation
- `Imag2`: Organization's values
- `Imag3`: Organization's customer relationships
- `Imag4`: Organization's internal relationships
- `Imag5`: Organization's external projection
- `Pay1`: Salary
- `Pay2`: Social benefits
- `Pay3`: My salary corresponds to my duties
- `Pay4`: My salary corresponds to my effort
- `Work1`: Enough personnel in the office
- `Work2`: Enough time to perform the tasks
- `Work3`: Conditions and tools for work
- `Lead1`: Agenda and planning
- `Lead2`: Receptiveness
- `Lead3`: Encouraging
- `Lead4`: Communication
- `Lead5`: Celebrating success
- `Sat1`: Overall rating of satisfaction

- Sat2: Tasks in accordance with capabilities
- Sat3: Possibility to know efficiency
- Sat4: Possibility to learn new things
- Sat5: Usefulness of performed job
- Sat6: Fulfilment of expectations
- Loy1: I am unwilling to leave in case of not finding alternative
- Loy2: I am committed to the institution
- Loy3: I trust in the proper direction of the management

Segmentation variables description

- Gender: Gender of the employees, a factor with levels: male and female
- Level: Level of the employees, a factor with levels: low, medium, and high
- Seniority: Time working in the bank, a factor with levels: <5y and 15-5y

References

Lamberti, G., Aluja Banet, T., & Rialp Criado, J. (2020). Work climate drivers and employee heterogeneity. *The International Journal of Human Resource Management*, 1-33. doi: 10.1080/09585192.2020.1711798.

Lamberti, G. (2021). Hybrid multigroup partial least squares structural equation modelling: an application to bank employee satisfaction and loyalty. *Quality and Quantity*, doi: 10.1007/s11135-021-01096-9.

---

csibank *csibank*

Description

csibank

Usage

```
csibank
```

Format

csibank data refers to a 2008 marketing research study of a leading Spanish firm providing retail financial services. For confidentiality reasons, the complete details of the survey-based study will not be provided, only a description of the variables. The data include a total of 32 variables, measured for 1707 clients. The 32 variables are divided into two groups: a group formed of 27 indicator variables for the structural model, and a group formed of 5 categorical variables. Each block of indicators refers to a specific construct.

Latent variable description:

- IMAG: Includes variables such as reputation, trustworthiness, seriousness, solidness, and caring about customer's needs
- EXPE: Includes variables such as products and services provided, customer service, solution provision, and expectations for overall quality
- QUAL: Includes variables such as reliable products and services, range of products and services, personal advice, and overall perceived quality
- VAL: Includes variables such as beneficial services and products, valuable investments, quality relative to price, and price relative to quality
- SAT: Includes variables such as overall satisfaction rating, fulfillment of expectations, satisfaction relative to other banks, and performance relative to an ideal bank
- LOY: Includes variables such as likelihood of choosing the same bank again, likelihood of switching to another bank, intention to recommend the bank to friends, and feeling of loyalty

Manifest variables description:

- imag1: Bank's reputation
- imag2: Trustworthiness
- imag3: Bank's solidity
- imag4: Bank's emphasis on public affairs
- imag5: Fifth MV of the block Image
- imag6: Caring about the customer's needs
- expe1: Providing products and services to meet the customer's needs
- expe2: Providing customer service
- expe3: Providing solutions to daily banking needs
- expe4: Expectations of overall quality
- qual1: Reliable products and services
- qual2: Range of products and services
- qual3: Degree to which customer feels well informed
- qual4: Personal advice
- qual5: Customer service
- qual6: Overall rating of perceived quality
- qual7: Overall rating of satisfaction
- val1: Beneficial services and products
- val2: Valuable investments
- val3: Quality relative to price

- `val4`: Price relative to quality
- `sat1`: Overall rating of satisfaction
- `sat2`: Fulfillment of expectations
- `sat3`: Rating the performance relative to customer's ideal bank
- `loy1`: Propensity to choose the same bank if the customer had to choose again
- `loy2`: Propensity to switch to other banks if they offered better terms
- `loy3`: Customer's intention to recommend the bank to friends or colleagues

Categorical variables description:

- `Gender`: Gender of the customers, a factor with levels: `Female` and `Male`
- `Age`: Age of the customers, a factor with levels: `<=25`, `26-35`, `36-45`, `46-55`, `56-65`, and `>=66`
- `Education`: Education of the customers, a factor with levels: `Elementary`, `Graduated`, `Highschool`, `Undergrad`, and `Unfinished`
- `Occupation`: Occupation of the customers, a factor with levels: `Manager`, `MediumEmplo`, `Notemploy`, `OwnFreelan`, and `Retired`
- `Region`: Region of residence of the customers, a factor with levels: `Center`, `East`, `North`

Source

Laboratory of Information Analysis and Modeling (LIAM). Facultat de Informatica de Barcelona, Universitat Politecnica de Catalunya.

References

Lamberti, G. et al. (2017). The Pathmox approach for PLS path modeling: discovering which constructs differentiate segments.*Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2270.

Lamberti, G. (2014) *Modeling with Heterogeneity.* PhD Dissertation.

`footdata` *footdata*

Description

footdata

Usage

```
footdata
```

Format

footdata data refers to a marketing research study from 2018 concerning the experience of watching a football match in the stadium of a top Spanish football club. For confidentiality reasons, the complete details of the survey-based study will not be provided. Only the description of the variables is given. The data consist of a total of 20 variables, measured for 362 spectators. The 20 variables are divided into two groups. One group is formed of 15 indicator variables for the structural model, and the other group is formed of 5 categorical variables. Each block of indicator refers to a specific construct.

Latent variable description

- `QUA`: Spectators' perception of service performance, based on evaluations of service dimensions
- `IMA`: Spectators' perception of the attributes, players, management and condition of the club
- `SAT`: Spectators' evaluation of the perceived benefits of attending a match
- `LOY`: Spectators' deeply held commitment to repeat and recommend assisting a match

Manifest variables description

- `QUA1`: Tickets (availability, information, and staff attitudes)
- `QUA2`: Accessibility (accessibility, signposting, queue safety, and admission organization)
- `QUA3`: Facilities (shops, restrooms, seating, restaurants)
- `QUA4`: Stadium (loudspeakers, appearance, staff competence, cleanliness, Security/safety)
- `IMA1`: It is a great club
- `IMA2`: It has a good team
- `IMA3`: It is an ambitious club
- `IMA4`: It is a heroic club
- `SAT1`: The stadium experience was satisfactory
- `SAT2`: The time spent at the stadium was worth it
- `SAT3`: The money spent at the stadium was worth it
- `SAT4`: The experience met all my expectations
- `SAT5`: Overall satisfaction
- `LOY1`: I would recommend the experience at this stadium
- `LOY2`: I intend to repeat the experience at this stadium

Categorical Variables description

- `gender`: Gender of the spectators, a factor with levels: `FEMALE` and `MALE`
- `age`: Age of the spectators, a factor with levels `<=30`, `31-45`, and `>=46`
- `tourist`: Whether the spectator was a tourist or not, a factor with levels: `YES` or `NO`
- `companion`: Who Accompanying the spectator, a factor with levels: `FRIENDS`, `FAMILY`, and `OTHERS`
- `Involvement`: Degree of involvement, a factor with levels: `FAN`, `MEMBER`, and `OTHERS`

Source

Universitat Autonoma of Barcelona . Business departament, Universitat Autonoma de Barcelona.

References

Lamberti, G., Rialp, J., and Simon, A. (2021). Antecedents of satisfaction and loyalty in different spectator tribes in a football context. *International Journal of Sports Marketing and Sponsorship*, doi: 10.1108/IJSMS-12-2020-0210;

`plot.plstree` *Plot function for the pathmox segmentation tree*

Description

The function `plot.plstree` allows to drow PATHMOX tree

Usage

```
## S3 method for class 'plstree'
plot(
  x,
  root.col = "#CCFFFF",
  node.col = "#99CCCC",
  leaf.col = "#009999",
  shadow.size = 0.003,
  node.shadow = "#669999",
  leaf.shadow = "#006666",
  cex = 0.7,
  seg.col = "#003333",
  lwd = 1,
  show.pval = TRUE,
  pval.col = "#009999",
  main = NULL,
  cex.main = 1,
  ...
)
```

Arguments

`x`	An object of the class `"plstree"`
`root.col`	Fill color of root node
`node.col`	Fill color of child nodes
`leaf.col`	Fill color of leaf
`shadow.size`	Relative size of shadows.
`node.shadow`	Color of shadow of child nodes

leaf.shadow	Color of shadow of leaf nodes
cex	A numerical value indicating the magnification to be used for plotting text
seg.col	The color to be used for the labels of the segmentation variables
lwd	The line width, a positive number, defaulting to 1
show.pval	Logical value indicating whether the p-values should be plotted
pval.col	The color to be used for the labels of the p-values
main	A main title for the plot
cex.main	The magnification to be used for the main title
...	Further arguments passed on to plot.plstree

Author(s)

Giuseppe Lamberti

References

Lamberti, G. et al. (2016). The Pathmox approach for PLS path modeling segmentation. *Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2168.

Lamberti, G. (2015). *Modeling with Heterogeneity*, PhD Dissertation.

See Also

summary.plstree, print.plstree, pls.pathmox, bar_terminal, and bar_impvar

Examples

```
 ## Not run:
# Example of PATHMOX approach in customer satisfaction analysis
# (Spanish financial company).
# Model with 5 LVs (4 reflective: Image (IMAG), Value (VAL),
# Satisfaction (SAT), and Loyalty (LOY); and 1 formative construct:
# Quality (QUAL))

# load library and dataset csibank
library(genpathmx)
data("csibank")

# Define the model using the lavaan syntax. Use a set of regression formulas to define
# first the structural model and then the measurement model

CSImodel <- "
# Structural model
VAL  ~ QUAL
SAT  ~ IMAG  + QUAL + VAL
LOY  ~ IMAG + SAT

# Measurement model
# Formative
```

```
QUAL <~ qual1 + qual2 + qual3 + qual4 + qual5 + qual6 + qual7

# Reflective
IMAG <~ imag1 + imag2 + imag3 + imag4 + imag5 + imag6
VAL  <~ val1  + val2  + val3  + val4
SAT  =~ sat1  + sat2  + sat3
LOY  =~ loy1  + loy2  + loy3

"

# Check if variables are well specified (they have to be factors
# and/or ordered factors)
str(CSIcatvar)

# Transform age and education into ordered factors
CSIcatvar$Age = factor(CSIcatvar$Age, levels=c("<=25",
                                    "26-35", "36-45", "46-55",
                                    "56-65", ">=66"),ordered=T)

CSIcatvar$Education = factor(CSIcatvar$Education,
                           levels=c("Unfinished","Elementary", "Highschool",
                           "Undergrad", "Graduated"),ordered=T)

# Run Pathmox analysis (Lamberti et al., 2016; 2017)
csi.pathmox = pls.pathmox(
 .model = CSImodel ,
 .data  = csibank,
 .catvar= CSIcatvar,
 .signif = 0.05,
 .deep=2
)

Visualize the tree
plot(csi.pathmox)


## End(Not run)
```

`pls.pathmox` *Pathmox Segmentation Trees in Partial Least Squares Structural Equation Modeling (PLS-SEM)*

Description

`pls.pathmox` calculates a binary segmentation tree in the context of partial least squares structural equation modeling (PLS-SEM) following the PATHMOX algorithm. It detects heterogeneity in PLS-SEM models when the segmentation variables (categorical variables), external to the model, are available and when the objective of the research is exploratory. `pls.pathmox` function returns the most significant different models associated with the terminal nodes of the tree. It also returns a

ranking according to importance of the categorical variables used in the split process. `pls.pathmox` also enables the hybrid multigroup analysis (Lamberti, 2021) to be run. In fact, the function also returns an object, `hybrid`, containing the datasets associated with the terminal nodes prepared to be treated with the `csem` package (Rademaker, 2020). It thus enables the MICOM and MGA procedures to be run (Hair et al. 2017; Henseler, 2016; Henseler, 2009).

Usage

```
pls.pathmox(
  .model,
  .data,
  .catvar,
  .scheme = "path",
  .signif = 0.05,
  .deep = 2,
  .size = 0.1,
  .size_candidate = 50,
  .tree = TRUE
)
```

Arguments

`.model`	A description of the user-specified model. The model is described using the lavaan syntax. Structural and measurement models are defined by enclosure between double quotes. The directional link between constructs is defined using the ("~") operator. On the left-hand side of the operator is the dependent construct and on the right-hand side are the explanatory constructs, separated by the ("+") operator. As for the outer model, constructs are defined by listing their corresponding MVs after the operator ("=~") if mode A is chosen for computing the outer weights, or the operator("<~") if mode B is chosen. On the left-hand side of the operator, is the construct and on the right-hand side are the MVs separated by the ("+") operator. Variable labels cannot contain (".")
`.data`	A matrix or dataframe containing the manifest variables
`.catvar`	A single factor or set of factors organized as a dataframe containing the categorical variables used as sources of heterogeneity
`.scheme`	A string indicating the type of inner weighting scheme. Possible values are `"centroid"`, `"factorial"`, or `"path"`. By default `.scheme` is equal to `"path"`
`.signif`	A decimal value indicating the minimum threshold significance for the partitioning algorithm. By default `.signif` is equal to 0.05
`.deep`	An integer indicating the maximum tree depth. Must be an integer equal to or greater than 1. By default `.deep` is equal to 2
`.size`	A decimal value indicating the minimum admissible size for a node. It is equal to 0.10 by default
`.size_candidate`	An integer indicating the minimum admissible size for a candidate node. It is equal to `50` by default
`.tree`	A string indicating if the tree plot must be shown. By default, it is equal to `TRUE`

Details

pls.pathmox uses the classical lavaan syntax to define inner and outer models and mode (A and B). The user can choose to perform the analysis for a single categorical variable or a set of factors. In the latter case, categorical variables must be organized as a dataframe. Scheme is equal to path by default following other PLS-SEM softwares (SMART-PLS (Ringle at al., 2015), cSEM R package (Rademaker, 2020)), but can be modified by the user to "centroid" or "factorial". Stops parameters (.signif (threshold significance for the partitioning algorithm), .deep (maximum tree depth), and .size (minimum admissible size for a node)) are fixed respectively to signif=0.05, depth=2, and size = 0.10 according to Lamberti et al. (2016). However, again the user can modify these parameters according to the specific objectives of the analysis. pls.pathmox also defines a minimum admissible size for a candidate node that restricts the search of the optimal split to that partitions that produce nodes with an adequate number of observations. This parameter (.size_candidate) is fixed to 50 observations by default. PLS-SEM model coefficients used in the split process are estimated by applying the classical PLS-SEM algorithm improved by Lohmöller (1989). pls.pathmox also returns an object containing the datasets associated with the terminal nodes (object$hybrid) prepared to be treated with the csem package (Rademaker, 2020). This means that, once the pathmox finalizes the search for the most significant different groups associated with the most significant different PLS-SEM models, the user can perform a detailed analysis for each group using the csem package, or can run the MICOM and MGA procedures (Hair et al. 2017; Henseler et al. 2016) on the terminal nodes.

Value

An object of class "plstree". This is a list with the following results:

MOX	dataframe containing the results of the segmentation tree
terminal_paths	dataframe containing PLS-SEM model terminal nodes (path coeff. & R^2)
var_imp	dataframe containing the categorical variable ranking by importance
Fg.r	dataframe containing the results of the F-global test for each node partition
Fc.r	list of dataframes containing the results of the F-coefficient test for each node
hybrid	list of datasets associated with the terminal node prepared for MGA with cSEM R package
other	Other parameters and results

Author(s)

Giuseppe Lamberti

References

Hair, J. F. et al. (2019). When to use and how to report the results of PLS-SEM. *European business review*, doi: 10.1108/EBR-11-2018-0203.

Hair Jr, J. F., et al. (2017). *Advanced issues in partial least squares structural equation modeling*. SAGE publications.

Henseler, J., et al. (2016). Testing measurement invariance of composites using partial least squares. International marketing review. doi: 10.1108/IMR-09-2014-0304

Lamberti, G. (2021). Hybrid multigroup partial least squares structural equation modelling: an application to bank employee satisfaction and loyalty. *Quality and Quantity*, doi: 10.1007/s11135-021-01096-9.

Lamberti, G. et al. (2017). The Pathmox approach for PLS path modeling: discovering which constructs differentiate segments.*Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2270.

Lamberti, G. et al. (2016). The Pathmox approach for PLS path modeling segmentation. *Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2168.

Lamberti, G. (2015). *Modeling with Heterogeneity*, PhD Dissertation.

Lohmoller, J.-B. (1989). *Latent Variable Path Modeling with Partial Least Squares*, Physica: Heidelberg.

Rademaker M. E. (2020). cSEM: Composite-Based Structural Equation Modeling. Available at https://CRAN.R-project.org/package=cSEM

Ringle, C. M. et al. (2015). SmartPLS 3. Boenningstedt: SmartPLS. Retrieved from https://www.smartpls.com

See Also

print.plstree, summary.plstree, bar_terminal, bar_impvar and plot.plstree

Examples

```
 ## Not run:
# Example of PATHMOX approach in customer satisfaction analysis
# (Spanish financial company).
# Model with 5 LVs (4 reflective: Image (IMAG), Value (VAL),
# Satisfaction (SAT), and Loyalty (LOY); and 1 formative construct:
# Quality (QUAL))

# Load library and dataset csibank
library(genpathmx)
data("csibank")

# Define the model using the laavan syntax. Use a set of regression formulas that define
# first the structural model and then the measurement model

CSImodel <- "
# Structural model
VAL  ~ QUAL
SAT  ~ IMAG  + QUAL + VAL
LOY  ~ IMAG + SAT

# Measurement model
# Formative
QUAL <~ qual1 + qual2 + qual3 + qual4 + qual5 + qual6 + qual7

# Reflective
IMAG <~ imag1 + imag2 + imag3 + imag4 + imag5 + imag6
VAL  <~ val1  + val2  + val3  + val4
SAT  =~ sat1  + sat2  + sat3
```

```
LOY  =~ loy1  + loy2  + loy3

"

# Identify the categorical variable to be used as input variables
# in the split process
CSIcatvar = csibank[,1:5]

# Check if variables are well specified (they have to be factors
# and/or ordered factors)
str(CSIcatvar)

# Transform Age and Education into ordered factors
CSIcatvar$Age = factor(CSIcatvar$Age, levels=c("<=25",
                                      "26-35", "36-45", "46-55",
                                      "56-65", ">=66"),ordered=T)

CSIcatvar$Education = factor(CSIcatvar$Education,
                             levels=c("Unfinished","Elementary", "Highschool",
                             "Undergrad", "Graduated"),ordered=T)

# Run Pathmox analysis (Lamberti et al., 2016; 2017)
csi.pathmox = pls.pathmox(
 .model = CSImodel ,
 .data  = csibank,
 .catvar= CSIcatvar,
 .signif = 0.05,
 .deep=2
)

# Visualize results by summary
# summary(csi.pathmox)

# Run pathmox on one single variable
age = csibank[,2]

#' # Transform Age into an ordered factor
age = factor(age, levels=c("<=25",
                                      "26-35", "36-45", "46-55",
                                      "56-65", ">=66"),ordered=T)
csi.pathmox.age = pls.pathmox(
 .model = CSImodel ,
 .data  = csibank,
 .catvar= age,
 .signif = 0.05,
 .deep=1
)

# Run hybrid multigroup analysis (Lamberti, 2021) using
# the cSEM package (Rademaker, 2020)
# Install and load cSEM library
# Install.packages("cSEM")
# library(cSEM)
```

```
# Run cSEM Model for Pathmox terminal nodes

csilocalmodel = csem(
 .model = CSImodel,
 .data = csi.pathmox.age$hybrid)

# Check invariance and run MGA analysis (Hair et al., 2019)

testMICOM(csilocalmodel, .R =60)

to_compare <- "
#' # Structural model
VAL  ~ QUAL
SAT  ~ IMAG  + QUAL + VAL
LOY  ~ IMAG + SAT
"

testMGD(csilocalmodel, .parameters_to_compare=to_compare,
.R_bootstrap= 60,.approach_mgd ="Henseler")


## End(Not run)
```

`print.plstree` *Print function for Pathmox Segmentation Trees*

Description

The function `print.plstree` returns the `pls.pathmox` results.

Usage

```
## S3 method for class 'plstree'
print(x, ...)
```

Arguments

`x`	An object of class "`plstree`".
`...`	Further arguments are ignored.

Author(s)

Giuseppe Lamberti

References

Lamberti, G. (2021). Hybrid multigroup partial least squares structural equation modelling: an application to bank employee satisfaction and loyalty. *Quality and Quantity*, doi: 10.1007/s11135-021-01096-9.

Lamberti, G. et al. (2017). The Pathmox approach for PLS path modeling: discovering which constructs differentiate segments.*Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2270.

Lamberti, G. et al. (2016). The Pathmox approach for PLS path modeling segmentation. *Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2168.

Lamberti, G. (2015). *Modeling with Heterogeneity*, PhD Dissertation.

See Also

summary.plstree, pls.pathmox, bar_terminal, bar_impvar and plot.plstree

Examples

```
 ## Not run:
# Example of PATHMOX approach in customer satisfaction analysis
# (Spanish financial company).
# Model with 5 LVs (4 reflective: Image (IMAG), Value (VAL),
# Satisfaction (SAT), and Loyalty (LOY); and 1 formative construct:
# Quality (QUAL))

# load library and dataset csibank
library(genpathmx)
data("csibank")

# Define the model using the laavan syntax. Use a set of regression formulas to define
# first the structural model and then the measurement model

CSImodel <- "
# Structural model
VAL  ~ QUAL
SAT  ~ IMAG  + QUAL + VAL
LOY  ~ IMAG + SAT

# Measurement model
# Formative
QUAL <~ qual1 + qual2 + qual3 + qual4 + qual5 + qual6 + qual7

# Reflective
IMAG <~ imag1 + imag2 + imag3 + imag4 + imag5 + imag6
VAL  <~ val1  + val2  + val3  + val4
SAT  =~ sat1  + sat2  + sat3
LOY  =~ loy1  + loy2  + loy3

"

# Run pathmox on one single variable
age = csibank[,2]
```

```
# Transform age into an ordered factor
age = factor(age, levels=c("<=25", "26-35", "36-45", "46-55",
                                      "56-65", ">=66"),ordered=T)

csi.pathmox.age = pls.pathmox(
 .model = CSImodel ,
 .data  = csibank,
 .catvar= age,
 .signif = 0.05,
 .deep=1
)

# Visualize the Pathmox results
print(csi.pathmox.age)


## End(Not run)
```

`summary.plstree` *Summary function for Pathmox Segmentation Trees*

Description

The function `summary.plstrees` returns the most important results obtained by the function `pls.pathmox`. In order, it provides the parameters of the algorithm (threshold significance, node size limit, tree depth level and the method used for the split partition), the basic characteristics of the tree (depth and number of terminal nodes), the split results (F-global and F-coefficient). It also returns a ranking of the categorical variables by importance and the terminal node results (path coefficients and R^2).

Usage

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

Arguments

`object`	An object of class `"plstree"`.
`...`	Further arguments are ignored.

Author(s)

Giuseppe Lamberti

References

Lamberti, G. (2021). Hybrid multigroup partial least squares structural equation modelling: an application to bank employee satisfaction and loyalty. *Quality and Quantity*, doi: 10.1007/s11135-021-01096-9.

Lamberti, G. et al. (2017). The Pathmox approach for PLS path modeling: discovering which constructs differentiate segments.*Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2270.

Lamberti, G. et al. (2016). The Pathmox approach for PLS path modeling segmentation. *Applied Stochastic Models in Business and Industry*, doi: 10.1002/asmb.2168.

Lamberti, G. (2015). *Modeling with Heterogeneity*, PhD Dissertation.

See Also

print.plstree, pls.pathmox, bar_terminal, bar_impvar and plot.plstree

Examples

```
 ## Not run:
# Example of PATHMOX approach in customer satisfaction analysis
# (Spanish financial company).
# Model with 5 LVs (4 reflective: Image (IMAG), Value (VAL),
# Satisfaction (SAT), and Loyalty (LOY); and 1 formative construct:
# Quality (QUAL))

# load library and dataset csibank
library(genpathmx)
data("csibank")

# Define the model using the laavan syntax. Use a set of regression formulas to define
# first the structural model and then the measurement model

CSImodel <- "
# Structural model
VAL  ~ QUAL
SAT  ~ IMAG  + QUAL + VAL
LOY  ~ IMAG + SAT

# Measurement model
# Formative
QUAL <~ qual1 + qual2 + qual3 + qual4 + qual5 + qual6 + qual7

# Reflective
IMAG <~ imag1 + imag2 + imag3 + imag4 + imag5 + imag6
VAL  <~ val1  + val2  + val3  + val4
SAT  =~ sat1  + sat2  + sat3
LOY  =~ loy1  + loy2  + loy3

"

# Run pathmox on one single variable
age = csibank[,2]
```

```
# Transform age into an ordered factor
age = factor(age, levels=c("<=25", "26-35", "36-45", "46-55",
                                      "56-65", ">=66"),ordered=T)

csi.pathmox.age = pls.pathmox(
 .model = CSImodel ,
 .data  = csibank,
 .catvar= age,
 .signif = 0.05,
 .deep=1
)

# Visualize the Pathmox results
summary(csi.pathmox.age)


## End(Not run)
```

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