Package 'qcpm'

July 22, 2025

Title Quantile Composite Path Modeling

Version 0.4

Description Implements the Quantile Composite-based Path Modeling approach (Davino and Vinzi, 2016 <doi:10.1007/s11634-015-0231-9>; Dolce et al., 2021 <doi:10.1007/s11634-021-00469-0>). The method complements the traditional PLS Path Modeling approach, analyzing the entire distribution of outcome variables and, therefore, overcoming the classical exploration of only average effects. It exploits quantile regression to investigate changes in the relationships among constructs and between constructs and observed variables.

Depends R (>= 3.5.0)

Imports quantreg,cSEM,broom

License GPL-3

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NeedsCompilation no

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Contents

`assessment` *Assessment measures of quantile composite-based path modeling*

Description

`assessment` returns the following measures for assessing both the inner and the outer model: communality of each manifest variable, communality of each block,redundancy of each manifest variable of endogenous blocks, redundancy of the endogenous blocks, and $pseudo - R^2$ for each inner equation.

Usage

```
assessment(qcpm)
```

Arguments

`qcpm`	is an object of class `qcpm`

Details

All the assessment measures discussed in Davino et al. (2016) and Dolce et al. (2021) are based on $pseudo - R^2$, proposed by Koenker and Machado (1999), which simulates the role and interpretation of the R^2 in classical regression analysis. The $pseudo - R^2$ is considered as a local measure of goodness of fit for a particular quantile as it measures the contribute of the selected regressors to the explanation of the dependent variable, with respect to the trivial model without regressors. In more technical way, $pseudo - R^2$ compares the residual absolute sum of weighted differences using the selected model with the total absolute sum of weighted differences using a model with the only intercept. The $pseudo - R^2$ can be used to assess the inner model measuring the amount of variability of a given endogenous construct explained by its explanatory constructs. A synthesis of the evaluations regarding the whole inner model can be obtained by the average of all the $pseudo - R^2$. Communality indicates how much of the MV variance is explained by the corresponding construct. It can be calculated for each MV, and for each block, using the average of MV communalities. Redundancy measures the percent of the variance of MVs in an endogenous block that is predicted from the explanatory constructs related to the endogenous construct. Redundancy can be computed only for each MVs of endogenous blocks and for the whole endogenous blocks, using the average of MV redundancies. Results are provided for each quantile of interest. When `fix.quantile=TRUE`, the function returns communalities and redundancies only for the quantile 0.5.

Value

`Communality`	Communality of each MV. It is the proportion of the MV variance explained by the corresponding construct.
`Block_Communality`	Communality of a whole block. It is computed as average of the MV communalities belonging to that block.

`Redundancy` Redundancy of each MV of the endogenous blocks. It measures the percent of the variance of MVs in endogenous blocks that is predicted from the explanatory constructs related to the endogenous construct.

`Block_Redundancy` Redundancy of a block. It is computed as average of MV redundancies belonging to that block.

`pseudo.R2` The $pseudo - R^2$. It assesses the goodness of fit of the inner model.

Author(s)

Cristina Davino, Pasquale Dolce, Giuseppe Lamberti, Domenico Vistocco

References

Davino, C., Dolce, P., Taralli, S. and Vistocco, D. (2020). Composite-based path modeling for conditional quantiles prediction. An application to assess health differences at local level in a well-being perspective. *Social Indicators Research*, doi:10.1007/s11205-020-02425-5..

Davino, C. and Esposito Vinzi, V. (2016). Quantile composite-based path modeling. *Advances in Data Analysis and Classification*, **10 (4)**, pp. 491–520, doi:10.1007/s11634-015-0231-9.

Davino, C., Esposito Vinzi, V. and Dolce, P. (2016). Assessment and validation in quantile composite-based path modeling. In: Abdi H., Esposito Vinzi, V., Russolillo, G., Saporta, G., Trinchera, L. (eds.). *The Multiple Facets of Partial Least Squares Methods*, chapter 13. Springer proceedings in mathematics and statistics. Springer, Berlin

Dolce, P., Davino, C. and Vistocco, D. (2021). Quantile composite-based path modeling: algorithms, properties and applications. *Advances in Data Analysis and Classification*, doi:10.1007/s11634-021-00469-0.

Koenker, R. and Machado, J.A. (1999). Goodness of fit and related inference processes for quantile regression. *Journal of the American Statistical Association*, **94 (448)** pp. 1296–1310, doi: 10.1080/01621459.1999.10473882

He, X.M. and Zhu, L.X. (2003). A lack-of-fit test for quantile regression. *Journal of the American Statistical Association* **98** pp. 1013–1022, doi: 10.1198/016214503000000963

See Also

`summary`, `qcpm`, `boot`, and `reliability`

Examples

```
# Example of QC-PM in Well-Being analysis
# model with three LVs and reflective indicators

# load library and dataset province
library(qcpm)
data(province)

# Define the model using laavan sintax. Use a set of regression formulas defining
# firstly the structural model and then the measurement model
model <- "
```

```
ECOW ~ EDU
HEALTH ~ EDU + ECOW

# Reflective measurement model
EDU =~ EDU1 + EDU2 + EDU3 + EDU4 + EDU5 + EDU6 + EDU7
ECOW =~ ECOW1 + ECOW2 + ECOW3 + ECOW4 + ECOW5 + ECOW6
HEALTH =~  HEALTH1 + HEALTH2 + HEALTH3
"


# Apply qcpm
well.qcpm = qcpm(model,province)
well.assessment = assessment(well.qcpm)
well.assessment
```

`boot` *Inference on QC-PM model parameters (i.e., loadings and path coefficients)*

Description

`boot` returns in order the estimates, std. errors, t-values, p-values, and confidence interval at the specified confidence level for loadings and path coefficients for each quantile.

Usage

```
boot(qcpm, conf.level = 0.95, br = 200)
```

Arguments

`qcpm`	is an object of class `qcpm`.
`conf.level`	is the value used to fix the confidence level to use for the confidence interval. It is equal to 0.95 by default.
`br`	specifies the number of bootstrap replications. It is fixed to `200` by default.

Details

The argument `qcpm` is an object of class qcpm returned by `qcpm` function. Std. errors are calculated by using the bootstrap method implemented in the `tidy.rq` function of the broom package (Robinson, 2014). When `fix.quantile=TRUE`, the function boot returns only loading results for the quantile 0.5.

Value

`boot.loadings`	the outer loading results for each considered quantile.
`boot.path`	the path coefficient results for each considered quantile.

Author(s)

Cristina Davino, Pasquale Dolce, Giuseppe Lamberti, Domenico Vistocco

References

Davino, C., Dolce, P., Taralli, S. and Vistocco, D. (2020). Composite-based path modeling for conditional quantiles prediction. An application to assess health differences at local level in a well-being perspective. *Social Indicators Research*, doi:10.1007/s11205-020-02425-5.

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Dolce, P., Davino, C. and Vistocco, D. (2021). Quantile composite-based path modeling: algorithms, properties and applications. *Advances in Data Analysis and Classification*, doi:10.1007/s11634-021-00469-0.

Robinson, D. (2014). broom: An R package for converting statistical analysis objects into tidy data frames. Available at https://CRAN.R-project.org/package=broom.

See Also

qcpm, assessment, summary, and reliability

Examples

```
# Example of QC-PM in Well-Being analysis
# model with three LVs and reflective indicators

# load library and dataset province
library(qcpm)
data(province)

# Define the model using laavan sintax. Use a set of regression formulas defining
# firstly the structural model and then the measurement model
model <- "
ECOW ~ EDU
HEALTH ~ EDU + ECOW

# Reflective measurement model
EDU =~ EDU1 + EDU2 + EDU3 + EDU4 + EDU5 + EDU6 + EDU7
ECOW =~ ECOW1 + ECOW2 + ECOW3 + ECOW4 + ECOW5 + ECOW6
HEALTH =~  HEALTH1 + HEALTH2 + HEALTH3
"


# Apply qcpm
well.qcpm = qcpm(model,province)
well.boot = boot(well.qcpm)
well.boot
```

province *Province dataset example*

Description

Province dataset example

Usage

```
province
```

Format

This data set allows to estimate the relationships among Health (HEALTH), Education and training (EDU) and Economic well-being (ECOW) in the Italian provinces using a subset of the indicators collected by the Italian Statistical Institute (ISTAT) to measure equitable and sustainable well-being (BES, from the Italian Benessere Equo e Sostenibile) in territories. Data refers to the 2019 edition of the BES report (ISTAT, 2018, 2019a, 2019b). A subset of 16 indicators (manifest variables) are observed on the 110 Italian provinces and metropolitan cities (i.e. at NUTS3 level) to measure the latent variables HEALTH, EDU and ECOW. The interest in such an application concerns both advances in knowledge about the dynamics producing the well-being outcomes at local level (multiplier effects or trade-offs) and a more complete evaluation of regional inequalities of well-being.

Data Strucuture

A data frame with 110 Italian provinces and metropolitan cities and 16 variables (i.e., indicators) related to three latent variables: Health (3 indicators), Education and training (7 indicators), and Economic well-being (6 indicators).

Manifest variables description for each latent variable:

LV1 Education and training (EDU)

- **MV1** EDU1**(O.2.2):** people with at least upper secondary education level (25-64 years old)
- **MV2** EDU2**(O.2.3):** people having completed tertiary education (30-34 years old)
- **MV3** EDU3**(O.2.4):** first-time entry rate to university by cohort of upper secondary graduates
- **MV4** EDU4**(O.2.5aa):** people not in education, employment or training (Neet)
- **MV5** EDU5**(O.2.6):** ratio of people aged 25-64 years participating in formal or non-formal education to the total people aged 25-64 years
- **MV6** EDU6**(O_2.7_2.8):** scores obtained in the tests of functional skills of the students in the II classes of upper secondary education
- **MV7** EDU7**(O_2.7_2.8_A):** Differences between males and females students in the level of numeracy and literacy

LV2 Economic wellbeing (ECOW)

- **MV8** ECOW1**(O.4.1):** per capita disposable income
- **MV9** ECOW2**(O.4.4aa):** pensioners with low pension amount
- **MV10** ECOW3**(O.4.5):** per capita net wealth
- **MV11** ECOW4**(O.4.6aa):** rate of bad debts of the bank loans to families

MV12 ECOW5(**O.4.2):** average annual salary of employees

MV13 ECOW6(**O.4.3):** average annual amount of pension income per capita

#'

LV3 Health (HEALTH)

MV14 HEALTH1(**O.1.1F):** life expectancy at birth of females

MV15 HEALTH2(**O.1.1M):** life expectancy at birth of males

MV16 HEALTH3(**O.1.2.MEAN_aa):** infant mortality rate

For a full description of the variables, see table 3 of Davino et al. (2020).

References

Davino, C., Dolce, P., Taralli, S. and Vistocco, D. (2020). Composite-based path modeling for conditional quantiles prediction. An application to assess health differences at local level in a well-being perspective. *Social Indicators Research*, doi:10.1007/s11205-020-02425-5.

Davino, C., Dolce, P., Taralli, S., Esposito Vinzi, V. (2018). A quantile composite-indicator approach for the measurement of equitable and sustainable well-being: A case study of the italian provinces. *Social Indicators Research*, **136**, pp. 999–1029, doi: 10.1007/s11205-016-1453-8

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ISTAT. (2019a). Misure del Benessere dei territori. Tavole di dati. Rome, Istat.

ISTAT. (2019b). Le differenze territoriali di benessere - Una lettura a livello provinciale. Rome, Istat.

ISTAT. (2018). Bes report 2018: Equitable and sustainable well-being in Italy. Rome, Istat.

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qcpm *QC-PM: Quantile Composite-based Path Modeling*

Description

qcpm estimates path model parameters by quantile composite-based path modeling approach.

Usage

```
qcpm(
  model,
  data,
  scheme = "factorial",
  tau = NULL,
  fix.quantile = FALSE,
  qcorr = FALSE,
  tol = 1e-05,
  maxiter = 100
)
```

Arguments

`model`	A description of the user-specified model. The model is described using the lavaan sintax. Structural and measurement model are defined enclosed between double quotes. The directional link between constructs is defined by using the tilde ("~") operator. On the left-hand side of the operator there is the dependent construct and on the right-hand side 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 the choice for computing the outer weights, or the operator("<~") if Mode B is chosen. On the left-hand side of the operator, there is the construct and on the right-hand side the MVs separated by the ("+") operator. Variable labels cannot contain (".")
`data`	is a data frame or a data matrix (statistical units x manifest variables).
`scheme`	is a string indicating the type of inner weighting scheme. It is equal to `factorial` by default. Possible values are `centroid` or `factorial`.
`tau`	indicates the specific quantile that must be considered for the estimation. It is equal to NULL by default, using the quantile default values (0.25, 0.5, 0.75). When specified, tau can be equal to a single value or to a vector, depending on the number of quantiles of interest.
`fix.quantile`	when equal to `TRUE`, the quantile used in the iterative procedure of the QC-PM algorithm is fixed to 0.5. It is used when measurement invariance is an issue. It is equal to `FALSE` by default.
`qcorr`	is a boolean. If it is equal to `TRUE`, loadings are estimated by using quantile correlations. By default, it is equal to `FALSE`.
`tol`	is a decimal value indicating the tolerance criterion for the iterations (tol=0.00001 by default).
`maxiter`	is an integer indicating the maximum number of iterations (maxiter=100 by default).

Details

Users can choose to estimate the model parameters for one or more specific quantiles (tau) of interest or to use the default quantile values: tau = (0.25, 0,50, 0.75). If more than one specific quantile is selected, the values must be defined as a numeric vector. It is also possible to fix the quantile to 0.5 in the iterative procedure of the QC-PM algorithm by using the parameter `fix.quantile = TRUE` for handling the measurement invariance issue (Dolce et al. 2021; Henseler et al. 2016).

Value

An object of class `qcpm`.

`outer.weights`	the outer weight estimates for each considered quantile.
`outer.loadings`	the outer loading estimates for each considered quantile.
`path.coefficients`	the path coefficient estimates for each considered quantile.
`latent.scores`	list of the composite scores for each considered quantile.
`data`	original dataset used for the analysis.
`model`	internal parameters related to the model estimation.

Author(s)

Cristina Davino, Pasquale Dolce, Giuseppe Lamberti, Domenico Vistocco

References

Davino, C., Dolce, P., Taralli, S. and Vistocco, D. (2020). Composite-based path modeling for conditional quantiles prediction. An application to assess health differences at local level in a well-being perspective. *Social Indicators Research*, doi:10.1007/s11205-020-02425-5.

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Dolce, P., Davino, C. and Vistocco, D. (2021). Quantile composite-based path modeling: algorithms, properties and applications. *Advances in Data Analysis and Classification*, doi:10.1007/s11634-021-00469-0.

Henseler J., Ringle, C.M. and Sarstedt, M. (2016). Testing measurement invariance of composites using partial least squares. *International Marketing Review*, **33 (3)**, pp. 405–431, doi:10.1108/IMR-09-2014-0304

Li, G., Li, Y. and Tsai, C. (2014). Quantile correlations and quantile autoregressive modeling. *Journal of the American Statistical Association*, **110 (509)** pp. 246–261, doi: 10.1080/01621459.2014.892007

See Also

summary, assessment, boot, and reliability

Examples

```
# Example of QC-PM in Well-Being analysis
# model with three LVs and reflective indicators

# load library and dataset province
library(qcpm)
data(province)

# Define the model using laavan sintax. Use a set of regression formulas defining
# firstly the structural model and then the measurement model
model <- "
ECOW ~ EDU
HEALTH ~ EDU + ECOW

# Reflective measurement model
EDU =~ EDU1 + EDU2 + EDU3 + EDU4 + EDU5 + EDU6 + EDU7
ECOW =~ ECOW1 + ECOW2 + ECOW3 + ECOW4 + ECOW5 + ECOW6
HEALTH =~  HEALTH1 + HEALTH2 + HEALTH3
"

# Apply qcpm
well.qcpm = qcpm(model,province)
well.qcpm
```

`reliability` *Measurement model reliability and internal consistence*

Description

`reliability` returns the classical indices used in PLS-PM to assess the reliability and internal consistence of the measurement model (Hair et al., 2019). In order it provides: Cronbach's alpha, Dillon-Goldstein's rho, the Dijkstra-Henseler rho, and first and second eigenvalue of the correlation matrix of the manifest variables. The function also returns the outer mode (A or B) and the number of manifest variables for each block.

Usage

```
reliability(qcpm)
```

Arguments

`qcpm`	is an object of class `qcpm`

Details

The function only returns Dijkstra-Henseler rho values for quantile 0.5. When mode B is selected, or there are some intra-block inverse correlations, the Dijkstra-Henseler rho, Cronbach's alpha, and Dillon-Goldstein's rho are not calculated.

Value

A table containing, for each block, the outer mode (A or B), the number of manifest variables, Cronbach's alpha, Dillon-Goldstein's rho, Dijkstra-Henseler rho, and first and second eigenvalue of the manifest variable correlation matrix.

Author(s)

Cristina Davino, Pasquale Dolce, Giuseppe Lamberti, Domenico Vistocco

References

Hair, J.F., Risher, J.J., Sarstedt, M. and Ringle, C.M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, **31 (1)**, pp. 2–24, doi: 10.1108/EBR-11-2018-0203

Sanchez, G. (2013). PLS Path Modeling with R Trowchez Editions. Berkeley, 2013. Available at https://www.gastonsanchez.com/PLS_Path_Modeling_with_R.pdf.

See Also

`qcpm`, `assessment`, `boot`, and `summary`

Examples

```
# Example of QC-PM in Well-Being analysis
# model with three LVs and reflective indicators

# load library and dataset province
library(qcpm)
data(province)

# Define the model using laavan sintax. Use a set of regression formulas defining
# firstly the structural model and then the measurement model
model <- "
ECOW ~ EDU
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ECOW =~ ECOW1 + ECOW2 + ECOW3 + ECOW4 + ECOW5 + ECOW6
HEALTH =~  HEALTH1 + HEALTH2 + HEALTH3
"


# Apply qcpm
well.qcpm = qcpm(model,province)
reliability(well.qcpm)
```

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