

Package ‘stdmod’

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Title Standardized Moderation Effect and Its Confidence Interval

Version 0.1.7.4

Description Functions for computing a standardized moderation effect in moderated regression and forming its confidence interval by nonparametric bootstrapping as proposed in Cheung, Cheung, Lau, Hui, and Vong (2022) <[doi:10.1037/hea0001188](https://doi.org/10.1037/hea0001188)>. Also includes simple-to-use functions for computing conditional effects (unstandardized or standardized) and plotting moderation effects.

URL <https://sfcheung.github.io/stdmod/>

BugReports <https://github.com/sfcheung/stdmod/issues>

License GPL-3

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add1.std_selected	<i>The 'add1' Method for a 'std_selected' Class Object</i>
-------------------	--

Description

Intercept the `add1()` method and raise an error.

Usage

```
## S3 method for class 'std_selected'
add1(object, ...)
```

Arguments

object	The output of <code>std_selected()</code> or <code>std_selected_boot()</code> .
...	Additional arguments. They will be ignored.

Details

`add1()` should not be used after the output of `lm()` is processed by `std_selected()` or `std_selected_boot()`.

Value

It returns nothing. It is called for its side effect.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

coef.stdmod_lavaan *Standardized Moderation Effect in a 'stdmod_lavaan' Class Object*

Description

Return the estimate of the standardized moderation effect in the output of `stdmod_lavaan()`.

Usage

```
## S3 method for class 'stdmod_lavaan'  
coef(object, ...)
```

Arguments

object The output of `stdmod_lavaan()`.
... Optional arguments. Ignored by the function.

Details

It just extracts and returns the element `stdmod`.

Value

A scalar: The estimate of the standardized moderation effect.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```
# Load a test data of 500 cases  
dat <- test_mod1  
library(lavaan)  
  
mod <-  
"  
med ~ iv + mod + iv:mod + cov1  
dv ~ med + cov2  
"
```

```

fit <- sem(mod, dat)
coef(fit)

# Compute the standardized moderation effect
out_noboot <- stdmod_lavaan(fit = fit,
                           x = "iv",
                           y = "med",
                           w = "mod",
                           x_w = "iv:mod")

coef(out_noboot)

# Compute the standardized moderation effect and
# its confidence interval based on nonparametric bootstrapping
set.seed(8479075)
system.time(out_boot <- stdmod_lavaan(fit = fit,
                                     x = "iv",
                                     y = "med",
                                     w = "mod",
                                     x_w = "iv:mod",
                                     boot_ci = TRUE,
                                     R = 50))

# In real analysis, R should be at least 2000.
coef(out_boot)

```

cond_effect

Conditional Effects

Description

Compute the conditional effects in a moderated regression model.

Usage

```

cond_effect(
  output,
  x = NULL,
  w = NULL,
  w_method = c("sd", "percentile"),
  w_percentiles = c(0.16, 0.5, 0.84),
  w_sd_to_percentiles = NA,
  w_from_mean_in_sd = 1
)

```

```

cond_effect_boot(
  output,
  x = NULL,
  w = NULL,
  ...,

```

```

    conf = 0.95,
    nboot = 100,
    boot_args = NULL,
    save_boot_est = TRUE,
    full_output = FALSE
  )

```

Arguments

output	The output from <code>stats::lm()</code> . It can also accept the output from <code>std_selected()</code> or <code>std_selected_boot()</code> .
x	The focal variable (independent variable), that is, the variable with its effect on the outcome variable (dependent) being moderated. It must be a numeric variable.
w	The moderator. Both numeric variables and categorical variables (character or factor) are supported.
w_method	How to define "low", "medium", and "high" for the moderator levels. Default is in terms of mean and standard deviation (SD) of the moderator, "sd": "low", "medium", and "high" are one SD below mean, mean, and one SD above mean, respectively. If equal to "percentile", then percentiles of the moderator in the dataset are used: "low", "medium", and "high" are 16th, 50th (median), and 84th percentiles, respectively. Ignored if w is categorical.
w_percentiles	If w_method is "percentile", then this argument specifies the three percentiles to be used, divided by 100. It must be a vector of two numbers. The default is <code>c(.16, .50, .84)</code> , the 16th, 50th, and 84th percentiles, which corresponds approximately to one SD below and above mean in a normal distribution, respectively. Ignored if w is categorical.
w_sd_to_percentiles	If w_method is "percentile" and this argument is set to a number, this number will be used to determine the percentiles to be used. The lower percentile is the percentile in a normal distribution that is w_sd_to_percentiles SD below the mean. The upper percentile is the percentile in a normal distribution that is w_sd_to_percentiles SD above the mean. Therefore, if w_sd_to_percentiles is set to 1, then the lower and upper percentiles are 16th and 84th, respectively. Default is NA.
w_from_mean_in_sd	How many SD from mean is used to define "low" and "high" for the moderator. Default is 1. Ignored if w is categorical.
...	Arguments to be passed to <code>cond_effect()</code> .
conf	The level of confidence for the confidence interval. Default is .95, to get 95% confidence intervals.
nboot	The number of bootstrap samples. Default is 100.
boot_args	A named list of arguments to be passed to <code>boot::boot()</code> . Default is NULL.
save_boot_est	If TRUE, the default, the bootstrap estimates will be saved in the element <code>boot_est</code> of the output.

`full_output` Whether the full output from `boot::boot()` will be returned. Default is FALSE. If TRUE, the full output from `boot::boot()` will be saved in the element `boot_out` of the output.

Details

`cond_effect()` uses the centering approach to find the conditional effect of the focal variable. For each level of the moderator, the value for this level is subtracted from the moderator scores, and the model is fitted to the modified data. The coefficient of the focal variable is then the conditional effect of the focal variable when the moderator's score is equal this value.

`cond_effect_boot()` function is a wrapper of `cond_effect()`. It calls `cond_effect()` once for each bootstrap sample, and then computes the nonparametric bootstrap percentile confidence intervals (Cheung, Cheung, Lau, Hui, & Vong, 2022). If the output object is the output of `std_selected()` or `std_selected_boot()`, in which mean-centering and/or standardization have been conducted, they will be repeated in each bootstrap sample. Therefore, like `std_selected_boot()`, it can be used for form nonparametric bootstrap confidence intervals for standardized effects, though `cond_effect_boot()` does this for the standardized conditional effects.

This function intentionally does not have an argument for setting the seed for random number. Users are recommended to set the seed, e.g., using `set.seed()` before calling it, to ensure reproducibility.

Value

`cond_effect()` returns a data-frame-like object of the conditional effects. The class is `cond_effect` and the print method will print additional information of the conditional effects. Additional information is stored in the following attributes:

- `call`: The original call.
- `output`: The output object, such as the output from `lm()`.
- `x`, `y`, and `w`: The three variables used to compute the conditional effects: focal variable (`x`), outcome variable (`y`), and the moderator (`w`).
- `w_method`: The method used to determine the values of the moderator at the selected levels.
- `w_percentiles`: The percentiles to use if `w_method = "percentile"`.
- `w_sd_to_percentiles`: If not equal to NA, this is a scalar, the number of standard deviation from the mean used to determine the percentiles for the "low" and "high" levels of the moderator.
- `w_from_mean_in_sd`: The number of SD above or below the mean, for determining the "low" and "high" levels of the moderator if `w_method` is "sd".
- `w_empirical_percentiles`: The actual percentile levels in the dataset for the selected levels of the moderator. A numeric vector.
- `w_empirical_z`: The actual distance from the mean, in SD, of each selected level of the moderator. A numeric vector.
- `y_standardized`, `x_standardized`, and `w_standardized`: Each of them is a logical scalar, indicating whether the outcome variable, focal variable, and moderator are standardized.

`cond_effect_boot()` also returns a data-frame-like object of the conditional effects of the class `cond_effect`, with additional information from the bootstrapping stored in these attributes:

- `boot_ci`: A data frame of the bootstrap confidence intervals of the conditional effects.
- `nboot`: The number of bootstrap samples requested.
- `conf`: The level of confidence, in proportion.
- `boot_est`: A matrix of the bootstrap estimates of the conditional effects. The number of rows equal to `nboot`, and the number of columns equal to the number of levels of the moderator.
- `cond_effect_boot_call`: The call to `cond_effect_boot()`.
- `boot_out`: If available, the original output from `boot::boot()`.

Functions

- `cond_effect_boot`: A wrapper of `cond_effect()` that forms nonparametric bootstrap confidence intervals.

Author(s)

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Examples

```
# Load a sample data set

dat <- test_x_1_w_1_v_1_cat1_n_500

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)
summary(lm_raw)
cond_effect(lm_raw, x = iv, w = mod)

lm_std <- std_selected(lm_raw, to_scale = ~ iv + mod, to_center = ~ iv + mod)
cond_effect(lm_std, x = iv, w = mod)

# Categorical moderator
lm_cat <- lm(dv ~ iv*cat1 + v1, dat)
summary(lm_cat)
cond_effect(lm_cat, x = iv, w = cat1)

# Load a sample data set

dat <- test_x_1_w_1_v_1_cat1_n_500

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)
summary(lm_raw)

lm_std <- std_selected(lm_raw, to_scale = ~ iv + mod, to_center = ~ iv + mod)
cond_effect(lm_std, x = iv, w = mod)

# Form nonparametric bootstrap confidence intervals
```

```
out <- cond_effect_boot(lm_std, x = iv, w = mod, nboot = 50)
out
```

confint.stdmod_lavaan *Confidence Intervals for a 'stdmod_lavaan' Class Object*

Description

Return the confidence interval of the standardized moderation effect in the output of `stdmod_lavaan()`.

Usage

```
## S3 method for class 'stdmod_lavaan'
confint(object, parm, level = 0.95, ...)
```

Arguments

<code>object</code>	The output of <code>stdmod_lavaan()</code> .
<code>parm</code>	Ignored. Always return the bootstrap confidence interval of the standardized moderation effect.
<code>level</code>	The level of confidence, default is .95, returning the 95% confidence interval.
<code>...</code>	Additional arguments. Ignored by the function.

Details

If bootstrapping is used to form the confidence interval by `stdmod_lavaan()`, users can request the percentile confidence interval of using the stored bootstrap estimate.

Value

A one-row matrix of the confidence intervals.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```
# Load a test data of 500 cases
dat <- test_mod1
library(lavaan)

mod <-
"
med ~ iv + mod + iv:mod + cov1
dv ~ med + cov2
```



```

"
fit <- sem(mod, dat)
coef(fit)

# Compute the standardized moderation effect and
# its confidence interval based on nonparametric bootstrapping
set.seed(8479075)
system.time(out_boot <- stdmod_lavaan(fit = fit,
                                     x = "iv",
                                     y = "med",
                                     w = "mod",
                                     x_w = "iv:mod",
                                     boot_ci = TRUE,
                                     R = 50))
# In real analysis, R should be at least 2000.
confint(out_boot)

```

confint.std_selected *Confidence Intervals for a 'std_selected' Class Object*

Description

Return the confidence intervals of estimates in the output of `std_selected()` or `std_selected_boot()`.

Usage

```
## S3 method for class 'std_selected'
confint(object, parm, level = 0.95, type = "lm", ...)
```

Arguments

object	The output of <code>std_selected()</code> or <code>std_selected_boot()</code> .
parm	The parameters (coefficients) for which confidence intervals should be returned. If missing, the confidence intervals of all parameters will be returned.
level	The level of confidence. For the confidence intervals returned by <code>lm()</code> , default is .95, i.e., 95%. For the bootstrap percentile confidence intervals, default is the level used in calling <code>std_selected_boot()</code> . If a level different from that in the original call is specified, <code>full_output</code> needs to be set in the call to <code>std_selected_boot()</code> such that the original bootstrapping output is stored.
type	The type of the confidence intervals. Default is "lm", returned by the <code>confint()</code> method of <code>lm()</code> . If set to "boot", the bootstrap percentile confidence intervals are returned.
...	Arguments to be passed to <code>summary.lm()</code> .

Details

If bootstrapping is used to form the confidence interval by `std_selected_boot()`, users can request the percentile confidence intervals of the bootstrap estimates. This method does not do the bootstrapping itself.

Value

A matrix of the confidence intervals.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```
# Load a sample data set

dat <- test_x_1_w_1_v_1_cat1_n_500

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)
summary(lm_raw)

# Standardize all variables except for categorical variables.
# Interaction terms are formed after standardization.
lm_std <- std_selected(lm_raw, to_scale = ~ .,
                      to_center = ~ .)

summary(lm_std)

confint(lm_std)

# With bootstrapping
# nboot = 100 just for illustration. nboot >= 2000 should be used in real
# research.
lm_std_boot <- std_selected_boot(lm_raw, to_scale = ~ .,
                                to_center = ~ .,
                                nboot = 100)

summary(lm_std_boot)

confint(lm_std_boot)

# Bootstrap percentile intervals

confint(lm_std_boot, type = "boot")
```

plotmod

*Moderation Effect Plot***Description**

Plot the moderation effect in a regression model

Usage

```
plotmod(
  output,
  x,
  w,
  x_label,
  w_label,
  y_label,
  title,
  digits = 3,
  x_from_mean_in_sd = 1,
  w_from_mean_in_sd = 1,
  w_method = c("sd", "percentile"),
  w_percentiles = c(0.16, 0.84),
  x_method = c("sd", "percentile"),
  x_percentiles = c(0.16, 0.84),
  w_sd_to_percentiles = NA,
  x_sd_to_percentiles = NA,
  note_standardized = TRUE,
  no_title = FALSE,
  line_width = 1,
  point_size = 5,
  graph_type = c("default", "tumble")
)
```

Arguments

output	The output of <code>stats::lm()</code> , <code>std_selected()</code> , or <code>std_selected_boot()</code> .
x	The name of the focal variable (x-axis) in ‘output’. It can be the name of the variable, with or without quotes. Currently only numeric variables are supported.
w	The name of the moderator in output. It can be the name of the variable, with or without quotes.
x_label	The label for the X-axis. Default is the value of x.
w_label	The label for the legend for the lines. Default is the value of w.
y_label	The label for the Y-axis. Default is the name of the response variable in the model.

title	The title of the graph. If not supplied, it will be generated from the variable names or labels (in <code>x_label</code> , <code>y_label</code> , and <code>w_label</code>). If "", no title will be printed. This can be used when the plot is for manuscript submission and figures are required to have no titles.
digits	Number of decimal places to print. Default is 3.
x_from_mean_in_sd	How many SD from mean is used to define "low" and "high" for the focal variable. Default is 1.
w_from_mean_in_sd	How many SD from mean is used to define "low" and "high" for the moderator. Default is 1. Ignored if <code>w</code> is categorical.
w_method	How to define "high" and "low" for the moderator levels. Default is in terms of the standard deviation of the moderator, "sd". If equal to "percentile", then the percentiles of the moderator in the dataset are used. Ignored if <code>w</code> is categorical.
w_percentiles	If <code>w_method</code> is "percentile", then this argument specifies the two percentiles to be used, divided by 100. It must be a vector of two numbers. The default is <code>c(.16, .84)</code> , the 16th and 84th percentiles, which corresponds approximately to one SD below and above mean for a normal distribution, respectively. Ignored if <code>w</code> is categorical.
x_method	How to define "high" and "low" for the focal variable levels. Default is in terms of the standard deviation of the focal variable, "sd". If equal to "percentile", then the percentiles of the focal variable in the dataset is used.
x_percentiles	If <code>x_method</code> is "percentile", then this argument specifies the two percentiles to be used, divided by 100. It must be a vector of two numbers. The default is <code>c(.16, .84)</code> , the 16th and 84th percentiles, which corresponds approximately to one SD below and above mean for a normal distribution, respectively.
w_sd_to_percentiles	If <code>w_method</code> is "percentile" and this argument is set to a number, this number will be used to determine the percentiles to be used. The lower percentile is the percentile in a normal distribution that is <code>w_sd_to_percentiles</code> SD below the mean. The upper percentile is the percentile in a normal distribution that is <code>w_sd_to_percentiles</code> SD above the mean. Therefore, if <code>w_sd_to_percentiles</code> is set to 1, then the lower and upper percentiles are 16th and 84th, respectively. Default is NA.
x_sd_to_percentiles	If <code>x_method</code> is "percentile" and this argument is set to a number, this number will be used to determine the percentiles to be used. The lower percentile is the percentile in a normal distribution that is <code>x_sd_to_percentiles</code> SD below the mean. The upper percentile is the percentile in a normal distribution that is <code>x_sd_to_percentiles</code> SD above the mean. Therefore, if <code>x_sd_to_percentiles</code> is set to 1, then the lower and upper percentiles are 16th and 84th, respectively. Default is NA.
note_standardized	If TRUE, will check whether a variable has SD nearly equal to one. If yes, will report this in the plot. Default is TRUE.

no_title	If TRUE, title will be suppressed. Default is FALSE.
line_width	The width of the lines as used in <code>ggplot2::geom_segment()</code> . Default is 1.
point_size	The size of the points as used in <code>ggplot2::geom_point()</code> . Default is 5.
graph_type	If "default", the typical line-graph with equal end-points will be plotted. If "tumble", then the tumble graph proposed by Bodner (2016) will be plotted. Default is "default".

Details

This function generate a basic `ggplot2` graph typically found in psychology manuscripts. It tries to check whether one or more variables are standardized, and report this in the plot if required.

This function only has features for typical plots of moderation effects. It is not intended to be a flexible tool for a fine control on the plots.

Value

A `ggplot2` graph. Plotted if not assigned to a name. It can be further modified like a usual `ggplot2` graph.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

References

Bodner, T. E. (2016). Tumble graphs: Avoiding misleading end point extrapolation when graphing interactions from a moderated multiple regression analysis. *Journal of Educational and Behavioral Statistics*, 41(6), 593-604. doi:10.3102/1076998616657080

Examples

```
# Do a moderated regression by lm
lm_out <- lm(sleep_duration ~ age + gender + emotional_stability*conscientiousness, sleep_emo_con)
plotmod(lm_out,
        x = emotional_stability,
        w = conscientiousness,
        x_label = "Emotional Stability",
        w_label = "Conscientiousness",
        y_label = "Sleep Duration")

# Standardize all variables except for categorical variables
lm_std <- std_selected(lm_out,
                      to_scale = ~ .,
                      to_center = ~ .)
plotmod(lm_std,
        x = emotional_stability,
        w = conscientiousness,
        x_label = "Emotional Stability",
        w_label = "Conscientiousness",
```

```

        y_label = "Sleep Duration")

# Tumble Graph
plotmod(lm_std,
        x = emotional_stability,
        w = conscientiousness,
        x_label = "Emotional Stability",
        w_label = "Conscientiousness",
        y_label = "Sleep Duration",
        graph_type = "tumble")

```

```
print.cond_effect
```

Print a 'cond_effect' Class Object

Description

Print the output of [cond_effect\(\)](#) or [cond_effect_boot\(\)](#).

Usage

```

## S3 method for class 'cond_effect'
print(
  x,
  nd = 3,
  nd_stat = 3,
  nd_p = 3,
  title = TRUE,
  model = TRUE,
  level_info = TRUE,
  standardized = TRUE,
  boot_info = TRUE,
  table_only = FALSE,
  ...
)

```

Arguments

<code>x</code>	The output of cond_effect() or cond_effect_boot() .
<code>nd</code>	The number of digits for the variables.
<code>nd_stat</code>	The number of digits for test statistics (e.g., t).
<code>nd_p</code>	The number of digits for p -values.
<code>title</code>	If TRUE, print a title. Default is TRUE.
<code>model</code>	If TRUE, print the regression model. Default is TRUE.
<code>level_info</code>	If TRUE, print information for interpreting the levels of the moderator, such as the values of the levels and distance from the mean. Default is TRUE.

standardized	If TRUE and one or more variables are standardized, report it. Default is TRUE.
boot_info	If TRUE and bootstrap estimates are in x, print information about the bootstrapping, such as the number of bootstrap samples. Default is TRUE.
table_only	If TRUE, will suppress of other elements except for the table of conditional effects. Override arguments such as title, model, and level_info.
...	Additional arguments. Ignored by this function.

Value

x is returned invisibility.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```
# Load a sample data set
dat <- test_x_1_w_1_v_1_cat1_n_500

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)

cond_effect(lm_raw, x = iv, w = mod)

lm_std <- std_selected(lm_raw, to_scale = ~ iv + mod,
                      to_center = ~ iv + mod)

cond_effect(lm_std, x = iv, w = mod)
```

print.stdmod_lavaan *Print a 'stdmod_lavaan' Class Object*

Description

Print the output of `stdmod_lavaan()`.

Usage

```
## S3 method for class 'stdmod_lavaan'
print(x, conf = 0.95, nd = 3, ...)
```

Arguments

x	The output of <code>stdmod_lavaan()</code> .
conf	If nonparametric bootstrapping has been conducted by <code>stdmod_lavaan()</code> , this is the level of confidence in proportion (.95 denotes 95%), of the confidence interval. Default is .95.
nd	The number of digits to be printed.
...	Optional arguments. Ignored.

Value

x is returned invisibly.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```
# Load a test data of 500 cases

dat <- test_mod1
library(lavaan)

mod <-
"
med ~ iv + mod + iv:mod + cov1
dv ~ med + cov2
"

fit <- sem(mod, dat)
coef(fit)

# Compute the standardized moderation effect
out_noboot <- stdmod_lavaan(fit = fit,
                           x = "iv",
                           y = "med",
                           w = "mod",
                           x_w = "iv:mod")

out_noboot

# Compute the standardized moderation effect and
# its percentile confidence interval based on nonparametric bootstrapping
set.seed(8479075)
system.time(out_boot <- stdmod_lavaan(fit = fit,
                                     x = "iv",
                                     y = "med",
                                     w = "mod",
                                     x_w = "iv:mod",
                                     boot_ci = TRUE,
                                     R = 50))
```



```
# In real analysis, R should be at least 2000.  
out_boot
```

print.std_selected *Print Basic Information of a 'std_selected' Class Object*

Description

Provide information of centering and scaling, along with basic model information printed by `print.lm()`.

Usage

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

Arguments

x The output of `std_selected()` or `std_selected_boot()`.
... Arguments to be passed to `print.lm()`.

Value

x is returned invisibly.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```
# Load a sample data set  
dat <- test_x_1_w_1_v_1_cat1_n_500  
  
# Do a moderated regression by lm  
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)  
summary(lm_raw)  
  
# Standardize all variables except for categorical variables.  
# Interaction terms are formed after standardization.  
lm_std <- std_selected(lm_raw, to_scale = ~ .,  
                          to_center = ~ .)  
lm_std  
  
# With bootstrapping
```



```

# With bootstrapping
# nboot = 100 just for illustration. nboot >= 2000 should be used in read
# research.
lm_std_boot <- std_selected_boot(lm_raw, to_scale = ~ .,
                                to_center = ~ .,
                                nboot = 100)

summary(lm_std_boot)

```

sleep_emo_con

Sample Dataset: Predicting Sleep Duration

Description

A random subset from a real dataset. For illustration.

Usage

```
sleep_emo_con
```

Format

A data frame with 500 rows and six variables:

case_id Case ID, integer

sleep_duration Sleep duration in hours

conscientiousness Conscientiousness score, continuous

emotional_stability Emotional stability score, continuous

age Age in years

gender Gender, string, "female" or "male"

stdmod

Standardized Moderation Effect Given an 'lm' Output

Description

Compute the standardized moderation effect in a moderated regression model.

Usage

```

stdmod(
  lm_out,
  x = NULL,
  w = NULL,
  y = NULL,
  x_rescale = TRUE,
  w_rescale = TRUE,
  y_rescale = TRUE
)

stdmod_boot(
  lm_out,
  ...,
  nboot = 100,
  conf = 0.95,
  boot_args = NULL,
  full_output = FALSE
)

```

Arguments

lm_out	The output from <code>lm()</code> .
x	The focal variable, that is, the variable with its effect being moderated. If supplied, its standard deviation will be used for rescaling. Also called the independent variable in some models. Default is NULL.
w	The moderator. If supplied, its standard deviation will be used for rescaling. Default is NULL.
y	The outcome variable (dependent variable) . If supplied, its standard deviation will be used for rescaling. Default is NULL.
x_rescale	If TRUE, will rescale x by its standard deviation. Default is TRUE.
w_rescale	If TRUE, will rescale w by its standard deviation. Default is TRUE.
y_rescale	If TRUE, will rescale y by its standard deviation. Default is TRUE.
...	Parameters to be passed to <code>stdmod()</code> .
nboot	The number of bootstrap samples. Default is 100.
conf	The level of confidence for the confidence interval. Default is .95.
boot_args	A named list of arguments to be passed to <code>boot::boot()</code> . Default is NULL.
full_output	Whether the full output from <code>boot::boot()</code> is returned. Default is FALSE.

Details

Two more general functions, `std_selected()` and `std_selected_boot()`, have been developed and can do what these functions do and more. Users are recommended to use them instead of `stdmod()` and `stdmod_boot()`. These two functions will not be updated in the near future.

Nevertheless, if computing the standardized moderation effect and forming its nonparametric bootstrap interval are all required, then these functions can still be used.

`stdmod()` computes the standardized moderation effect given an `lm()` output using the formula from Cheung, Cheung, Lau, Hui, and Vong (2022). Users specify the moderator, the focal variable (the variable with its effect on the outcome variable moderated), the outcome variable (dependent variable), and the corresponding standardized moderation effect. Users can also select which variable(s) will be standardized.

`stdmod_boot()` is a wrapper of `stdmod()`. It computes the nonparametric bootstrap confidence interval of the standardized moderation effect, as suggested by Cheung, Cheung, Lau, Hui, and Vong (2022), given the output of `lm()`

Percentile interval from `boot::boot.ci()` is returned by this function. If other types of confidence intervals are desired, set `full_output = TRUE` and use `boot::boot.ci()` on the element `boot_out` in the output of this function.

Value

`stdmod()` returns a scalar: The standardized moderation effect.

`stdmod_boot()` returns a list with two elements. The element `ci` is a numeric vector of the bootstrap confidence interval. The element `boot_out`, if not NA, is the output of `boot::boot()`, which is used to do the bootstrapping.

Functions

- `stdmod`: The base function for computing standardized moderation effect
- `stdmod_boot`: A wrapper of `stdmod()` that computes the nonparametric bootstrap confidence interval of the standardized moderation effect.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

References

Cheung, S. F., Cheung, S.-H., Lau, E. Y. Y., Hui, C. H., & Vong, W. N. (2022) Improving an old way to measure moderation effect in standardized units. Advance online publication. *Health Psychology*. doi:10.1037/hea0001188

Examples

```
# Load a test data of 500 cases

dat <- test_x_1_w_1_v_2_n_500

# Do regression as usual:
lm_raw <- lm(dv ~ iv*mod + v1 + v2, dat)
summary(lm_raw)

# The standard deviations of iv, dv, and mod:
```

```

sds <- apply(dat, 2, sd)
sds

# Compute the standardized moderation effect:
stdmod_xyw <- stdmod(lm_raw, x = iv, y = dv, w = mod)
stdmod_xyw
# By default, all three variables will be standardized.

# Check against self-computed standardized moderation effect:
coef(lm_raw)["iv:mod"] * sds["iv"] * sds["mod"] / sds["dv"]

# Standardize only the iv, i.e., do not standardized dv and the moderator:
stdmod_x <- stdmod(lm_raw, x = iv, y = dv, w = mod,
                  x_rescale = TRUE, y_rescale = FALSE, w_rescale = FALSE)
stdmod_x
# Check against self-computed moderation effect with only iv standardized:
coef(lm_raw)["iv:mod"] * sds["iv"]

dat <- test_x_1_w_1_v_2_n_500
# Do regression as usual:
lm_raw <- lm(dv ~ iv*mod + v1 + v2, dat)

# Compute the standardized moderation effect.
# Form its confidence interval by nonparametric bootstrapping.
set.seed(85740917)
stdmod_xyw_boot <- stdmod_boot(lm_raw, x = iv, w = mod, y = dv, nboot = 100)
# In real analysis, nboot should be at least 2000.

# Print the ci
stdmod_xyw_boot$ci

# Repeat the analysis but keep the results from boot:
set.seed(85740917)
stdmod_xyw_boot <- stdmod_boot(lm_raw, x = iv, w = mod, y = dv,
                              nboot = 200, full_output = TRUE)
# In real analysis, nboot should be at least 2000.

# Print the 95% percentile confidence interval
stdmod_xyw_boot$ci

```

stdmod_lavaan

Standardized Moderation Effect and Its Bootstrap CI in 'lavaan'

Description

Compute the standardized moderation effect in a structural equation model fitted by `lavaan::lavaan()` or its wrappers and form the nonparametric bootstrap confidence interval.

Usage

```
stdmod_lavaan(fit, x, y, w, x_w, boot_ci = FALSE, R = 100, conf = 0.95, ...)
```

Arguments

<code>fit</code>	The SEM output by <code>lavaan::lavaan()</code> or its wrappers.
<code>x</code>	The name of the focal variable in the model, the variable with its effect on the outcome variable being moderated.
<code>y</code>	The name of the outcome variable (dependent variable) in the model.
<code>w</code>	The name of the moderator in the model.
<code>x_w</code>	The name of the product term ($x * w$) in the model. It can be the variable generated by the colon operator, e.g., "x:w", which is only in the model and not in the original data set.
<code>boot_ci</code>	Boolean. Whether nonparametric bootstrapping will be conducted. Default is FALSE.
<code>R</code>	The number of nonparametric bootstrapping samples. Default is 100. Set this to at least 2000 in actual use.
<code>conf</code>	The level of confidence. Default is .95, i.e., 95%.
<code>...</code>	Optional arguments to be passed to <code>boot::boot()</code> . Parallel processing can be used by adding the appropriate arguments in <code>boot::boot()</code> .

Details

`stdmod_lavaan()` accepts a `lavaan::lavaan` object, the structural equation model output returned by `lavaan::lavaan()` and its wrappers (e.g. `lavaan::sem()`) and computes the standardized moderation effect using the formula in the appendix of Cheung, Cheung, Lau, Hui, and Vong (2022).

The standard deviations of the focal variable (the variable with its effect on the outcome variable being moderated), moderator, and outcome variable (dependent variable) are computed from the implied covariance matrix returned by `lavaan::lavInspect()`. Therefore, models fitted to data sets with missing data (e.g., with `missing = "fiml"`) are also supported.

If nonparametric bootstrap confidence interval is requested with R bootstrap samples, the model will be fitted R times to these samples, and the standardized moderation effect will be computed in each sample. This ensures that all components used in the computation, including the standard deviations, are also computed from the bootstrapping samples.

Note that the computation can be slow because `lavaan::lavaan()` or its wrappers will be called R times.

Value

A list of class `stdmod_lavaan` with these elements:

- `stdmod`: The standardized moderation effect.
- `ci`: The nonparametric bootstrap confidence interval. NA if confidence interval not requested.
- `boot_out`: The raw output from `boot::boot()`. NA if confidence interval not requested.
- `fit`: The original fit object.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

References

Cheung, S. F., Cheung, S.-H., Lau, E. Y. Y., Hui, C. H., & Vong, W. N. (2022) Improving an old way to measure moderation effect in standardized units. Advance online publication. *Health Psychology*. doi:10.1037/hea0001188

Examples

```
#Load a test data of 500 cases

dat <- test_mod1
library(lavaan)
mod <-
"
med ~ iv + mod + iv:mod + cov1
dv ~ med + cov2
"
fit <- sem(mod, dat)

# Compute the standardized moderation effect
out_noboot <- stdmod_lavaan(fit = fit,
                           x = "iv",
                           y = "med",
                           w = "mod",
                           x_w = "iv:mod")
out_noboot

# Compute the standardized moderation effect and
# its percentile confidence interval using
# nonparametric bootstrapping
set.seed(8479075)
system.time(out_boot <- stdmod_lavaan(fit = fit,
                                     x = "iv",
                                     y = "med",
                                     w = "mod",
                                     x_w = "iv:mod",
                                     boot_ci = TRUE,
                                     R = 50))
# In real analysis, R should be at least 2000.
out_boot
```


Description

Standardize, mean center, or scale by standard deviation selected variables in a regression model and refit the model

Usage

```
std_selected(lm_out, to_scale = NULL, to_center = NULL)
```

```
std_selected_boot(
  lm_out,
  ...,
  conf = 0.95,
  nboot = 100,
  boot_args = NULL,
  save_boot_est = TRUE,
  full_output = FALSE
)
```

Arguments

lm_out	The output from <code>lm()</code> .
to_scale	The terms to be rescaled by standard deviation, specified by a formula as in <code>lm()</code> . For example, if the terms to be scaled are <code>x1</code> and <code>x3</code> , use <code>~ x1 + x3</code> . No need to specify the interaction term. To scale the outcome variable, list it on the <i>right hand side</i> as a predictor. Specify only the original variables. If <code>NULL</code> , then no terms will be rescaled by their standard deviations. Variables that are not numeric will be ignored. Default is <code>NULL</code> .
to_center	The terms to be mean centered, specified by a formula as in <code>lm()</code> . For example, if the terms to be centered is <code>x1</code> and <code>x3</code> , use <code>~ x1 + x3</code> . No need to specify the interaction term. To center the outcome variable, list it on the <i>right hand side</i> as a predictor. Specify only the original variables. If <code>NULL</code> , then no term will be centered. Default is <code>NULL</code> .
...	Arguments to be passed to <code>std_selected()</code> .
conf	The level of confidence for the confidence interval. Default is <code>.95</code> .
nboot	The number of bootstrap samples. Default is <code>100</code> .
boot_args	A named list of arguments to be passed to <code>boot::boot()</code> . Default is <code>NULL</code> .
save_boot_est	If <code>TRUE</code> , the default, the bootstrap estimates will be saved in the element <code>boot_est</code> of the output.
full_output	Whether the full output from <code>boot::boot()</code> is returned. Default is <code>FALSE</code> . If <code>TRUE</code> , the full output from <code>boot::boot()</code> will be saved in the element <code>boot_out</code> of the output.

Details

`std_selected()` was originally developed to compute the standardized moderation effect and the standardized coefficients for other predictors given an `lm()` output (Cheung, Cheung, Lau, Hui, &

Vong, 2022). It has been extended such that users can specify which variables in a regression model are to be mean-centered and/or rescaled by their standard deviations. If the model has one or more interaction terms, they will be formed after the transformation, yielding the correct standardized solution for a moderated regression model. Moreover, categorical predictors will be automatically skipped in mean-centering and rescaling.

Standardization is conducted when a variable is mean-centered and then rescaled by its standard deviation. Therefore, if the goal is to get the standardized solution of a moderated regression, users just instruct the function to standardize all non-categorical variables in the regression model.

`std_selected_boot()` is a wrapper of `std_selected()`. It calls `std_selected()` once for each bootstrap sample, and then computes the nonparametric bootstrap percentile confidence intervals (Cheung, Cheung, Lau, Hui, & Vong, 2022).

This function intentionally does not have an argument for setting the seed for random number. Users are recommended to set the seed, e.g., using `set.seed()` before calling it, to ensure reproducibility.

Value

The updated `lm()` output, with the class `std_selected` added. It will be treated as a usual `lm()` object by most functions. These are the major additional element in the list:

- `scaled_terms`: If not NULL, a character vector of the variables scaled.
- `centered_terms`: If not NULL, a character vector of the variables mean-centered.
- `scaled_by`: A numeric vector of the scaling factors for all the variables in the model. The value is 1 for terms not scaled.
- `centered_by`: A numeric vector of the numbers used for centering for all the variables in the model. The value is 0 for terms not centered.
- `std_selected_call`: The original call.
- `lm_out_call`: The call in `lm_out`.

Like `std_selected()`, `std_selected_boot()` returns the updated `lm()` output, with the class `std_selected` added. The output of `std_selected_boot()` contain these additional elements in the list:

- `boot_ci`: A data frame of the bootstrap confidence intervals of the regression coefficient.
- `nboot`: The number of bootstrap samples requested.
- `conf`: The level of confidence, in proportion.
- `boot_est`: A matrix of the bootstrap estimates of the regression coefficients. The number of rows equal to `nboot`, and the number of columns equal to the number of terms in the regression model.
- `std_selected_boot_call`: The call to `std_selected_boot()`.
- `boot_out`: If available, the original output from `boot::boot()`.

Functions

- `std_selected`: The base function to center or scale selected variables in a regression model
- `std_selected_boot`: A wrapper of `std_selected()` that forms nonparametric bootstrap confidence intervals.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

References

Cheung, S. F., Cheung, S.-H., Lau, E. Y. Y., Hui, C. H., & Vong, W. N. (2022) Improving an old way to measure moderation effect in standardized units. Advance online publication. *Health Psychology*. doi:10.1037/hea0001188

Examples

```
# Load a sample data set

dat <- test_x_1_w_1_v_1_cat1_n_500
head(dat)

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)
summary(lm_raw)

# Mean center mod only
lm_cw <- std_selected(lm_raw, to_center = ~ mod)
summary(lm_cw)

# Mean center mod and iv
lm_cwx <- std_selected(lm_raw, to_center = ~ mod + iv)
summary(lm_cwx)

# Standardize both mod and iv
lm_stdwx <- std_selected(lm_raw, to_scale = ~ mod + iv,
                        to_center = ~ mod + iv)
summary(lm_stdwx)

# Standardize all variables except for categorical variables.
# Interaction terms are formed after standardization.
lm_std <- std_selected(lm_raw, to_scale = ~ .,
                      to_center = ~ .)
summary(lm_std)

dat <- test_x_1_w_1_v_1_cat1_n_500
head(dat)

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)
summary(lm_raw)
# Standardize all variables as in std_selected above, and compute the
# nonparametric bootstrapping percentile confidence intervals.
lm_std_boot <- std_selected_boot(lm_raw,
                                to_scale = ~ .,
                                to_center = ~ .,
```

```

                                conf = .95,
                                nboot = 100)
# In real analysis, nboot should be at least 2000.
summary(lm_std_boot)

```

summary.std_selected *Summary Method for a 'std_selected' Class Object*

Description

Summarize the results of `std_selected()` or `std_selected_boot()`.

Usage

```

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

```

Arguments

`object` The output of `std_selected()` or `std_selected_boot()`.
`...` Additional arguments. Ignored by this function.

Value

An object of class `summary.std_selected`, with bootstrap confidence intervals added if present in the object. The object is a list. Its main element `coefficients` is similar to the coefficient table in the `summary()` printout of `lm()`. This object is for printing summary information of the results from `std_selected()` or `std_selected_boot()`.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```

# Load a sample data set

dat <- test_x_1_w_1_v_1_cat1_n_500

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)
summary(lm_raw)

# Standardize all variables except for categorical variables.
# Interaction terms are formed after standardization.
lm_std <- std_selected(lm_raw, to_scale = ~ .,
                       to_center = ~ .)

```

```
summary(lm_std)

# With bootstrapping
# nboot = 100 just for illustration. nboot >= 2000 should be used in real
# research.
lm_std_boot <- std_selected_boot(lm_raw, to_scale = ~ .,
                                to_center = ~ .,
                                nboot = 100)

summary(lm_std_boot)
```

test_mod1

Sample Dataset: A Path Model With A Moderator

Description

For testing. Generated from the following model.

```
mod <-
"
med ~ iv + mod + iv:mod + cov1
dv ~ med + cov2
"
```

Usage

```
test_mod1
```

Format

A data frame with 300 rows and 6 variables:

dv Dependent variable, continuous

iv Independent variable, continuous

med Mediator, continuous

mod Moderator, continuous

cov1 Covariate, continuous

cov2 Covariate, continuous

 test_mod2

Sample Dataset: A Path Model With A Moderator

Description

For testing. Generated from the following model.

```
mod <-
"
med ~ iv + cov1
dv ~ med + mod + med:mod + cov2
"
```

Usage

```
test_mod2
```

Format

A data frame with 300 rows and 6 variables:

dv Dependent variable, continuous
iv Independent variable, continuous
med Mediator, continuous
mod Moderator, continuous
cov1 Covariate, continuous
cov2 Covariate, continuous

 test_mod3_miss

Sample Dataset: A Path Model With A Moderator

Description

For testing the handling of warnings in `stdmod_lavaan()`. Generated from the following model. `dv` has about 88% missing. A warning on missing data will be raised in some bootstrap samples.

```
mod <-
"
med ~ iv + mod + iv:mod + cov1
dv ~ med + cov2
"
```

Usage

```
test_mod3_miss
```

Format

A data frame with 500 rows and 6 variables:

dv Dependent variable, continuous

iv Independent variable, continuous

med Mediator, continuous

mod Moderator, continuous

cov1 Covariate, continuous

cov2 Covariate, continuous

test_x_1_w_1_v_1_cat1_n_500

Sample Dataset: One IV, One Moderator, Two Covariates

Description

A covariate (cat1) is categorical. For testing.

Usage

test_x_1_w_1_v_1_cat1_n_500

Format

A data frame with 500 rows and five variables:

dv Dependent variable, continuous

iv Independent variable, continuous

mod Moderator variable, continuous

v1 Covariate, continuous

cat1 Covariate, categorical (string) with three values: "gp1", "gp2", and "gp3"

test_x_1_w_1_v_1_cat1_xw_cov_n_500

Sample Dataset: One IV, One Moderator, Two Covariates

Description

The independent variable and the moderator are associated. For demonstrating the use of tumble graph.

Usage

test_x_1_w_1_v_1_cat1_xw_cov_n_500

Format

A data frame with 500 rows and 5 variables:

dv Dependent variable, continuous

iv Independent variable, continuous

mod Moderator variable, continuous

v1 Covariate, continuous

cat1 Covariate, categorical (string) with three values, "gp1", "gp2", and "gp3"

test_x_1_w_1_v_1_cat1_xw_cov_wcat3_n_500

Sample Dataset: One IV, One 3-Category Moderator, Two Covariates

Description

The independent variable and the categorical moderator are associated. For demonstrating the use of tumble graph.

Usage

test_x_1_w_1_v_1_cat1_xw_cov_wcat3_n_500

Format

A data frame with 500 rows and 5 variables:

dv Dependent variable, continuous

iv Independent variable, continuous

mod Moderator variable, categorical (string) with three categories, "City Alpha", "City Gamma", and "City Beta"

v1 Covariate, continuous

cat1 Covariate, categorical (string) with three values, "gp1", "gp2", and "gp3"

 test_x_1_w_1_v_2_n_500

Sample Dataset: One IV, One Moderator, Two Covariates

Description

All variables are continuous. For testing.

Usage

```
test_x_1_w_1_v_2_n_500
```

Format

A data frame with 500 rows and five variables:

dv Dependent variable, continuous

iv Independent variable, continuous

mod Moderator variable, continuous

v1 Covariate, continuous

v2 Covariate, continuous

 update.std_selected *The 'update' Method for a 'std_selected' Class Object*

Description

This should be used only to update the call to `lm()`, not to the call to `std_selected()` or `std_selected_boot()`.

Usage

```
## S3 method for class 'std_selected'
update(object, formula., ..., evaluate = TRUE)
```

Arguments

object	The output of the class <code>std_selected()</code> .
formula.	Changes to the formula.
...	Optional arguments to be changed.
evaluate	Whether the call will be evaluated.

Details

Although supported, it is not recommended to update an analysis processed by `std_selected()` or `std_selected_boot()`. It is recommended to call `lm()` again and pass the output to `std_selected()` or `std_selected_boot()`.

Value

If `evaluate = TRUE`, it returns the updated fitted object, otherwise, the updated call.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```
# Load a sample data set

dat <- test_x_1_w_1_v_1_cat1_n_500
head(dat)

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)
summary(lm_raw)

# Standardize all variables except for categorical variables.
# Interaction terms are formed after standardization.
lm_std <- std_selected(lm_raw, to_scale = ~ .,
                      to_center = ~ .)

summary(lm_std)

# Update the model
lm_std2 <- update(lm_std, . ~ . - v1)
summary(lm_std2)
```

vcov.std_selected *The 'vcov' Method for a 'std_selected' Class Object*

Description

Compute the variance-covariance matrix of estimates in the output of `std_selected()` or `std_selected_boot()`.

Usage

```
## S3 method for class 'std_selected'
vcov(object, type = "lm", ...)
```

Arguments

object	The output of <code>std_selected()</code> or <code>std_selected_boot()</code> .
type	The type of variance-covariance matrix. Default is "lm", returned by the <code>stats::vcov()</code> method for the output of <code>lm()</code> . If set to "boot", the variance-covariance matrix of the bootstrap estimates is returned.
...	Arguments to be passed to <code>stats::vcov()</code> .

Details

If bootstrapping was used to form the confidence intervals, users can request the variance-covariance matrix of the bootstrap estimates.

Value

A matrix of the variances and covariances of the parameter estimates.

Author(s)

Shu Fai Cheung <https://orcid.org/0000-0002-9871-9448>

Examples

```
# Load a sample data set

dat <- test_x_1_w_1_v_1_cat1_n_500
head(dat)

# Do a moderated regression by lm
lm_raw <- lm(dv ~ iv*mod + v1 + cat1, dat)

# Standardize all variables except for categorical variables.
# Interaction terms are formed after standardization.
lm_std <- std_selected(lm_raw, to_scale = ~ .,
                      to_center = ~ .)

# VCOV of lm output
vcov(lm_std)

# Standardize all variables as in std_selected above, and compute the
# nonparametric bootstrapping percentile confidence intervals.
lm_std_boot <- std_selected_boot(lm_raw,
                                to_scale = ~ .,
                                to_center = ~ .,
                                conf = .95,
                                nboot = 100)

# In real analysis, nboot should be at least 2000.

# VCOV of lm output
vcov(lm_std_boot)

# VCOV of bootstrap estimates
```

```
vcov(lm_std_boot, type = "boot")
```

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