

# Bootstrapping a PLS-SEM

## Bootstrapping in SEMinR

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updated: 2021-07-12

# PLS model estimation in SEMinR

1. Why we bootstrap
2. How bootstrapping works
3. Bootstrapping a model
4. The SEMinR bootstrapped model object

# Why we bootstrap

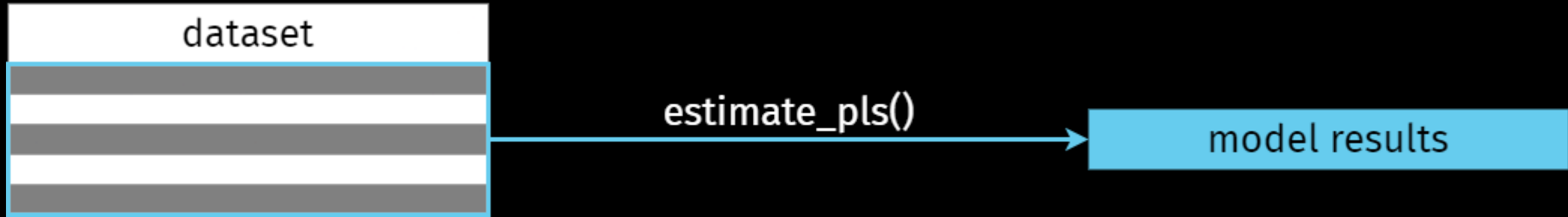
Bootstrapping gives you significance information for

- path coefficients
- weights
- loadings
- HTMT ratios

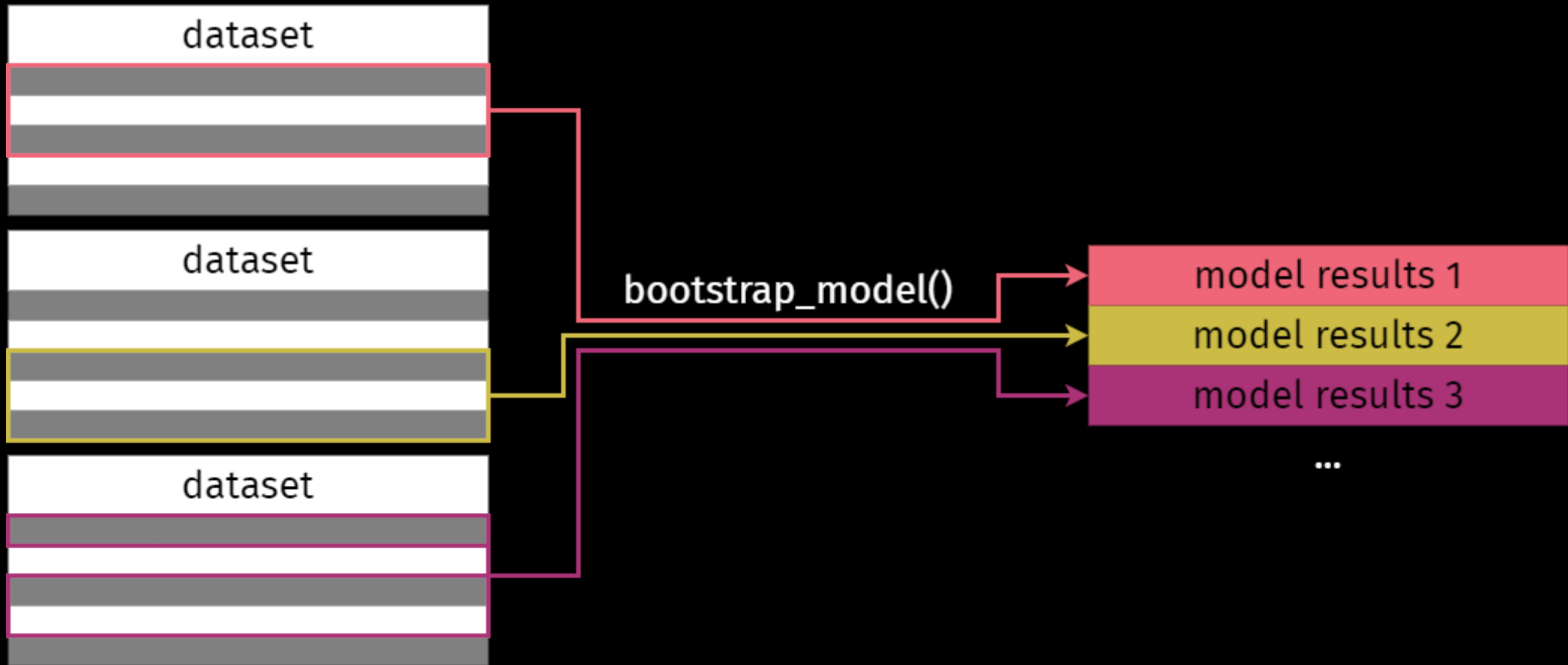
**... given your data**

# How bootstrapping works

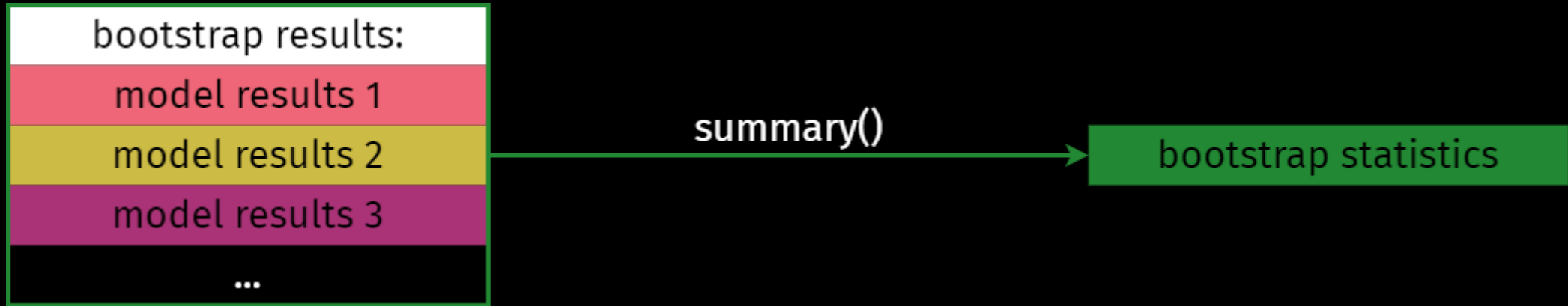
Regular model estimation process:



# How bootstrapping works



# How bootstrapping works



Statistics include mean, standard deviation and confidence intervals on the basis of the different model results.

# Bootstrapping a model - preparation

```
# load semnr library
library(semnr)
# quickly estimate model
model <- estimate_pls(
  data = mobi,
  measurement_model = constructs(
    composite("Reputation", multi_items("IMAG", 1:5)),
    composite("Satisfaction", multi_items("CUSA", 1:3)),
    composite("Loyalty", multi_items("CUSL", 1:3)),
    structural_model = relationships(
      paths(from = "Reputation", to = c("Satisfaction", "Loyalty")),
      paths(from = "Satisfaction", to = "Loyalty"))
  )
)
```

```
## Generating the semnr model
```

```
## All 250 observations are valid.
```

# Bootstrapping a model - the fundamentals

```
# bootstrap the model
bootstrapmodel <- bootstrap_model(
  seminr_model = model,    # a pls model
  nboot = 500,             # the number of bootstrap iterations
  cores = NULL,
  seed = NULL
)
```



# Bootstrapping a model - *cores* and *seed*

```
# bootstrap the model
bootstrapmodel <- bootstrap_model(
  semnr_model = model,
  nboot = 500,
  cores = NULL,           # the maximum number of cores to use
  seed = NULL             # the random seed
)
```

# Bootstrapping a model

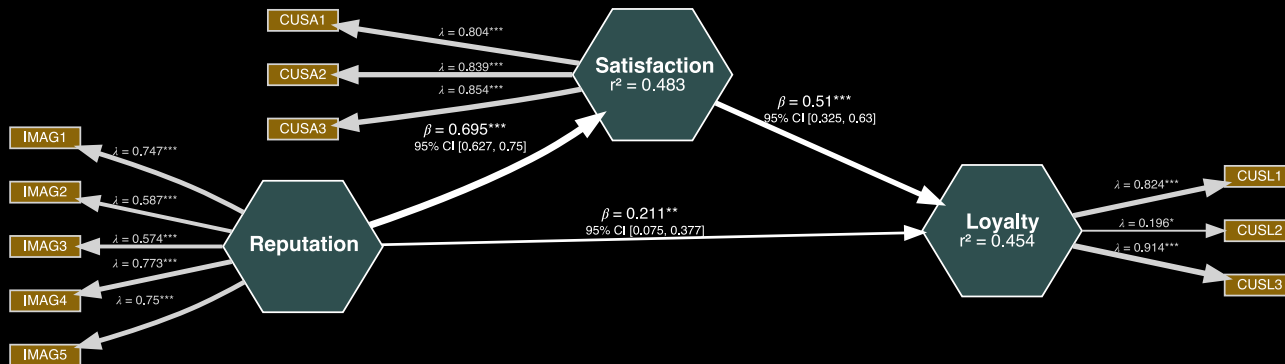
```
# bootstrap the model  
bootstrapmodel <- bootstrap_model(  
  seminr_model = model,  
  nboot = 100  
)
```

```
## Bootstrapping model using seminr...
```

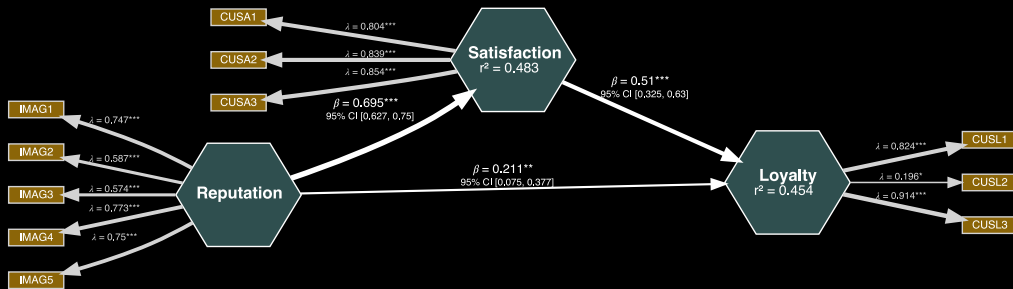
```
## SEMinR Model successfully bootstrapped
```

# The SEMinR bootstrap model object - plot

```
plot(bootstrapmodel)
```



# The SEMinR bootstrap model object - plot



\*\*\* $p < .001$ , \*\* $p < .01$ , \* $p < .05$

95% CI[lower bound, upper bound]

# The SEMinR bootstrap model object - subobjects

```
> bootstrapmodel$
```

```
bootstrapmodel$boot_paths
```

```
## , , 1
```

```
##
```

	Reputation	Satisfaction	Loyalty
## Reputation	0	0.6975628	0.1547664
## Satisfaction	0	0.0000000	0.5838384
## Loyalty	0	0.0000000	0.0000000

```
##
```

```
## , , 2
```

```
##
```

	Reputation	Satisfaction	Loyalty
## Reputation	0	0.6904222	0.2015742
## Satisfaction	0	0.0000000	0.5927379
## Loyalty	0	0.0000000	0.0000000

```
##
```

# The SEMinR bootstrap model object - summary

```
# print summary of the bootstrapped model
summary(bootstrapmodel)
```

```
##
## Results from Bootstrap resamples: 100
##
## Bootstrapped Structural Paths:
##
```

	Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	2.5% CI	97.5% CI
## Reputation -> Satisfaction	0.695	0.697	0.033	20.926	0.627	0.750
## Reputation -> Loyalty	0.211	0.218	0.076	2.763	0.075	0.377
## Satisfaction -> Loyalty	0.510	0.501	0.086	5.904	0.325	0.630

```
##
## Bootstrapped Weights:
##
```

	Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	2.5% CI	97.5% CI
## IMAG1 -> Reputation	0.305	0.306	0.024	12.726	0.262	0.348
## IMAG2 -> Reputation	0.243	0.247	0.032	7.697	0.190	0.312
## IMAG3 -> Reputation	0.211	0.206	0.034	6.162	0.148	0.264
## IMAG4 -> Reputation	0.335	0.331	0.026	13.061	0.280	0.378
## IMAG5 -> Reputation	0.333	0.335	0.030	11.238	0.285	0.397

# The SEMinR model object - summary subobjects

```
# save summary of the bootstrapped model  
summarybootmodel <- summary(bootstrapmodel)
```

```
# number of bootstrap iterations  
summarybootmodel$nboot
```

```
## [1] 100
```

# The SEMinR model object - summary subobjects

```
# bootstrapped paths  
summarybootmodel$bootstrapped_paths
```

##		Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	2.5% CI	97.5% CI
##	Reputation -> Satisfaction	0.695	0.697	0.033	20.926	0.627	0.750
##	Reputation -> Loyalty	0.211	0.218	0.076	2.763	0.075	0.377
##	Satisfaction -> Loyalty	0.510	0.501	0.086	5.904	0.325	0.630



# The SEMinR model object - summary subobjects

```
# bootstrapped weights
summarybootmodel$bootstrapped_weights
# bootstrapped loadings
summarybootmodel$bootstrapped_loadings
# bootstrapped HTMT
summarybootmodel$bootstrapped_HTMT
```

```
# bootstrapped total paths - includes mediated influence
summarybootmodel$bootstrapped_total_paths
```

##		Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	2.5% CI	97.5% CI
##	Reputation -> Satisfaction	0.695	0.697	0.033	20.926	0.627	0.750
##	Reputation -> Loyalty	0.565	0.568	0.054	10.468	0.457	0.680
##	Satisfaction -> Loyalty	0.510	0.501	0.086	5.904	0.325	0.630

# Summary

- Why we bootstrap
- How bootstrapping works
- Model bootstrapping with `bootstrap_model()`
- Bootstrapped model object and bootstrapped model summary object

# Sources for this video

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). A primer on partial least squares structural equation modeling (PLS-SEM) (Second edition). Sage.

Ray, S. & Danks. N. (2020). SEMinR Vignette. <https://cran.r-project.org/web/packages/seminr/vignettes/SEMinR.html>