

**spearman** — Spearman's and Kendall's correlations
[Description](#)[Options for spearman](#)[Methods and formulas](#)[Quick start](#)[Options for ktau](#)[Acknowledgment](#)[Menu](#)[Remarks and examples](#)[References](#)[Syntax](#)[Stored results](#)[Also see](#)

## Description

`spearman` displays Spearman's rank correlation coefficients for all pairs of variables in *varlist* or, if *varlist* is not specified, for all the variables in the dataset.

`ktau` displays Kendall's rank correlation coefficients between the variables in *varlist* or, if *varlist* is not specified, for all the variables in the dataset. `ktau` is intended for use on small- and moderate-sized datasets; it requires considerable computation time for larger datasets.

## Quick start

Spearman's rank correlation coefficients for all pairs of `v1`, `v2`, and `v3`

```
spearman v1 v2 v3
```

Same as above

```
spearman v1 v2 v3, stats(rho)
```

Also display significance levels

```
spearman v1 v2 v3, stats(rho p)
```

As above, but perform Bonferroni's adjustment to *p*-values

```
spearman v1 v2 v3, stats(rho p) bonferroni
```

Kendall's rank correlation coefficients, scores, and std. err. of the scores for pairs of `v1`, `v2`, and `v3`

```
ktau v1 v2 v3, stats(taua taub score se)
```

As above, but use pairwise instead of casewise deletion

```
ktau v1 v2 v3, stats(taua taub score se) pw
```

## Menu

### **spearman**

Statistics > Nonparametric analysis > Tests of hypotheses > Spearman's rank correlation

### **ktau**

Statistics > Nonparametric analysis > Tests of hypotheses > Kendall's rank correlation

## Syntax

*Spearman's rank correlation coefficients*

```
spearman [varlist] [if] [in] [, spearman_options]
```

*Kendall's rank correlation coefficients*

```
ktau [varlist] [if] [in] [, ktau_options]
```

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<i>spearman_options</i>	Description
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Main

<code>stats(<i>spearman_list</i>)</code>	list of statistics; select up to three statistics; default is <code>stats(rho)</code>
<code>print(#)</code>	significance level for displaying coefficients
<code>star(#)</code>	significance level for displaying with a star
<code>bonferroni</code>	use Bonferroni-adjusted significance level
<code>sidak</code>	use Šidák-adjusted significance level
<code>pw</code>	calculate all pairwise correlation coefficients by using all available data
<code>matrix</code>	display output in matrix form

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<i>ktau_options</i>	Description
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Main

<code>stats(<i>ktau_list</i>)</code>	list of statistics; select up to six statistics; default is <code>stats(taua)</code>
<code>print(#)</code>	significance level for displaying coefficients
<code>star(#)</code>	significance level for displaying with a star
<code>bonferroni</code>	use Bonferroni-adjusted significance level
<code>sidak</code>	use Šidák-adjusted significance level
<code>pw</code>	calculate all pairwise correlation coefficients by using all available data
<code>matrix</code>	display output in matrix form

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by and collect are allowed with `spearman` and `ktau`; see [U] 11.1.10 [Prefix commands](#).

where the elements of *spearman\_list* may be

<code>rho</code>	correlation coefficient
<code>obs</code>	number of observations
<code>p</code>	significance level

and the elements of *ktau\_list* may be

<code>taua</code>	correlation coefficient $\tau_a$
<code>taub</code>	correlation coefficient $\tau_b$
<code>score</code>	score
<code>se</code>	standard error of score
<code>obs</code>	number of observations
<code>p</code>	significance level

## Options for spearman

Main

`stats(spearman_list)` specifies the statistics to be displayed in the matrix of output. `stats(rho)` is the default. Up to three statistics may be specified; `stats(rho obs p)` would display the correlation coefficient, number of observations, and significance level. If *varlist* contains only two variables, all statistics are shown in tabular form, and `stats()`, `print()`, and `star()` have no effect unless the `matrix` option is specified.

`print(#)` specifies the significance level of correlation coefficients to be printed. Correlation coefficients with larger significance levels are left blank in the matrix. Typing `spearman, print(.10)` would list only those correlation coefficients that are significant at the 10% level or lower.

`star(#)` specifies the significance level of correlation coefficients to be marked with a star. Typing `spearman, star(.05)` would “star” all correlation coefficients significant at the 5% level or lower.

`bonferroni` makes the Bonferroni adjustment to calculated significance levels. This adjustment affects printed significance levels and the `print()` and `star()` options. Thus, `spearman, print(.05) bonferroni` prints coefficients with Bonferroni-adjusted significance levels of 0.05 or less.

`sidak` makes the Šidák adjustment to calculated significance levels. This adjustment affects printed significance levels and the `print()` and `star()` options. Thus, `spearman, print(.05) sidak` prints coefficients with Šidák-adjusted significance levels of 0.05 or less.

`pw` specifies that correlations be calculated using pairwise deletion of observations with missing values. By default, `spearman` uses casewise deletion, where observations are ignored if any of the variables in *varlist* are missing.

`matrix` forces `spearman` to display the statistics as a matrix, even if *varlist* contains only two variables. `matrix` is implied if more than two variables are specified.

## Options for ktau

Main

`stats(ktau_list)` specifies the statistics to be displayed in the matrix of output. `stats(taua)` is the default. Up to six statistics may be specified; `stats(taua taub score se obs p)` would display the correlation coefficients  $\tau_a$ ,  $\tau_b$ , score, standard error of score, number of observations, and significance level. If *varlist* contains only two variables, all statistics are shown in tabular form and `stats()`, `print()`, and `star()` have no effect unless the `matrix` option is specified.

`print(#)` specifies the significance level of correlation coefficients to be printed. Correlation coefficients with larger significance levels are left blank in the matrix. Typing `ktau, print(.10)` would list only those correlation coefficients that are significant at the 10% level or lower.

`star(#)` specifies the significance level of correlation coefficients to be marked with a star. Typing `ktau, star(.05)` would “star” all correlation coefficients significant at the 5% level or lower.

`bonferroni` makes the Bonferroni adjustment to calculated significance levels. This adjustment affects printed significance levels and the `print()` and `star()` options. Thus, `ktau, print(.05) bonferroni` prints coefficients with Bonferroni-adjusted significance levels of 0.05 or less.

`sidak` makes the Šidák adjustment to calculated significance levels. This adjustment affects printed significance levels and the `print()` and `star()` options. Thus, `ktau, print(.05) sidak` prints coefficients with Šidák-adjusted significance levels of 0.05 or less.

`pw` specifies that correlations be calculated using pairwise deletion of observations with missing values.

By default, `ktau` uses casewise deletion, where observations are ignored if any of the variables in *varlist* are missing.

`matrix` forces `ktau` to display the statistics as a matrix, even if *varlist* contains only two variables.

`matrix` is implied if more than two variables are specified.

## Remarks and examples

[stata.com](https://www.stata.com)

### ▷ Example 1

We wish to calculate the correlation coefficients among marriage rate (`mrgrate`), divorce rate (`divorce_rate`), and median age (`medage`) in state data. We can calculate the standard Pearson correlation coefficients and significance by typing

```
. use https://www.stata-press.com/data/r17/states2
(State data)
```

```
. pwcorr mrgrate divorce_rate medage, sig
```

	mrgrate	divorc~e	medage
mrgrate	1.0000		
divorce_rate	0.7895 0.0000	1.0000	
medage	0.0011 0.9941	-0.1526 0.2900	1.0000

We can calculate Spearman's rank correlation coefficients by typing

```
. spearman mrgrate divorce_rate medage, stats(rho p)
(obs=50)
```

Key
<i>rho</i>
<i>Sig. level</i>

	mrgrate	divorc~e	medage
mrgrate	1.0000		
divorce_rate	0.6933 0.0000	1.0000	
medage	-0.4869 0.0003	-0.2455 0.0857	1.0000

The large difference in the results is caused by one observation. Nevada's marriage rate is almost 10 times higher than the state with the next-highest marriage rate. An important feature of the Spearman rank correlation coefficient is its reduced sensitivity to extreme values compared with the Pearson correlation coefficient.

We can calculate Kendall's rank correlations by typing

```
. ktau mrgrate divorce_rate medage, stats(taua taub p)
(obs=50)
```

Key
tau_a
tau_b
Sig. level

	mrgrate	divorce_rate	medage
mrgrate	0.9829 1.0000		
divorce_rate	0.5110 0.5206 0.0000	0.9804 1.0000	
medage	-0.3486 -0.3544 0.0004	-0.1698 -0.1728 0.0828	0.9845 1.0000

There are tied values for variables `mrgrate`, `divorce_rate`, and `medage`, so tied ranks are used. As a result,  $\tau_a < 1$  on the diagonal (see *Methods and formulas* for the definition of  $\tau_a$ ).

◀

### □ Technical note

According to [Conover \(1999, 323\)](#), “Spearman's  $\rho$  tends to be larger than Kendall's  $\tau$  in absolute value. However, as a test of significance, there is no strong reason to prefer one over the other because both will produce nearly identical results in most cases.”

□

### ▷ Example 2

We illustrate `spearman` and `ktau` with the auto data, which contains some missing values.

```
. use https://www.stata-press.com/data/r17/auto
(1978 automobile data)
. spearman mpg rep78

Number of obs =      69
Spearman's rho =    0.3098

Test of H0: mpg and rep78 are independent
Prob > |t| =    0.0096
```

## 6 spearman — Spearman's and Kendall's correlations

Because we specified two variables, `spearman` displayed the sample size, correlation, and  $p$ -value in tabular form. To obtain just the correlation coefficient displayed in matrix form, we type

```
. spearman mpg rep78, stats(rho) matrix  
(obs=69)
```

	mpg	rep78
mpg	1.0000	
rep78	0.3098	1.0000

We can specify the `pw` option with `spearman` and `ktau` so that all nonmissing observations between a pair of variables when calculating their correlation coefficient are used. In the output below, some correlations are based on 74 observations, whereas others are based on 69 because 5 observations contain a missing value for `rep78`.

```
. spearman mpg price rep78, pw stats(rho obs p) star(0.01)
```

Key
<i>rho</i>
<i>Number of obs</i>
<i>Sig. level</i>

	mpg	price	rep78
mpg	1.0000 74		
price	-0.5419* 74	1.0000 74	
rep78	0.3098* 69	0.1028 69	1.0000 69
	0.0096	0.4008	

Finally, the `bonferroni` and `sidak` options provide adjusted significance levels:

```
. ktau mpg price rep78, stats(taua taub score se p) bonferroni
(obs=69)
```

Key
<code>tau_a</code>
<code>tau_b</code>
<code>score</code>
<code>se of score</code>
<code>Sig. level</code>

	mpg	price	rep78
mpg	0.9471 1.0000 2222.0000 191.8600		
price	-0.3973 -0.4082 -932.0000 192.4561 0.0000	1.0000 1.0000 2346.0000 193.0682	
rep78	0.2076 0.2525 487.0000 181.7024 0.0224	0.0648 0.0767 152.0000 182.2233 1.0000	0.7136 1.0000 1674.0000 172.2161

◀

Charles Edward Spearman (1863–1945) was a British psychologist who made contributions to correlation, factor analysis, test reliability, and psychometrics. After several years' military service, he obtained a PhD in experimental psychology at Leipzig and became a professor at University College London, where he sustained a long program of work on the interpretation of intelligence tests. Ironically, the rank correlation version bearing his name is not the formula he advocated.

Maurice George Kendall (1907–1983) was a British statistician who contributed to rank correlation, time series, multivariate analysis, among other topics, and wrote many statistical texts. Most notably, perhaps, his advanced survey of the theory of statistics went through several editions, later ones with Alan Stuart; the baton has since passed to others. Kendall was employed in turn as a government and business statistician, as a professor at the London School of Economics, as a consultant, and as director of the World Fertility Survey. He was knighted in 1974.

## Stored results

`spearman` stores the following in `r()`:

### Scalars

<code>r(N)</code>	number of observations (last variable pair)
<code>r(rho)</code>	$\rho$ (last variable pair)
<code>r(p)</code>	two-sided $p$ -value (last variable pair)

### Matrices

<code>r(Nobs)</code>	number of observations
<code>r(Rho)</code>	$\rho$
<code>r(P)</code>	two-sided $p$ -value

`ktau` stores the following in `r()`:

### Scalars

<code>r(N)</code>	number of observations (last variable pair)
<code>r(tau_a)</code>	$\tau_a$ (last variable pair)
<code>r(tau_b)</code>	$\tau_b$ (last variable pair)
<code>r(score)</code>	Kendall's score (last variable pair)
<code>r(se_score)</code>	standard error of score (last variable pair)
<code>r(p)</code>	two-sided $p$ -value (last variable pair)

### Matrices

<code>r(Nobs)</code>	number of observations
<code>r(Tau_a)</code>	$\tau_a$
<code>r(Tau_b)</code>	$\tau_b$
<code>r(Score)</code>	Kendall's score
<code>r(Se_Score)</code>	standard error of score
<code>r(P)</code>	two-sided $p$ -value

## Methods and formulas

Spearman's (1904) rank correlation is calculated as Pearson's correlation computed on the ranks and average ranks (Conover 1999, 314–315). Ranks are as calculated by `egen`; see [D] `egen`. The significance is calculated using the approximation

$$p = 2 \times \text{ttail}(n - 2, |\hat{\rho}| \sqrt{n - 2} / \sqrt{1 - \hat{\rho}^2})$$

For any two pairs of ranks  $(x_i, y_i)$  and  $(x_j, y_j)$  of one variable pair ( $\text{varname}_1, \text{varname}_2$ ),  $1 \leq i, j \leq n$ , where  $n$  is the number of observations, define them as concordant if

$$(x_i - x_j)(y_i - y_j) > 0$$

and discordant if this product is less than zero.

Kendall's (1938; also see Kendall and Gibbons [1990] or Bland [2015], 187–188) score  $S$  is defined as  $C - D$ , where  $C$  ( $D$ ) is the number of concordant (discordant) pairs. Let  $N = n(n - 1)/2$  be the total number of pairs, so  $\tau_a$  is given by

$$\tau_a = S/N$$

and  $\tau_b$  is given by

$$\tau_b = \frac{S}{\sqrt{N - U} \sqrt{N - V}}$$



where

$$U = \sum_{i=1}^{N_1} u_i(u_i - 1)/2$$

$$V = \sum_{j=1}^{N_2} v_j(v_j - 1)/2$$

and where  $N_1$  is the number of sets of tied  $x$  values,  $u_i$  is the number of tied  $x$  values in the  $i$ th set,  $N_2$  is the number of sets of tied  $y$  values, and  $v_j$  is the number of tied  $y$  values in the  $j$ th set. Under the null hypothesis of independence between  $varname_1$  and  $varname_2$ , the variance of  $S$  is exactly (Kendall and Gibbons 1990, 66)

$$\begin{aligned} \text{Var}(S) = & \frac{1}{18} \left\{ n(n-1)(2n+5) - \sum_{i=1}^{N_1} u_i(u_i-1)(2u_i+5) - \sum_{j=1}^{N_2} v_j(v_j-1)(2v_j+5) \right\} \\ & + \frac{1}{9n(n-1)(n-2)} \left\{ \sum_{i=1}^{N_1} u_i(u_i-1)(u_i-2) \right\} \left\{ \sum_{j=1}^{N_2} v_j(v_j-1)(v_j-2) \right\} \\ & + \frac{1}{2n(n-1)} \left\{ \sum_{i=1}^{N_1} u_i(u_i-1) \right\} \left\{ \sum_{j=1}^{N_2} v_j(v_j-1) \right\} \end{aligned}$$

Using a normal approximation with a continuity correction,

$$z = \frac{|S| - 1}{\sqrt{\text{Var}(S)}}$$

For the hypothesis of independence, the statistics  $S$ ,  $\tau_a$ , and  $\tau_b$  produce equivalent tests and give the same significance.

For Kendall's  $\tau$ , the normal approximation is surprisingly accurate for sample sizes as small as 8, at least for calculating  $p$ -values under the null hypothesis for continuous variables. (See Kendall and Gibbons [1990, chap. 4], who also present some tables for calculating exact  $p$ -values for  $n < 10$ .) For Spearman's  $\rho$ , the normal approximation requires larger samples to be valid.

Let  $v$  be the number of variables specified so that  $k = v(v-1)/2$  correlation coefficients are to be estimated. If `bonferroni` is specified, the adjusted significance level is  $p' = \min(1, kp)$ . If `sidak` is specified,  $p' = \min\{1, 1 - (1-p)^n\}$ . See *Methods and formulas* in [R] `oneway` for a more complete description of the logic behind these adjustments.

Early work on rank correlation is surveyed by Kruskal (1958).

## Acknowledgment

The original version of `ktau` was written by Sean Beckett, a past editor of the *Stata Technical Bulletin* and author of the Stata Press book *Introduction to Time Series Using Stata, Revised Edition*.

## References

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## Also see

- [R] **correlate** — Correlations of variables
- [R] **nptrend** — Tests for trend across ordered groups