

**roccomp** — Tests of equality of ROC areas

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## Description

`roccomp` and `rocgold` are used to perform receiver operating characteristic (ROC) analyses with rating and discrete classification data.

The two variables *refvar* and *classvar* must be numeric. The reference variable indicates the true state of the observation, such as diseased and nondiseased or normal and abnormal, and must be coded as 0 and 1. The rating or outcome of the diagnostic test or test modality is recorded in *classvar*, which must be at least ordinal, with higher values indicating higher risk.

`roccomp` tests the equality of two or more ROC areas obtained from applying two or more test modalities to the same sample or to independent samples. `roccomp` expects the data to be in wide form when comparing areas estimated from the same sample and in long form for areas estimated from independent samples.

`rocgold` independently tests the equality of the ROC area of each of several test modalities, specified by *classvar*, against a “gold standard” ROC curve, *goldvar*. For each comparison, `rocgold` reports the raw and the Bonferroni-adjusted *p*-value. Optionally, Šidák’s adjustment for multiple comparisons can be obtained.

See [\[R\] rocfit](#) and [\[R\] rocreg](#) for commands that fit maximum-likelihood ROC models.

## Quick start

Equality of AUCs for rating *v1* of true state `true` between samples defined by *catvar*

```
roccomp true v1, by(catvar)
```

Equality of AUCs for ratings *v1* and *v2* for the same sample

```
roccomp true v1 v2
```

As above, but plot ROC curves without reporting summary statistics and test of equality

```
roccomp true v1 v2, graph
```

As above, but plot *v1* with a dashed line and *v2* with a solid line

```
roccomp true v1 v2, graph plot1opts(lpattern(dash)) ///
plot2opts(lpattern(solid))
```

Use contrast matrix *mymat* to compare ROC areas for *v1*, *v2*, *v3*, and *v4*

```
matrix mymat = (1,0,-1,0 \ 0,1,0,-1)
roccomp true v1 v2 v3 v4, test(mymat)
```

Test equality of ROC area for *v1* against a “gold standard” *gold*

```
rocgold true gold v1
```

## Menu

### **roccomp**

Statistics > Epidemiology and related > ROC analysis > Test equality of two or more ROC areas

### **rocgold**

Statistics > Epidemiology and related > ROC analysis > Test equality of ROC area against gold standard

## Syntax

*Test equality of ROC areas*

```
roccomp refvar classvar [classvars] [if] [in] [weight] [, roccomp_options]
```

*Test equality of ROC area against a standard ROC curve*

```
rocgold refvar goldvar classvar [classvars] [if] [in] [weight] [, rocgold_options]
```

*roccomp\_options*

Description

Main

<code>by(<i>varname</i>)</code>	split into groups by variable
<code>test(<i>matname</i>)</code>	use contrast matrix for comparing ROC areas
<code>graph</code>	graph the ROC curve
<code>noreflines</code>	suppress plotting the 45-degree reference line
<code>separate</code>	place each ROC curve on its own graph
<code>summary</code>	report the area under the ROC curve
<code>binormal</code>	estimate areas by using binormal distribution assumption
<code>line#opts(<i>cline_options</i>)</code>	affect rendition of the #th binormal fit line
<code>level(#)</code>	set confidence level; default is level(95)

Plot

`plot#opts(plot_options)` affect rendition of the #th ROC curve

Reference line

`rlopts(cline_options)` affect rendition of the reference line

Y axis, X axis, Titles, Legend, Overall

`twoway_options` any options other than `by()` documented in [G-3] *twoway\_options*

<i>rocgold_options</i>	Description
Main	
<u>sidak</u>	adjust the $p$ -value by using Šidák's method
<u>test(matname)</u>	use contrast matrix for comparing ROC areas
<u>graph</u>	graph the ROC curve
<u>noreflne</u>	suppress plotting the 45-degree reference line
<u>separate</u>	place each ROC curve on its own graph
<u>summary</u>	report the area under the ROC curve
<u>binormal</u>	estimate areas by using binormal distribution assumption
<u>line#opts(cline_options)</u>	affect rendition of the #th binormal fit line
<u>level(#)</u>	set confidence level; default is level(95)
Plot	
<u>plot#opts(plot_options)</u>	affect rendition of the #th ROC curve; plot 1 is the “gold standard”
Reference line	
<u>rlopts(cline_options)</u>	affect rendition of the reference line
Y axis, X axis, Titles, Legend, Overall	
<u>twoway_options</u>	any options other than by() documented in [G-3] <i>twoway_options</i>

<i>plot_options</i>	Description
<i>marker_options</i>	change look of markers (color, size, etc.)
<i>marker_label_options</i>	add marker labels; change look or position
<i>cline_options</i>	change the look of the line

*fweights* are allowed; see [U] 11.1.6 *weight*.

## Options

### Main

by(*varname*) (roccomp only) is required when comparing independent ROC areas. The by() variable identifies the groups to be compared.

sidak (rocgold only) requests that the  $p$ -value be adjusted for the effect of multiple comparisons by using Šidák's method. Bonferroni's adjustment is reported by default.

test(*matname*) specifies the contrast matrix to be used when comparing ROC areas. By default, the null hypothesis that all areas are equal is tested.

graph produces graphical output of the ROC curve.

noreflne suppresses plotting the 45-degree reference line from the graphical output of the ROC curve.

separate is meaningful only with roccomp and specifies that each ROC curve be placed on its own graph rather than one curve on top of the other.

summary reports the area under the ROC curve, its standard error, and its confidence interval. This option is needed only when also specifying graph.

`binormal` specifies that the areas under the ROC curves to be compared should be estimated using the binormal distribution assumption. By default, areas to be compared are computed using the trapezoidal rule.

`line#opts(cline_options)` affect the rendition of the line representing the #th ROC curve drawn using the binormal distribution assumption; see [G-3] *cline\_options*. These lines are drawn only if the `binormal` option is specified.

`level(#)` specifies the confidence level, as a percentage, for the confidence intervals. The default is `level(95)` or as set by `set level`; see [R] *level*.

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#### Plot

`plot#opts(plot_options)` affect the rendition of the #th ROC curve—the curve’s plotted points connected by lines. The *plot\_options* can affect the size and color of markers, whether and how the markers are labeled, and whether and how the points are connected; see [G-3] *marker\_options*, [G-3] *marker\_label\_options*, and [G-3] *cline\_options*.

For `rocgold`, `plot1opts()` are applied to the ROC for the gold standard.

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#### Reference line

`r1opts(cline_options)` affects the rendition of the reference line; see [G-3] *cline\_options*.

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#### Y axis, X axis, Titles, Legend, Overall

*twoway\_options* are any of the options documented in [G-3] *twoway\_options*. These include options for titling the graph (see [G-3] *title\_options*), options for saving the graph to disk (see [G-3] *saving\_option*), and the `by()` option (see [G-3] *by\_option*).

## Remarks and examples

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

Remarks are presented under the following headings:

- [Introduction](#)
- [Comparing areas under the ROC curve](#)
- [Correlated data](#)
- [Independent data](#)
- [Comparing areas with a gold standard](#)

## Introduction

`roccomp` provides comparison of the ROC curves of multiple classifiers. `rocgold` compares the ROC curves of multiple classifiers with a single “gold standard” classifier. Adjustment of inference for multiple comparisons is also provided by `rocgold`.

See [Pepe \(2003\)](#) for a discussion of ROC analysis. Pepe has posted Stata datasets and programs used to reproduce results presented in the book (<http://www.stata.com/bookstore/pepe.html>).

## Comparing areas under the ROC curve

The area under multiple ROC curves can be compared by using `roccomp`. The command syntax is slightly different if the ROC curves are correlated (that is, different diagnostic tests are applied to the same sample) or independent (that is, diagnostic tests are applied to different samples).

### Correlated data

#### ► Example 1

Hanley and McNeil (1983) presented data from an evaluation of two computer algorithms designed to reconstruct CT images from phantoms. We will call these two algorithms' modalities 1 and 2. A sample of 112 phantoms was selected; 58 phantoms were considered normal, and the remaining 54 were abnormal. Each of the two modalities was applied to each phantom, and the resulting images were rated by a reviewer using a six-point scale: 1 = definitely normal, 2 = probably normal, 3 = possibly normal, 4 = possibly abnormal, 5 = probably abnormal, and 6 = definitely abnormal. Because each modality was applied to the same sample of phantoms, the two sets of outcomes are correlated.

We list the first 7 observations:

```
. use http://www.stata-press.com/data/r15/ct
. list in 1/7, sep(0)
```

	mod1	mod2	status
1.	2	1	0
2.	5	5	1
3.	2	1	0
4.	2	3	0
5.	5	6	1
6.	2	2	0
7.	3	2	0

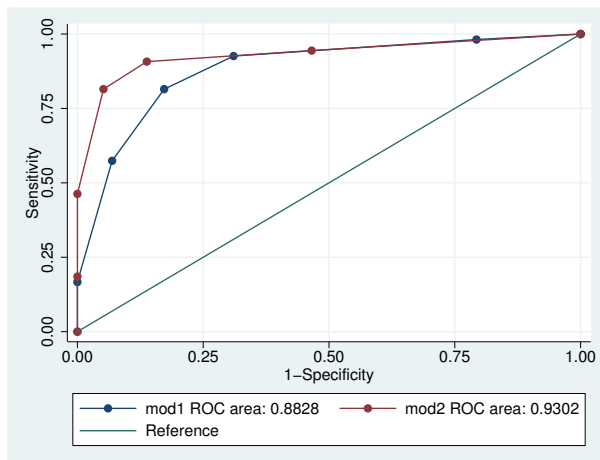
The data are in wide form, which is required when dealing with correlated data. Each observation corresponds to one phantom. The variable `mod1` identifies the rating assigned for the first modality, and `mod2` identifies the rating assigned for the second modality. The true status of the phantoms is given by `status=0` if they are normal and `status=1` if they are abnormal. The observations with at least one missing rating were dropped from the analysis.

We plot the two ROC curves and compare their areas.

```
. roccomp status mod1 mod2, graph summary
```

	Obs	ROC Area	Std. Err.	-Asymptotic Normal— [95% Conf. Interval]	
mod1	112	0.8828	0.0317	0.82067	0.94498
mod2	112	0.9302	0.0256	0.88005	0.98042

```
Ho: area(mod1) = area(mod2)
chi2(1) = 2.31 Prob>chi2 = 0.1282
```



By default, `roccomp`, with the `graph` option specified, plots the ROC curves on the same graph. Optionally the curves can be plotted side by side, each on its own graph, by also specifying `separate`.

For each curve, `roccomp` reports summary statistics and provides a test for the equality of the area under the curves, using an algorithm suggested by [DeLong, DeLong, and Clarke-Pearson \(1988\)](#).

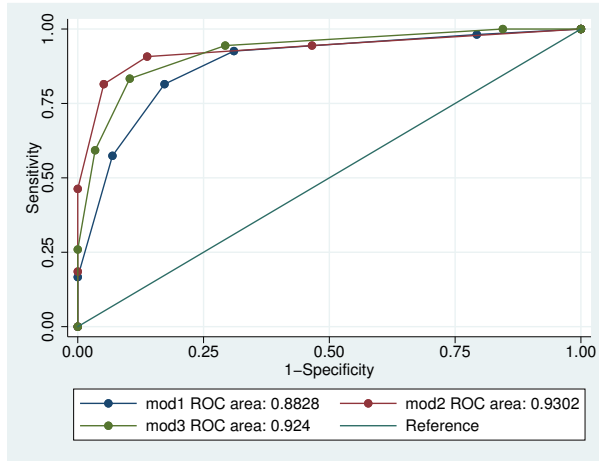
Although the area under the ROC curve for modality 2 is larger than that of modality 1, the chi-squared test yielded a  $p$ -value of 0.1282, suggesting that there is no significant difference between these two areas.

The `roccomp` command can also be used to compare more than two ROC areas. To illustrate this, we modified the previous dataset by including a fictitious third modality.

```
. use http://www.stata-press.com/data/r15/ct2
. roccomp status mod1 mod2 mod3, graph summary
```

	Obs	ROC Area	Std. Err.	—Asymptotic Normal— [95% Conf. Interval]	
mod1	112	0.8828	0.0317	0.82067	0.94498
mod2	112	0.9302	0.0256	0.88005	0.98042
mod3	112	0.9240	0.0241	0.87670	0.97132

```
Ho: area(mod1) = area(mod2) = area(mod3)
chi2(2) = 6.54 Prob>chi2 = 0.0381
```



By default, `roccomp` tests whether the areas under the ROC curves are all equal. Other comparisons can be tested by creating a contrast matrix and specifying `test(matname)`, where `matname` is the name of the contrast matrix.

For example, assume that we are interested in testing whether the area under the ROC for `mod1` is equal to that of `mod3`. To do this, we can first create an appropriate contrast matrix and then specify its name with the `test()` option.

Of course, this is a trivial example because we could have just specified

```
. roccomp status mod1 mod3
```

without including `mod2` to obtain the same test results. However, for illustration, we will continue with this example.

The contrast matrix must have its number of columns equal to the number of `classvars` (that is, the total number of ROC curves) and a number of rows less than or equal to the number of `classvars`, and the elements of each row must add to zero.

```
. matrix C=(1,0,-1)
. roccomp status mod1 mod2 mod3, test(C)
```

	Obs	ROC Area	Std. Err.	—Asymptotic Normal— [95% Conf. Interval]	
mod1	112	0.8828	0.0317	0.82067	0.94498
mod2	112	0.9302	0.0256	0.88005	0.98042
mod3	112	0.9240	0.0241	0.87670	0.97132

```
Ho: Comparison as defined by contrast matrix: C
chi2(1) = 5.25 Prob>chi2 = 0.0220
```

Although all three areas are reported, the comparison is made using the specified contrast matrix.

Perhaps more interesting would be a comparison of the area from `mod1` and the average area of `mod2` and `mod3`.

```
. matrix C=(1,-.5,-.5)
. roccomp status mod1 mod2 mod3, test(C)
```

	Obs	ROC Area	Std. Err.	—Asymptotic Normal— [95% Conf. Interval]	
mod1	112	0.8828	0.0317	0.82067	0.94498
mod2	112	0.9302	0.0256	0.88005	0.98042
mod3	112	0.9240	0.0241	0.87670	0.97132

```
Ho: Comparison as defined by contrast matrix: C
chi2(1) = 3.43 Prob>chi2 = 0.0642
```

Other contrasts could be made. For example, we could test if mod3 is different from at least one of the other two by first creating the following contrast matrix:

```
. matrix C=(-1,0,1 \ 0,-1,1)
. mat list C
C[2,3]
   c1  c2  c3
r1 -1  0  1
r2  0 -1  1
```

◀

## Independent data

### ▷ Example 2

In [example 1](#), we noted that because each test modality was applied to the same sample of phantoms, the classification outcomes were correlated. Now assume that we have collected the same data presented by [Hanley and McNeil \(1983\)](#), except that we applied the first test modality to one sample of phantoms and the second test modality to a different sample of phantoms. The resulting measurements are now considered independent.

Here are a few of the observations.

```
. use http://www.stata-press.com/data/r15/ct3
. list in 1/7, sep(0)
```

	pop	status	rating	mod
1.	12	0	1	1
2.	31	0	1	2
3.	1	1	1	1
4.	3	1	1	2
5.	28	0	2	1
6.	19	0	2	2
7.	3	1	2	1

The data are in long form, which is required when dealing with independent data. The data consist of 24 observations: 6 observations corresponding to abnormal phantoms and 6 to normal phantoms evaluated using the first modality, and similarly 6 observations corresponding to abnormal phantoms and 6 to normal phantoms evaluated using the second modality. The number of phantoms corresponding to each observation is given by the `pop` variable. Once again we have frequency-weighted data. The variable `mod` identifies the modality, and `rating` is the assigned classification.



We can better view our data by using the table command.

```
. table status rating [fw=pop], by(mod) row col
```

mod and status	rating						Total
	1	2	3	4	5	6	
1	0	12	28	8	6	4	58
	1	1	3	6	13	22	54
	Total	13	31	14	19	26	9
2	0	31	19	5	3		58
	1	3	2	5	19	15	54
	Total	34	21	10	22	15	10

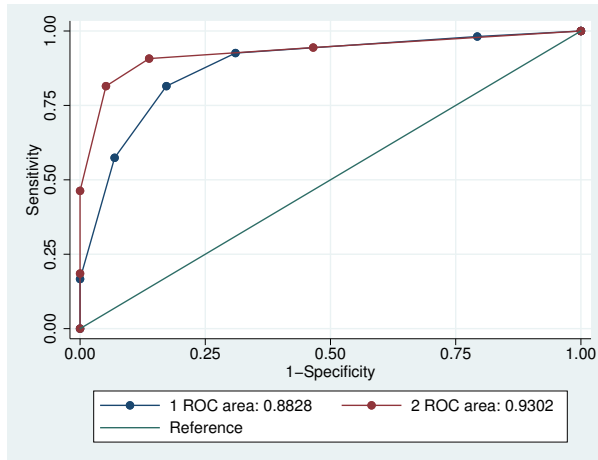
The status variable indicates the true status of the phantoms: status = 0 if they are normal and status = 1 if they are abnormal.

We now compare the areas under the two ROC curves.

```
. roccomp status rating [fw=pop], by(mod) graph summary
```

mod	Obs	ROC Area	Std. Err.	-Asymptotic Normal- [95% Conf. Interval]	
1	112	0.8828	0.0317	0.82067	0.94498
2	112	0.9302	0.0256	0.88005	0.98042

```
Ho: area(1) = area(2)
chi2(1) = 1.35 Prob>chi2 = 0.2447
```



## Comparing areas with a gold standard

The area under multiple ROC curves can be compared with a gold standard using `rocgold`. The command syntax is similar to that of `roccomp`. The tests are corrected for the effect of multiple comparisons.

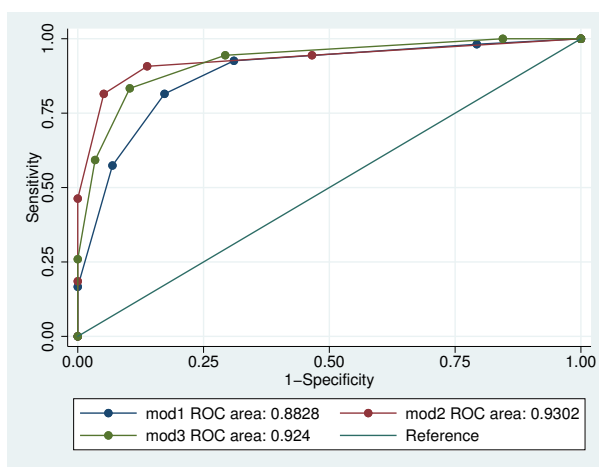
### ▷ Example 3

We will use the same data (presented by [Hanley and McNeil \[1983\]](#)) as in the `roccomp` examples. Let's assume that the first modality is considered to be the standard against which both the second and third modalities are compared.

We want to plot and compare both the areas of the ROC curves of `mod2` and `mod3` with `mod1`. Because we consider `mod1` to be the gold standard, it is listed first after the reference variable in the `rocgold` command line.

```
. use http://www.stata-press.com/data/r15/ct2
. rocgold status mod1 mod2 mod3, graph summary
```

	ROC Area	Std. Err.	chi2	df	Pr>chi2	Bonferroni Pr>chi2
mod1 (standard)	0.8828	0.0317				
mod2	0.9302	0.0256	2.3146	1	0.1282	0.2563
mod3	0.9240	0.0241	5.2480	1	0.0220	0.0439



Equivalently, we could have done this in two steps by using the `roccomp` command.

```
. roccomp status mod1 mod2, graph summary
. roccomp status mod1 mod3, graph summary
```

## Stored results

roccomp stores the following in  $r()$ :

Scalars

$r(N\_g)$	number of groups	$r(df)$	$\chi^2$ degrees of freedom
$r(p)$	$p$ -value for $\chi^2$ test	$r(chi2)$	$\chi^2$

Matrices

$r(V)$	variance–covariance matrix
--------	----------------------------

rocgold stores the following in  $r()$ :

Scalars

$r(N\_g)$	number of groups
-----------	------------------

Matrices

$r(V)$	variance–covariance matrix	$r(p)$	vector of $p$ -values for $\chi^2$ tests
$r(chi2)$	$\chi^2$ vector	$r(p\_adj)$	vector of adjusted $p$ -values
$r(df)$	$\chi^2$ degrees-of-freedom vector		

## Methods and formulas

Assume that we applied a diagnostic test to each of  $N_n$  normal and  $N_a$  abnormal subjects. Further assume that the higher the outcome value of the diagnostic test, the higher the risk of the subject being abnormal. Let  $\hat{\theta}$  be the estimated area under the curve, and let  $X_i, i = 1, 2, \dots, N_a$  and  $Y_j, j = 1, 2, \dots, N_n$  be the values of the diagnostic test for the abnormal and normal subjects, respectively.

Areas under ROC curves are compared using an algorithm suggested by DeLong, DeLong, and Clarke-Pearson (1988). Let  $\hat{\theta} = (\hat{\theta}^1, \hat{\theta}^2, \dots, \hat{\theta}^k)$  be a vector representing the areas under  $k$  ROC curves. See *Methods and formulas* in [R] **roctab** for the definition of these area estimates.

For the  $r$ th area, define

$$V_{10}^r(X_i) = \frac{1}{N_n} \sum_{j=1}^{N_n} \psi(X_i^r, Y_j^r)$$

and for each normal subject,  $j$ , define

$$V_{01}^r(Y_j) = \frac{1}{N_a} \sum_{i=1}^{N_a} \psi(X_i^r, Y_j^r)$$

where

$$\psi(X^r, Y^r) = \begin{cases} 1 & Y^r < X^r \\ \frac{1}{2} & Y^r = X^r \\ 0 & Y^r > X^r \end{cases}$$

Define the  $k \times k$  matrix  $S_{10}$  such that the  $(r, s)$ th element is

$$S_{10}^{r,s} = \frac{1}{N_a - 1} \sum_{i=1}^{N_a} \{V_{10}^r(X_i) - \hat{\theta}^r\} \{V_{10}^s(X_i) - \hat{\theta}^s\}$$

and  $S_{01}$  such that the  $(r, s)$ th element is

$$S_{01}^{r,s} = \frac{1}{N_n - 1} \sum_{j=1}^{N_n} \{V_{01}^r(Y_j) - \hat{\theta}^r\} \{V_{01}^s(Y_j) - \hat{\theta}^s\}$$

Then the covariance matrix is

$$S = \frac{1}{N_a} S_{10} + \frac{1}{N_n} S_{01}$$

Let  $\mathbf{L}$  be a contrast matrix defining the comparison, so that

$$(\hat{\theta} - \theta)' \mathbf{L}' (\mathbf{L} \mathbf{S} \mathbf{L}')^{-1} \mathbf{L} (\hat{\theta} - \theta)$$

has a chi-squared distribution with degrees of freedom equal to the rank of  $\mathbf{L} \mathbf{S} \mathbf{L}'$ .

## References

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## Also see

- [R] **logistic postestimation** — Postestimation tools for logistic
- [R] **roc** — Receiver operating characteristic (ROC) analysis
- [R] **rocf** — Parametric ROC models
- [R] **roclog** — Receiver operating characteristic (ROC) regression
- [R] **roctab** — Nonparametric ROC analysis