

**stcox PH-assumption tests** — Tests of proportional-hazards assumption
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## Description

`stphplot` plots  $-\ln\{-\ln(\text{survival})\}$  curves for each category of a nominal or ordinal covariate versus  $\ln(\text{analysis time})$ . These are often referred to as “log-log” plots. Optionally, these estimates can be adjusted for covariates. The proportional-hazards assumption is not violated when the curves are parallel.

`stcoxkm` plots Kaplan–Meier observed survival curves and compares them with the Cox predicted curves for the same variable. The closer the observed values are to the predicted, the less likely it is that the proportional-hazards assumption has been violated. Do not run `stcox` before running this command; `stcoxkm` will execute `stcox` itself to fit the model and obtain predicted values.

`estat phtest` tests the proportional-hazards assumption on the basis of Schoenfeld residuals after fitting a model with `stcox`.

## Quick start

*Log-log plot of survival*

Check for parallel lines in plot of  $-\ln\{-\ln(\text{survival})\}$  versus  $\ln(\text{analysis time})$  for each category of covariate `a` using `stset` data

```
stphplot, by(a)
```

As above, but adjust for average values of covariates `x1` and `x2`

```
stphplot, by(a) adjust(x1 x2)
```

Adjust for `x1 = 0` and `x2 = 0`

```
stphplot, by(a) adjust(x1 x2) zero
```

*Kaplan–Meier and predicted survival plot*

Compare Kaplan–Meier survival curve with predicted survival from Cox model for each category of covariate `a` using `stset` data

```
stcoxkm, by(a)
```

As above, but create separate plots for each level of `a`

```
stcoxklm, by(a) separate
```

*Test using Schoenfeld residuals*

Test the proportional-hazards assumption after `stcox x1 x2 x3`

```
estat phtest
```

As above, and report separate test for each covariate

```
estat phtest, detail
```

## Menu

### stphplot

Statistics > Survival analysis > Regression models > Graphically assess proportional-hazards assumption

### stcoxkm

Statistics > Survival analysis > Regression models > Kaplan-Meier versus predicted survival

### estat phtest

Statistics > Survival analysis > Regression models > Test proportional-hazards assumption

## Syntax

Check proportional-hazards assumption:

*Log-log plot of survival*

```
stphplot [if] , {by(varname) | strata(varname)} [stphplot_options]
```

*Kaplan-Meier and predicted survival plot*

```
stcoxkm [if] , by(varname) [stcoxkm_options]
```

*Using Schoenfeld residuals*

```
estat phtest [ , phtest_options]
```

*stphplot\_options*

Description

Main

* <b>by</b> (varname)	fit separate Cox models; the default
* <b>strata</b> (varname)	fit stratified Cox model
<b>adjust</b> (varlist)	adjust to average values of varlist
<b>zero</b>	adjust to zero values of varlist; use with adjust()

Options

<b>nonegative</b>	plot $\ln\{-\ln(\text{survival})\}$
<b>novertime</b>	plot curves against analysis time
<b>noshow</b>	do not show st setting information

Plot

**plot#opts**(*stphplot\_plot\_options*) affect rendition of the #th connected line and #th plotted points

Add plots

**addplot**(plot) add other plots to the generated graph

Y axis, X axis, Titles, Legend, Overall

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

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\*Either by(varname) or strata(varname) is required with stphplot.

<i>stphplot</i> _plot_options	Description
<i>cline_options</i>	change look of lines or connecting method
<i>marker_options</i>	change look of markers (color, size, etc.)

<i>stcoxkm_options</i>	Description
------------------------	-------------

Main

* <b>by</b> ( <i>varname</i> )	report the nominal or ordinal covariate
<b>ties</b> ( <b>breslow</b> )	use Breslow method to handle tied failures
<b>ties</b> ( <b>efron</b> )	use Efron method to handle tied failures
<b>ties</b> ( <b>exactm</b> )	use exact marginal-likelihood method to handle tied failures
<b>ties</b> ( <b>exactp</b> )	use exact partial-likelihood method to handle tied failures
<b>separate</b>	draw separate plot for predicted and observed curves
<b>noshow</b>	do not show st setting information

Observed plot

<b>obsopts</b> ( <i>stcoxkm_plot_options</i> )	affect rendition of the observed curve
<b>obs#opts</b> ( <i>stcoxkm_plot_options</i> )	affect rendition of the #th observed curve; not allowed with <b>separate</b>

Predicted plot

<b>predopts</b> ( <i>stcoxkm_plot_options</i> )	affect rendition of the predicted curve
<b>pred#opts</b> ( <i>stcoxkm_plot_options</i> )	affect rendition of the #th predicted curve; not allowed with <b>separate</b>

Add plots

<b>addplot</b> ( <i>plot</i> )	add other plots to the generated graph
--------------------------------	--

Y axis, X axis, Titles, Legend, Overall

<i>twoway_options</i>	any options other than <b>by</b> () documented in [G-3] <i>twoway_options</i>
<b>byopts</b> ( <i>byopts</i> )	how subgraphs are combined, labeled, etc.

\* **by**(*varname*) is required with *stcoxkm*.

<i>stcoxkm_plot_options</i>	Description
<i>connect_options</i>	change look of connecting method
<i>marker_options</i>	change look of markers (color, size, etc.)

You must **stset** your data before using **stphplot** and **stcoxkm**; see [ST] **stset**.

**fweights**, **iwweights**, and **pweights** may be specified using **stset**; see [ST] **stset**.

<i>phptest_options</i>	Description
Main	
<code>log</code>	use natural logarithm time-scaling function
<code>km</code>	use 1 – KM product-limit estimate as the time-scaling function
<code>rank</code>	use rank of analysis time as the time-scaling function
<code>time(<i>varname</i>)</code>	use <i>varname</i> containing a monotone transformation of analysis time as the time-scaling function
<code>plot(<i>varname</i>)</code>	plot smoothed, scaled Schoenfeld residuals versus time
<code>bwidth(#)</code>	use bandwidth of #; default is <code>bwidth(0.8)</code>
<code>detail</code>	test proportional-hazards assumption separately for each covariate
Scatterplot	
<code>marker_options</code>	change look of markers (color, size, etc.)
<code>marker_label_options</code>	add marker labels; change look or position
Smoothed line	
<code>lineopts(<i>cline_options</i>)</code>	affect rendition of the smoothed line
Y axis, X axis, Titles, Legend, Overall	
<code>twoway_options</code>	any options other than <code>by()</code> documented in [G-3] <code>twoway_options</code>

`estat phptest` is not appropriate after estimation with `svy`.

## Options

Options are presented under the following headings:

[Options for `stphplot`](#)  
[Options for `stcoxkm`](#)  
[Options for `estat phptest`](#)

### Options for `stphplot`

#### Main

`by(varname)` specifies the nominal or ordinal covariate. Either `by()` or `strata()` is required with `stphplot`.

`strata(varname)` is an alternative to `by()`. Rather than fitting separate Cox models for each value of *varname*, `strata()` fits one stratified Cox model. You must also specify `adjust(varlist)` with the `strata(varname)` option; see [ST] [sts graph](#).

`adjust(varlist)` adjusts the estimates to that for the average values of the *varlist* specified. The estimates can also be adjusted to zero values of *varlist* by specifying the `zero` option. `adjust(varlist)` can be specified with `by()`; it is required with `strata(varname)`.

`zero` is used with `adjust()` to specify that the estimates be adjusted to the 0 values of the *varlist* rather than to average values.

#### Options

`nonegative` specifies that  $\ln\{-\ln(\text{survival})\}$  be plotted instead of  $-\ln\{-\ln(\text{survival})\}$ .

`noIntime` specifies that curves be plotted against analysis time instead of against  $\ln(\text{analysis time})$ .

`noshow` prevents `stphplot` from showing the key `st` variables. This option is seldom used because most people type `stset`, `show` or `stset`, `noshow` to set whether they want to see these variables mentioned at the top of the output of every `st` command; see [ST] [stset](#).

## Plot

`plot#opts`(*stphplot\_plot\_options*) affects the rendition of the `#th` connected line and `#th` plotted points; see [G-3] [cline\\_options](#) and [G-3] [marker\\_options](#).

## Add plots

`addplot`(*plot*) provides a way to add other plots to the generated graph; see [G-3] [addplot\\_option](#).

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

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

Options for `stcoxkm`

## Main

`by`(*varname*) specifies the nominal or ordinal covariate. `by()` is required.

`ties`(`breslow`|`efron`|`exactm`|`exactp`) specifies one of the methods available to `stcox` for handling tied failures. If none is specified, `ties(breslow)` is assumed; see [ST] [stcox](#).

`separate` produces separate plots of predicted and observed values for each value of the variable specified with `by()`.

`noshow` prevents `stcoxkm` from showing the key `st` variables. This option is seldom used because most people type `stset`, `show` or `stset`, `noshow` to set whether they want to see these variables mentioned at the top of the output of every `st` command; see [ST] [stset](#).

## Observed plot

`obs#opts`(*stcoxkm\_plot\_options*) affects the rendition of the observed curve; see [G-3] [connect\\_options](#) and [G-3] [marker\\_options](#).

`obs#opts`(*stcoxkm\_plot\_options*) affects the rendition of the `#th` observed curve; see [G-3] [connect\\_options](#) and [G-3] [marker\\_options](#). This option is not allowed with `separate`.

## Predicted plot

`pred#opts`(*stcoxkm\_connect\_options*) affects the rendition of the predicted curve; see [G-3] [connect\\_options](#) and [G-3] [marker\\_options](#).

`pred#opts`(*stcoxkm\_connect\_options*) affects the rendition of the `#th` predicted curve; see [G-3] [connect\\_options](#) and [G-3] [marker\\_options](#). This option is not allowed with `separate`.

## Add plots

`addplot`(*plot*) provides a way to add other plots to the generated graph; see [G-3] [addplot\\_option](#).

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 Y axis, X axis, Titles, Legend, Overall
 

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

`byopts` (*byopts*) affects the appearance of the combined graph when `by()` and `separate` are specified, including the overall graph title and the organization of subgraphs. See [G-3] *by\_option*.

## Options for `estat phtest`

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 Main
 

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`log`, `km`, `rank`, and `time()` are used to specify the time scaling function.

By default, `estat phtest` performs the tests using the identity function, that is, analysis time itself.

`log` specifies that the natural log of analysis time be used.

`km` specifies that 1 minus the Kaplan–Meier product-limit estimate be used.

`rank` specifies that the rank of analysis time be used.

`time(varname)` specifies a variable containing an arbitrary monotonic transformation of analysis time. You must ensure that *varname* is a monotonic transform.

`plot(varname)` specifies that a scatterplot and smoothed plot of scaled Schoenfeld residuals versus time be produced for the covariate specified by *varname*. By default, the smoothing is performed using the running-mean method implemented in `lowess`, `mean noweight`; see [R] *lowess*.

`bwidth(#)` specifies the bandwidth. Centered subsets of `bwidth() × N` observations are used for calculating smoothed values for each point in the data except for endpoints, where smaller, uncentered subsets are used. The greater the `bwidth()`, the greater the smoothing. The default is `bwidth(0.8)`.

`detail` specifies that a separate test of the proportional-hazards assumption be produced for each covariate in the Cox model. By default, `estat phtest` produces only the global test.

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 Scatterplot
 

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*marker\_options* affect the rendition of markers drawn at the plotted points, including their shape, size, color, and outline; see [G-3] *marker\_options*.

*marker\_label\_options* specify if and how the markers are to be labeled; see [G-3] *marker\_label\_options*.

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 Smoothed line
 

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

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 Y axis, X axis, Titles, Legend, Overall
 

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

## Remarks and examples

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Cox proportional hazards models assume that the hazard ratio is constant over time. Suppose that a group of cancer patients on an experimental treatment is monitored for 10 years. If the hazard of dying for the nontreated group is twice the rate as that of the treated group ( $HR = 2.0$ ), the proportional-hazards assumption implies that this ratio is the same at 1 year, at 2 years, or at any point on the time scale. Because the Cox model, by definition, is constrained to follow this assumption, it is important to evaluate its validity. If the assumption fails, alternative modeling choices would be more appropriate (for example, a stratified Cox model, time-varying covariates). For examples of testing the proportional-hazards assumption using Stata, see [Allison \(2014\)](#).

`stphplot` and `stcoxkm` provide graphical methods for assessing violations of the proportional-hazards assumption. Although using graphs to assess the validity of the assumption is subjective, it can be a helpful tool.

`stphplot` plots  $-\ln\{-\ln(\text{survival})\}$  curves for each category of a nominal or ordinal covariate versus  $\ln(\text{analysis time})$ . These are often referred to as “log–log” plots. Optionally, these estimates can be adjusted for covariates. If the plotted lines are reasonably parallel, the proportional-hazards assumption has not been violated, and it would be appropriate to base the estimate for that variable on one baseline survivor function.

Another graphical method of evaluating the proportional-hazards assumption, though less common, is to plot the Kaplan–Meier observed survival curves and compare them with the Cox predicted curves for the same variable. This plot is produced with `stcoxkm`. When the predicted and observed curves are close together, the proportional-hazards assumption has not been violated. See [Garrett \(1997\)](#) for more details.

Many popular tests for proportional hazards are, in fact, tests of nonzero slope in a generalized linear regression of the scaled Schoenfeld residuals on time (see [Grambsch and Therneau \[1994\]](#)). The `estat phtest` command tests, for individual covariates and globally, the null hypothesis of zero slope, which is equivalent to testing that the log hazard-ratio function is constant over time. Thus rejection of the null hypothesis of a zero slope indicates deviation from the proportional-hazards assumption. The `estat phtest` command allows three common time-scaling options (`log`, `km`, and `rank`) and also allows you to specify a user-defined function of time through the `time()` option. When no option is specified, the tests are performed using analysis time without further transformation.

### ▷ Example 1

These examples use data from a leukemia remission study ([Garrett 1997](#)). The data consist of 42 patients who are monitored over time to see how long (`weeks`) it takes them to go out of remission (`relapse`: 1 = yes, 0 = no). Half the patients receive a new experimental drug, and the other half receive a standard drug (`treatment1`: 1 = drug A, 0 = standard). White blood cell count, a strong indicator of the presence of leukemia, is divided into three categories (`wbc3cat`: 1 = normal, 2 = moderate, 3 = high).

```

. use http://www.stata-press.com/data/r14/leukemia
(Leukemia Remission Study)
. describe
Contains data from http://www.stata-press.com/data/r14/leukemia.dta
  obs:                42                Leukemia Remission Study
  vars:                8                23 Mar 2014 10:39
  size:               336

```

---

variable name	storage type	display format	value label	variable label
weeks	byte	%8.0g		Weeks in Remission
relapse	byte	%8.0g	yesno	Relapse
treatment1	byte	%8.0g	trt11bl	Treatment I
treatment2	byte	%8.0g	trt21bl	Treatment II
wbc3cat	byte	%9.0g	wbc1bl	White Blood Cell Count
wbc1	byte	%8.0g		wbc3cat==Normal
wbc2	byte	%8.0g		wbc3cat==Moderate
wbc3	byte	%8.0g		wbc3cat==High

---

Sorted by: weeks

```

. stset weeks, failure(relapse)
      failure event:  relapse != 0 & relapse < .
obs. time interval:  (0, weeks]
exit on or before:  failure

```

---

```

      42 total observations
      0 exclusions

```

---

```

      42 observations remaining, representing
      30 failures in single-record/single-failure data
      541 total analysis time at risk and under observation
                at risk from t =                0
                earliest observed entry t =      0
                last observed exit t =           35

```

In this example, we examine whether the proportional-hazards assumption holds for drug A versus the standard drug (treatment1). First, we will use `stphplot`, followed by `stcoxkm`.



```
. sthplot, by(treatment1)
      failure _d: relapse
      analysis time _t: weeks
```

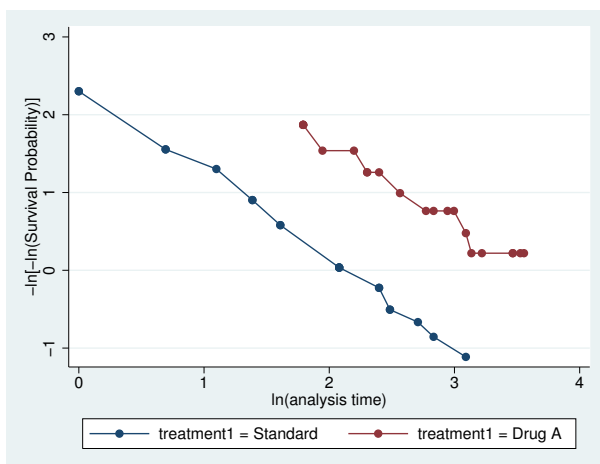


Figure 1.

```
. stcoxkm, by(treatment1) legend(cols(1))
      failure _d: relapse
      analysis time _t: weeks
```

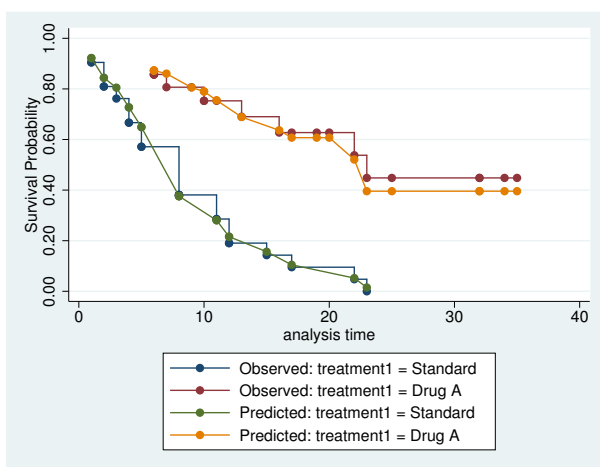


Figure 2.

Figure 1 (`sthplot`) displays lines that are parallel, implying that the proportional-hazards assumption for `treatment1` has not been violated. This is confirmed in figure 2 (`stcoxkm`), where the observed values and predicted values are close together.

The graph in figure 3 is the same as the one in figure 1, adjusted for white blood cell count (using two dummy variables). The adjustment variables were centered temporarily by `sthplot` before the adjustment was made.

```
. stphtplot, strata(treatment1) adj(wbc2 wbc3)
      failure_d: relapse
      analysis time _t: weeks
```

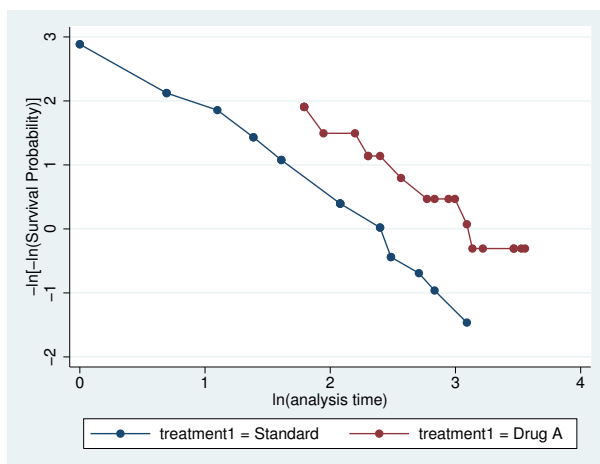


Figure 3.

The lines in figure 3 are still parallel, although they are somewhat closer together. Examining the proportional-hazards assumption on a variable without adjusting for covariates is usually adequate as a diagnostic tool before using the Cox model. However, if you know that adjustment for covariates in a final model is necessary, you may wish to reexamine whether the proportional-hazards assumption still holds.

Another variable in this dataset measures a different drug (`treatment2`: 1 = drug B, 0 = standard). We wish to examine the proportional-hazards assumption for this variable.

```
. stphtplot, by(treatment2)
      failure_d: relapse
      analysis time _t: weeks
```

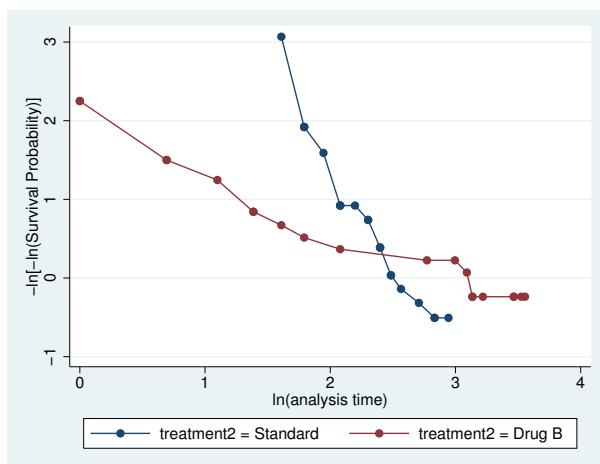


Figure 4.

```
. stcoxkm, by(treatment2) separate legend(cols(1))
      failure _d: relapse
      analysis time _t: weeks
```

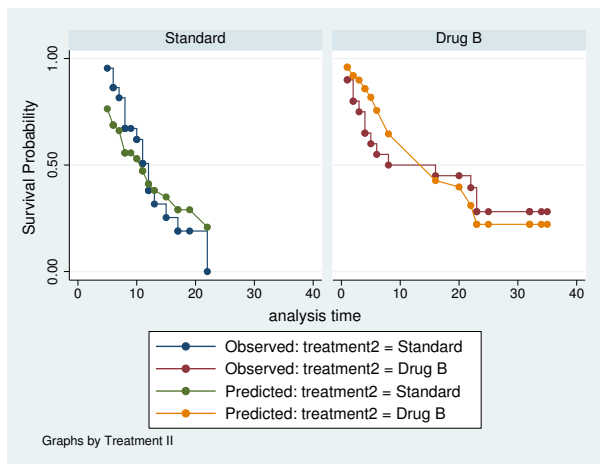


Figure 5.

This variable violates the proportional-hazards assumption. In figure 4, we see that the lines are not only nonparallel but also cross in the data region. In figure 5, we see that there are considerable differences between the observed and predicted values. We have overestimated the positive effect of drug B for the first half of the study and have underestimated it in the later weeks. One hazard ratio describing the effect of this drug would be inappropriate. We definitely would want to stratify on this variable in our Cox model.



### Example 2: estat phtest

In this example, we use `estat phtest` to examine whether the proportional-hazards assumption holds for a model with covariates `wbc2`, `wbc1`, and `treatment1`. After `stsetting` the data, we first run `stcox` with these three variables as regressors. Then we use `estat phtest`:

```
. stset weeks, failure(relapse)
      failure event:  relapse != 0 & relapse < .
      obs. time interval:  (0, weeks]
      exit on or before:  failure
```

---

42	total observations	
0	exclusions	

---

42	observations remaining, representing	
30	failures in single-record/single-failure data	
541	total analysis time at risk and under observation	
	at risk from t =	0
	earliest observed entry t =	0
	last observed exit t =	35

```

. stcox treatment1 wbc2 wbc3, nolog
      failure _d: relapse
      analysis time _t: weeks
Cox regression -- Breslow method for ties
No. of subjects =          42          Number of obs   =          42
No. of failures =          30
Time at risk   =          541
Log likelihood = -77.476905          LR chi2(3)       =          33.02
                                          Prob > chi2    =          0.0000

```

_t	Haz. Ratio	Std. Err.	z	P> z	[95% Conf. Interval]	
treatment1	.2834551	.1229874	-2.91	0.004	.1211042	.6634517
wbc2	3.637825	2.201306	2.13	0.033	1.111134	11.91015
wbc3	10.92214	7.088783	3.68	0.000	3.06093	38.97284

```

. estat phtest, detail
      Test of proportional-hazards assumption
      Time: Time

```

	rho	chi2	df	Prob>chi2
treatment1	-0.07019	0.15	1	0.6948
wbc2	-0.03223	0.03	1	0.8650
wbc3	0.01682	0.01	1	0.9237
global test		0.33	3	0.9551

Because we specified the `detail` option with the `estat phtest` command, both covariate-specific and global tests were produced. We can see that there is no evidence that the proportional-hazards assumption has been violated.

Another variable in this dataset measures a different drug (`treatment2`: 1 = drug B, 0 = standard). We now wish to examine the proportional-hazards assumption for the previous model by substituting `treatment2` for `treatment1`.

We fit a new Cox model and perform the test for proportional hazards:

```

. stcox treatment2 wbc2 wbc3, nolog
      failure _d: relapse
      analysis time _t: weeks
Cox regression -- Breslow method for ties
No. of subjects =          42          Number of obs   =          42
No. of failures =          30
Time at risk   =          541
Log likelihood = -82.019053          LR chi2(3)       =          23.93
                                          Prob > chi2    =          0.0000

```

_t	Haz. Ratio	Std. Err.	z	P> z	[95% Conf. Interval]	
treatment2	.8483777	.3469054	-0.40	0.688	.3806529	1.890816
wbc2	3.409628	2.050784	2.04	0.041	1.048905	11.08353
wbc3	14.0562	8.873693	4.19	0.000	4.078529	48.44314

```
. estat phtest, detail
```

```
Test of proportional-hazards assumption
```

```
Time: Time
```

	rho	chi2	df	Prob>chi2
treatment2	-0.51672	10.19	1	0.0014
wbc2	-0.09860	0.29	1	0.5903
wbc3	-0.03559	0.04	1	0.8448
global test		10.24	3	0.0166

`treatment2` violates the proportional-hazards assumption. A single hazard ratio describing the effect of this drug is inappropriate.

The test of the proportional-hazards assumption is based on the principle that, for a given regressor, the assumption restricts  $\beta(t_j) = \beta$  for all  $t_j$ . This implies that a plot of  $\beta(t_j)$  versus time will have a slope of zero. Grambsch and Therneau (1994) showed that  $E(s_j^*) + \hat{\beta} \approx \beta(t_j)$ , where  $s_j^*$  is the scaled Schoenfeld residual at failure time  $t_j$  and  $\hat{\beta}$  is the estimated coefficient from the Cox model. Thus a plot of  $s_j^* + \hat{\beta}$  versus some function of time provides a graphical assessment of the assumption.

Continuing from above, if you type

```
. predict sch*, scaledsch
```

you obtain three variables—`sch1`, `sch2`, and `sch3`—corresponding to the three regressors, `treatment2`, `wbc2`, and `wbc3`. Given the utility of  $s_j^* + \hat{\beta}$ , what is stored in variable `sch1` is actually  $s_{j1}^* + \hat{\beta}_1$  and not just the scaled Schoenfeld residual for the first variable,  $s_{j1}^*$ , itself. The estimated coefficient,  $\hat{\beta}_1$ , is added automatically. The same holds true for the second created variable representing the second regressor, `sch2` =  $s_{j2}^* + \hat{\beta}_2$ , and so on.

As such, a graphical assessment of the proportional-hazards assumption for the first regressor is as simple as

```
. scatter sch1 _t || lfit sch1 _t
```

which plots a scatter of  $s_{j1}^* + \hat{\beta}_1$  versus analysis time, `_t`, and overlays a linear fit. Is the slope zero? The answer is no for the first regressor, `treatment2`, and that agrees with our results from `estat phtest`.

◀

## □ Technical note

The tests of the proportional-hazards assumption assume homogeneity of variance across risk sets. This allows the use of the estimated overall (pooled) variance–covariance matrix in the equations. Although these tests have been shown by Grambsch and Therneau (1994) to be fairly robust to departures from this assumption, exercise care where this assumption may not hold, particularly when performing a stratified Cox analysis. In such cases, we recommend that you check the proportional-hazards assumption separately for each stratum.

□

## Video example

How to fit a Cox proportional hazards model and check proportional-hazards assumption

## Stored results

`estat phtest` stores the following in `r()`:

Scalars

`r(df)` global test degrees of freedom      `r(chi2)` global test  $\chi^2$

## Methods and formulas

For one covariate,  $x$ , the Cox proportional hazards model reduces to

$$h(t; x) = h_0(t) \exp(x\beta)$$

where  $h_0(t)$  is the baseline hazard function from the Cox model. Let  $S_0(t)$  and  $H_0(t)$  be the corresponding Cox baseline survivor and baseline cumulative hazard functions, respectively.

The proportional-hazards assumption implies that

$$H(t) = H_0(t) \exp(x\beta)$$

or

$$\ln H(t) = \ln H_0(t) + x\beta$$

where  $H(t)$  is the cumulative hazard function. Thus, under the proportional-hazards assumption, the logs of the cumulative hazard functions at each level of the covariate have equal slope. This is the basis for the method implemented in `stphplot`.

The proportional-hazards assumption also implies that

$$S(t) = S_0(t) \exp(x\beta)$$

Let  $\widehat{S}(t)$  be the estimated survivor function based on the Cox model. This function is a step function like the Kaplan–Meier estimate and, in fact, reduces to the Kaplan–Meier estimate when  $x = 0$ . Thus for each level of the covariate of interest, we can assess violations of the proportional-hazards assumption by comparing these survival estimates with estimates calculated independently of the model. See [Kalbfleisch and Prentice \(2002\)](#) or [Hess \(1995\)](#).

`stcoxkm` plots Kaplan–Meier estimated curves for each level of the covariate together with the Cox model predicted baseline survival curve. The closer the observed values are to the predicted values, the less likely it is that the proportional-hazards assumption has been violated.

[Grambsch and Therneau \(1994\)](#) presented a scaled adjustment for the Schoenfeld residuals that permits the interpretation of the smoothed residuals as a nonparametric estimate of the log hazard-ratio function. These scaled Schoenfeld residuals,  $r_{S_i}^*$ , can be obtained directly with `predict`'s `scaledsch` option; see [\[ST\] stcox postestimation](#).

Scaled Schoenfeld residuals are centered at  $\widehat{\beta}$  for each covariate and, when there is no violation of proportional hazards, should have slope zero when plotted against functions of time. The `estat phtest` command uses these residuals, tests the null hypothesis that the slope is equal to zero for each covariate in the model, and performs the global test proposed by [Grambsch and Therneau \(1994\)](#). The test of zero slope is equivalent to testing that the log hazard-ratio function is constant over time.

For a specified function of time,  $g(t)$ , the statistic for testing the  $p$ th individual covariate is, for  $\bar{g}(t) = d^{-1} \sum_{i=1}^N \delta_i g(t_i)$ ,

$$\chi_c^2 = \frac{\left[ \sum_{i=1}^N \{ \delta_i g(t_i) - \bar{g}(t) \} r_{S_{pi}}^* \right]^2}{d \text{Var}(\hat{\beta}_p) \sum_{i=1}^N \{ \delta_i g(t_i) - \bar{g}(t) \}^2}$$

which is asymptotically distributed as  $\chi^2$  with 1 degree of freedom.  $r_{S_{pi}}^*$  is the scaled Schoenfeld residual for observation  $i$ , and  $\delta_i$  indicates failure for observation  $i$ , with  $d = \sum \delta_i$ .

The statistic for the global test is calculated as

$$\chi_g^2 = \left[ \sum_{i=1}^N \{ \delta_i g(t_i) - \bar{g}(t) \} \mathbf{r}_{S_i} \right]' \left[ \frac{d \text{Var}(\hat{\beta})}{\sum_{i=1}^N \{ \delta_i g(t_i) - \bar{g}(t) \}^2} \right] \left[ \sum_{i=1}^N \{ \delta_i g(t_i) - \bar{g}(t) \} \mathbf{r}_{S_i} \right]$$

for  $\mathbf{r}_{S_i}$ , a vector of the  $m$  (unscaled) Schoenfeld residuals for the  $i$ th observation; see [ST] **stcox postestimation**. The global test statistic is asymptotically distributed as  $\chi^2$  with  $m$  degrees of freedom.

The equations for the scaled Schoenfeld residuals and the two test statistics just described assume homogeneity of variance across risk sets. Although these tests are fairly robust to deviations from this assumption, care must be exercised, particularly when dealing with a stratified Cox model.

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## Also see

[ST] **stcox** — Cox proportional hazards model

[ST] **sts** — Generate, graph, list, and test the survivor and cumulative hazard functions

[ST] **stset** — Declare data to be survival-time data

[U] **20 Estimation and postestimation commands**