

prais — Prais–Winsten and Cochrane–Orcutt regression

Syntax	Menu	Description	Options
Remarks and examples	Stored results	Methods and formulas	Acknowledgment
References	Also see		

Syntax

```
prais depar [indepvars] [if] [in] [, options]
```

<i>options</i>	Description
Model	
<code>rho</code> (<u>regress</u>)	base ρ on single-lag OLS of residuals; the default
<code>rho</code> (<u>freg</u>)	base ρ on single-lead OLS of residuals
<code>rho</code> (<u>tscorr</u>)	base ρ on autocorrelation of residuals
<code>rho</code> (<u>dw</u>)	base ρ on autocorrelation based on Durbin–Watson
<code>rho</code> (<u>theil</u>)	base ρ on adjusted autocorrelation
<code>rho</code> (<u>nagar</u>)	base ρ on adjusted Durbin–Watson
<code>corc</code>	use Cochrane–Orcutt transformation
<code>ssesearch</code>	search for ρ that minimizes SSE
<code>twostep</code>	stop after the first iteration
<code>noconstant</code>	suppress constant term
<code>hascons</code>	has user-defined constant
<code>savespace</code>	conserve memory during estimation
SE/Robust	
<code>vce</code> (<i>vcetype</i>)	<i>vcetype</i> may be <code>ols</code> , <code>robust</code> , <code>cluster</code> <i>clustvar</i> , <code>hc2</code> , or <code>hc3</code>
Reporting	
<code>level</code> (#)	set confidence level; default is <code>level(95)</code>
<code>nodw</code>	do not report the Durbin–Watson statistic
<code>display_options</code>	control column formats, row spacing, line width, display of omitted variables and base and empty cells, and factor-variable labeling
Optimization	
<code>optimize_options</code>	control the optimization process; seldom used
<code>coeflegend</code>	display legend instead of statistics

You must `tsset` your data before using `prais`; see [TS] `tsset`.

indepvars may contain factor variables; see [U] 11.4.3 **Factor variables**.

depar and *indepvars* may contain time-series operators; see [U] 11.4.4 **Time-series varlists**.

`by`, `fp`, `rolling`, and `statsby` are allowed; see [U] 11.1.10 **Prefix commands**.

`coeflegend` does not appear in the dialog box.

See [U] 20 **Estimation and postestimation commands** for more capabilities of estimation commands.

Menu

Statistics > Time series > Prais–Winsten regression

Description

`prais` uses the generalized least-squares method to estimate the parameters in a linear regression model in which the errors are serially correlated. Specifically, the errors are assumed to follow a first-order autoregressive process.

Options

Model

`rhotype(rhmethod)` selects a specific computation for the autocorrelation parameter ρ , where *rhmethod* can be

<code>regress</code>	$\rho_{\text{reg}} = \beta$ from the residual regression $\epsilon_t = \beta\epsilon_{t-1}$
<code>freg</code>	$\rho_{\text{freg}} = \beta$ from the residual regression $\epsilon_t = \beta\epsilon_{t+1}$
<code>tscorr</code>	$\rho_{\text{tscorr}} = \epsilon' \epsilon_{t-1} / \epsilon' \epsilon$, where ϵ is the vector of residuals
<code>dw</code>	$\rho_{\text{dw}} = 1 - \text{dw}/2$, where <i>dw</i> is the Durbin–Watson <i>d</i> statistic
<code>theil</code>	$\rho_{\text{theil}} = \rho_{\text{tscorr}}(N - k)/N$
<code>nagar</code>	$\rho_{\text{nagar}} = (\rho_{\text{dw}} * N^2 + k^2) / (N^2 - k^2)$

The `prais` estimator can use any consistent estimate of ρ to transform the equation, and each of these estimates meets that requirement. The default is `regress`, which produces the minimum sum-of-squares solution (`ssesearch` option) for the Cochrane–Orcutt transformation—none of these computations will produce the minimum sum-of-squares solution for the full Prais–Winsten transformation. See [Judge et al. \(1985\)](#) for a discussion of each estimate of ρ .

`corc` specifies that the Cochrane–Orcutt transformation be used to estimate the equation. With this option, the Prais–Winsten transformation of the first observation is not performed, and the first observation is dropped when estimating the transformed equation; see [Methods and formulas](#) below.

`ssesearch` specifies that a search be performed for the value of ρ that minimizes the sum-of-squared errors of the transformed equation (Cochrane–Orcutt or Prais–Winsten transformation). The search method is a combination of quadratic and modified bisection searches using golden sections.

`twostep` specifies that `prais` stop on the first iteration after the equation is transformed by ρ —the two-step efficient estimator. Although iterating these estimators to convergence is customary, they are efficient at each step.

`noconstant`; see [\[R\] estimation options](#).

`hascons` indicates that a user-defined constant, or a set of variables that in linear combination forms a constant, has been included in the regression. For some computational concerns, see the discussion in [\[R\] regress](#).

`savespace` specifies that `prais` attempt to save as much space as possible by retaining only those variables required for estimation. The original data are restored after estimation. This option is rarely used and should be used only if there is insufficient space to fit a model without the option.

SE/Robust

`vce(vcetype)` specifies the estimator for the variance–covariance matrix of the estimator; see [R] [vce_option](#).

`vce(ols)`, the default, uses the standard variance estimator for ordinary least-squares regression.

`vce(robust)` specifies to use the Huber/White/sandwich estimator.

`vce(cluster clustvar)` specifies to use the intragroup correlation estimator.

`vce(hc2)` and `vce(hc3)` specify an alternative bias correction for the `vce(robust)` variance calculation; for more information, see [R] [regress](#). You may specify only one of `vce(hc2)`, `vce(hc3)`, or `vce(robust)`.

All estimates from `prais` are conditional on the estimated value of ρ . Robust variance estimates here are robust only to heteroskedasticity and are not generally robust to misspecification of the functional form or omitted variables. The estimation of the functional form is intertwined with the estimation of ρ , and all estimates are conditional on ρ . Thus estimates cannot be robust to misspecification of functional form. For these reasons, it is probably best to interpret `vce(robust)` in the spirit of White's (1980) original paper on estimation of heteroskedastic-consistent covariance matrices.

Reporting

`level(#)`; see [R] [estimation options](#).

`nodw` suppresses reporting of the Durbin–Watson statistic.

`display_options`: `noomitted`, `vsquish`, `noemptycells`, `baselevels`, `allbaselevels`, `novlabel`, `fvwrap(#)`, `fvwrapon(style)`, `cformat(%fmt)`, `pformat(%fmt)`, `sformat(%fmt)`, and `no1stretch`; see [R] [estimation options](#).

Optimization

`optimize_options`: `iterate(#)`, `[no]log`, `tolerance(#)`. `iterate()` specifies the maximum number of iterations. `log/nolog` specifies whether to show the iteration log. `tolerance()` specifies the tolerance for the coefficient vector; `tolerance(1e-6)` is the default. These options are seldom used.

The following option is available with `prais` but is not shown in the dialog box:

`coeflegend`; see [R] [estimation options](#).

Remarks and examples

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

`prais` fits a linear regression of *depvar* on *indepvars* that is corrected for first-order serially correlated residuals by using the Prais–Winsten (1954) transformed regression estimator, the Cochrane–Orcutt (1949) transformed regression estimator, or a version of the search method suggested by Hildreth and Lu (1960). Davidson and MacKinnon (1993) provide theoretical details on the three methods (see pages 333–335 for the latter two and pages 343–351 for Prais–Winsten). See Beckett (2013) for more examples showing how to use `prais`.

The most common autocorrelated error process is the first-order autoregressive process. Under this assumption, the linear regression model can be written as

$$y_t = \mathbf{x}_t\beta + u_t$$

where the errors satisfy

$$u_t = \rho u_{t-1} + e_t$$

and the e_t are independently and identically distributed as $N(0, \sigma^2)$. The covariance matrix Ψ of the error term u can then be written as

$$\Psi = \frac{1}{1 - \rho^2} \begin{bmatrix} 1 & \rho & \rho^2 & \cdots & \rho^{T-1} \\ \rho & 1 & \rho & \cdots & \rho^{T-2} \\ \rho^2 & \rho & 1 & \cdots & \rho^{T-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho^{T-1} & \rho^{T-2} & \rho^{T-3} & \cdots & 1 \end{bmatrix}$$

The Prais–Winsten estimator is a generalized least-squares (GLS) estimator. The Prais–Winsten method (as described in [Judge et al. 1985](#)) is derived from the AR(1) model for the error term described above. Whereas the Cochrane–Orcutt method uses a lag definition and loses the first observation in the iterative method, the Prais–Winsten method preserves that first observation. In small samples, this can be a significant advantage.

□ Technical note

To fit a model with autocorrelated errors, you must specify your data as time series and have (or create) a variable denoting the time at which an observation was collected. The data for the regression should be equally spaced in time. □

▷ Example 1

Say that we wish to fit a time-series model of `usr` on `idle` but are concerned that the residuals may be serially correlated. We will declare the variable `t` to represent time by typing

```
. use http://www.stata-press.com/data/r13/idle
. tsset t
    time variable: t, 1 to 30
      delta: 1 unit
```

We can obtain Cochrane–Orcutt estimates by specifying the `corc` option:

```
. prais usr idle, corc
Iteration 0: rho = 0.0000
Iteration 1: rho = 0.3518
(output omitted)
Iteration 13: rho = 0.5708
Cochrane-Orcutt AR(1) regression -- iterated estimates
```

Source	SS	df	MS	Number of obs =		
Model	40.1309584	1	40.1309584	F(1, 27) =	6.49	
Residual	166.898474	27	6.18142498	Prob > F =	0.0168	
				R-squared =	0.1938	
				Adj R-squared =	0.1640	
Total	207.029433	28	7.39390831	Root MSE =	2.4862	
usr	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
idle	-.1254511	.0492356	-2.55	0.017	-.2264742	-.024428
_cons	14.54641	4.272299	3.40	0.002	5.78038	23.31245
rho	.5707918					

```
Durbin-Watson statistic (original) 1.295766
Durbin-Watson statistic (transformed) 1.466222
```

The fitted model is

$$\text{usr}_t = -0.1255 \text{idle}_t + 14.55 + u_t \quad \text{and} \quad u_t = 0.5708 u_{t-1} + e_t$$

We can also fit the model with the Prais–Winsten method,

```
. prais usr idle
Iteration 0: rho = 0.0000
Iteration 1: rho = 0.3518
(output omitted)
Iteration 14: rho = 0.5535
Prais-Winsten AR(1) regression -- iterated estimates
```

Source	SS	df	MS			
Model	43.0076941	1	43.0076941	Number of obs =	30	
Residual	169.165739	28	6.04163354	F(1, 28) =	7.12	
				Prob > F =	0.0125	
				R-squared =	0.2027	
				Adj R-squared =	0.1742	
				Root MSE =	2.458	
Total	212.173433	29	7.31632528			

usr	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
idle	-.1356522	.0472195	-2.87	0.008	-.2323769	-.0389275
_cons	15.20415	4.160391	3.65	0.001	6.681978	23.72633
rho	.5535476					

```
Durbin-Watson statistic (original) 1.295766
Durbin-Watson statistic (transformed) 1.476004
```

where the Prais–Winsten fitted model is

$$\text{usr}_t = -.1357 \text{idle}_t + 15.20 + u_t \quad \text{and} \quad u_t = .5535 u_{t-1} + e_t$$

As the results indicate, for these data there is little difference between the Cochrane–Orcutt and Prais–Winsten estimators, whereas the OLS estimate of the slope parameter is substantially different. ◀

▶ Example 2

We have data on quarterly sales, in millions of dollars, for 5 years, and we would like to use this information to model sales for company X. First, we fit a linear model by OLS and obtain the Durbin–Watson statistic by using `estat dwatson`; see [\[R\] regress postestimation time series](#).

```
. use http://www.stata-press.com/data/r13/qsales
. regress csales isales
```

Source	SS	df	MS			
Model	110.256901	1	110.256901	Number of obs =	20	
Residual	.133302302	18	.007405683	F(1, 18) =	14888.15	
				Prob > F =	0.0000	
				R-squared =	0.9988	
				Adj R-squared =	0.9987	
				Root MSE =	.08606	
Total	110.390204	19	5.81001072			

csales	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
isales	.1762828	.0014447	122.02	0.000	.1732475	.1793181
_cons	-1.454753	.2141461	-6.79	0.000	-1.904657	-1.004849

```
. estat dwatson
Durbin-Watson d-statistic( 2, 20) = .7347276
```

Because the Durbin–Watson statistic is far from 2 (the expected value under the null hypothesis of no serial correlation) and well below the 5% lower limit of 1.2, we conclude that the disturbances are serially correlated. (Upper and lower bounds for the d statistic can be found in most econometrics texts; for example, [Harvey \[1990\]](#). The bounds have been derived for only a limited combination of regressors and observations.) To reinforce this conclusion, we use two other tests to test for serial correlation in the error distribution.

```
. estat bgodfrey, lags(1)
Breusch-Godfrey LM test for autocorrelation
```

lags(p)	chi2	df	Prob > chi2
1	7.998	1	0.0047

H0: no serial correlation

```
. estat durbinalt
Durbin's alternative test for autocorrelation
```

lags(p)	chi2	df	Prob > chi2
1	11.329	1	0.0008

H0: no serial correlation

`estat bgodfrey` reports the Breusch–Godfrey Lagrange multiplier test statistic, and `estat durbinalt` reports the Durbin’s alternative test statistic. Both tests give a small p -value and thus reject the null hypothesis of no serial correlation. These two tests are asymptotically equivalent when testing for AR(1) process. See [\[R\] regress postestimation time series](#) if you are not familiar with these two tests.

We correct for autocorrelation with the `ssesearch` option of `prais` to search for the value of ρ that minimizes the sum-of-squared residuals of the Cochrane–Orcutt transformed equation. Normally, the default Prais–Winsten transformations is used with such a small dataset, but the less-efficient Cochrane–Orcutt transformation allows us to demonstrate an aspect of the estimator’s convergence.

```
. prais csales isales, corc ssesearch
Iteration 1: rho = 0.8944 , criterion = -.07298558
Iteration 2: rho = 0.8944 , criterion = -.07298558
(output omitted)
Iteration 15: rho = 0.9588 , criterion = -.07167037
Cochrane-Orcutt AR(1) regression -- SSE search estimates
```

Source	SS	df	MS	Number of obs =	19
Model	2.33199178	1	2.33199178	F(1, 17) =	553.14
Residual	.071670369	17	.004215904	Prob > F =	0.0000
				R-squared =	0.9702
				Adj R-squared =	0.9684
Total	2.40366215	18	.133536786	Root MSE =	.06493

csales	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
isales	.1605233	.0068253	23.52	0.000	.1461233 .1749234
_cons	1.738946	1.432674	1.21	0.241	-1.283732 4.761624
rho	.9588209				

```
Durbin-Watson statistic (original) 0.734728
Durbin-Watson statistic (transformed) 1.724419
```

We noted in *Options* that, with the default computation of ρ , the Cochrane–Orcutt method produces an estimate of ρ that minimizes the sum-of-squared residuals—the same criterion as the `sssearch` option. Given that the two methods produce the same results, why would the search method ever be preferred? It turns out that the back-and-forth iterations used by Cochrane–Orcutt may have difficulty converging if the value of ρ is large. Using the same data, the Cochrane–Orcutt iterative procedure requires more than 350 iterations to converge, and a higher tolerance must be specified to prevent premature convergence:

```
. prais csales isales, corc tol(1e-9) iterate(500)
Iteration 0: rho = 0.0000
Iteration 1: rho = 0.6312
Iteration 2: rho = 0.6866
      (output omitted)
Iteration 377: rho = 0.9588
Iteration 378: rho = 0.9588
Iteration 379: rho = 0.9588
Cochrane-Orcutt AR(1) regression -- iterated estimates
```

Source	SS	df	MS	Number of obs =	19
Model	2.33199171	1	2.33199171	F(1, 17) =	553.14
Residual	.071670369	17	.004215904	Prob > F =	0.0000
				R-squared =	0.9702
				Adj R-squared =	0.9684
Total	2.40366208	18	.133536782	Root MSE =	.06493

csales	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
isales	.1605233	.0068253	23.52	0.000	.1461233	.1749234
_cons	1.738946	1.432674	1.21	0.241	-1.283732	4.761625
rho	.9588209					

```
Durbin-Watson statistic (original) 0.734728
Durbin-Watson statistic (transformed) 1.724419
```

Once convergence is achieved, the two methods produce identical results.

Stored results

`prais` stores the following in `e()`:

Scalars

<code>e(N)</code>	number of observations
<code>e(N_gaps)</code>	number of gaps
<code>e(mss)</code>	model sum of squares
<code>e(df_m)</code>	model degrees of freedom
<code>e(rss)</code>	residual sum of squares
<code>e(df_r)</code>	residual degrees of freedom
<code>e(r2)</code>	R^2
<code>e(r2_a)</code>	adjusted R^2
<code>e(F)</code>	F statistic
<code>e(rmse)</code>	root mean squared error
<code>e(ll)</code>	log likelihood
<code>e(N_clust)</code>	number of clusters
<code>e(rho)</code>	autocorrelation parameter ρ
<code>e(dw)</code>	Durbin–Watson d statistic for transformed regression
<code>e(dw_0)</code>	Durbin–Watson d statistic of untransformed regression
<code>e(rank)</code>	rank of <code>e(V)</code>
<code>e(tol)</code>	target tolerance
<code>e(max_ic)</code>	maximum number of iterations
<code>e(ic)</code>	number of iterations

Macros

<code>e(cmd)</code>	<code>prais</code>
<code>e(cmdline)</code>	command as typed
<code>e(depvar)</code>	name of dependent variable
<code>e(title)</code>	title in estimation output
<code>e(clustvar)</code>	name of cluster variable
<code>e(cons)</code>	<code>noconstant</code> or not reported
<code>e(method)</code>	<code>twostep</code> , <code>iterated</code> , or <code>SSE search</code>
<code>e(tranmeth)</code>	<code>corc</code> or <code>prais</code>
<code>e(rhotype)</code>	method specified in <code>rhotype()</code> option
<code>e(vce)</code>	<code>vcetype</code> specified in <code>vce()</code>
<code>e(vcetype)</code>	title used to label Std. Err.
<code>e(properties)</code>	<code>b V</code>
<code>e(predict)</code>	program used to implement <code>predict</code>
<code>e(marginsok)</code>	predictions allowed by <code>margins</code>
<code>e(asbalanced)</code>	factor variables <code>fvset</code> as <code>asbalanced</code>
<code>e(asobserved)</code>	factor variables <code>fvset</code> as <code>asobserved</code>

Matrices

<code>e(b)</code>	coefficient vector
<code>e(V)</code>	variance–covariance matrix of the estimators
<code>e(V_modelbased)</code>	model-based variance

Functions

<code>e(sample)</code>	estimation sample
------------------------	-------------------

Methods and formulas

Consider the command ‘`prais y x z`’. The 0th iteration is obtained by estimating a , b , and c from the standard linear regression:

$$y_t = ax_t + bz_t + c + u_t$$

An estimate of the correlation in the residuals is then obtained. By default, `prais` uses the auxiliary regression:

$$u_t = \rho u_{t-1} + e_t$$

This can be changed to any computation noted in the `rhotype()` option.

Next we apply a Cochrane–Orcutt transformation (1) for observations $t = 2, \dots, n$

$$y_t - \rho y_{t-1} = a(x_t - \rho x_{t-1}) + b(z_t - \rho z_{t-1}) + c(1 - \rho) + v_t \quad (1)$$

and the transformation (1') for $t = 1$

$$\sqrt{1 - \rho^2} y_1 = a(\sqrt{1 - \rho^2} x_1) + b(\sqrt{1 - \rho^2} z_1) + c\sqrt{1 - \rho^2} + \sqrt{1 - \rho^2} v_1 \quad (1')$$

Thus the differences between the Cochrane–Orcutt and the Prais–Winsten methods are that the latter uses (1') in addition to (1), whereas the former uses only (1), necessarily decreasing the sample size by one.

Equations (1) and (1') are used to transform the data and obtain new estimates of a , b , and c .

When the `twostep` option is specified, the estimation process stops at this point and reports these estimates. Under the default behavior of iterating to convergence, this process is repeated until the change in the estimate of ρ is within a specified tolerance.

The new estimates are used to produce fitted values

$$\hat{y}_t = \hat{a}x_t + \hat{b}z_t + \hat{c}$$

and then ρ is reestimated using, by default, the regression defined by

$$y_t - \hat{y}_t = \rho(y_{t-1} - \hat{y}_{t-1}) + u_t \quad (2)$$

We then reestimate (1) by using the new estimate of ρ and continue to iterate between (1) and (2) until the estimate of ρ converges.

Convergence is declared after `iterate()` iterations or when the absolute difference in the estimated correlation between two iterations is less than `tol()`; see [R] [maximize](#). Sargan (1964) has shown that this process will always converge.

Under the `sssearch` option, a combined quadratic and bisection search using golden sections searches for the value of ρ that minimizes the sum-of-squared residuals from the transformed equation. The transformation may be either the Cochrane–Orcutt (1 only) or the Prais–Winsten (1 and 1').

All reported statistics are based on the ρ -transformed variables, and ρ is assumed to be estimated without error. See Judge et al. (1985) for details.

The Durbin–Watson d statistic reported by `prais` and `estat dwatson` is

$$d = \frac{\sum_{j=1}^{n-1} (u_{j+1} - u_j)^2}{\sum_{j=1}^n u_j^2}$$

where u_j represents the residual of the j th observation.

This command supports the Huber/White/sandwich estimator of the variance and its clustered version using `vce(robust)` and `vce(cluster clustvar)`, respectively. See [P] [_robust](#), particularly [Introduction](#) and [Methods and formulas](#).

All estimates from `prais` are conditional on the estimated value of ρ . Robust variance estimates here are robust only to heteroskedasticity and are not generally robust to misspecification of the functional form or omitted variables. The estimation of the functional form is intertwined with the estimation of ρ , and all estimates are conditional on ρ . Thus estimates cannot be robust to misspecification of functional form. For these reasons, it is probably best to interpret `vce(robust)` in the spirit of White's original paper on estimation of heteroskedastic-consistent covariance matrices.

Acknowledgment

We thank Richard Dickens of the Centre for Economic Performance at the London School of Economics and Political Science for testing and assistance with an early version of this command.

Sigbert Jon Prais (1928–2014) was born in Frankfurt and moved to Britain in 1934 as a refugee. After earning degrees at the universities of Birmingham and Cambridge and serving in various posts in research and industry, he settled at the National Institute of Economic and Social Research. Prais's interests extended widely across economics, including studies of the influence of education on economic progress.

Christopher Blake Winsten (1923–2005) was born in Welwyn Garden City, England; the son of the writer Stephen Winsten and the painter and sculptress Clare Blake. He was educated at the University of Cambridge and worked with the Cowles Commission at the University of Chicago and at the universities of Oxford, London (Imperial College) and Essex, making many contributions to economics and statistics, including the Prais–Winsten transformation and joint authorship of a celebrated monograph on transportation economics.

Donald Cochrane (1917–1983) was an Australian economist and econometrician. He was born in Melbourne and earned degrees at Melbourne and Cambridge. After wartime service in the Royal Australian Air Force, he held chairs at Melbourne and Monash, being active also in work for various international organizations and national committees.

Guy Henderson Orcutt (1917–) was born in Michigan and earned degrees in physics and economics at the University of Michigan. He worked at Harvard, the University of Wisconsin, and Yale. He has contributed to econometrics and economics in several fields, most distinctively in developing microanalytical models of economic behavior.

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Also see

- [TS] **prais postestimation** — Postestimation tools for prais
- [TS] **tsset** — Declare data to be time-series data
- [TS] **arima** — ARIMA, ARMAX, and other dynamic regression models
- [R] **regress** — Linear regression
- [R] **regress postestimation time series** — Postestimation tools for regress with time series
- [U] **20 Estimation and postestimation commands**