EViews7

Unit Root Testing

The theory behind ARMA estimation is based on stationary time series. A series is said to be (weakly or covariance) *stationary* if the mean and autocovariances of the series do not depend on time. Any series that is not stationary is said to be *nonstationary*.

A common example of a nonstationary series is the *random walk*:

(30.1) $$y_t = y_{t-1} + \epsilon_t,$$

where ϵ is a stationary random disturbance term. The series y has a constant forecast value, conditional on t, and the variance is increasing over time. The random walk is a difference stationary series since the first difference of y is stationary:

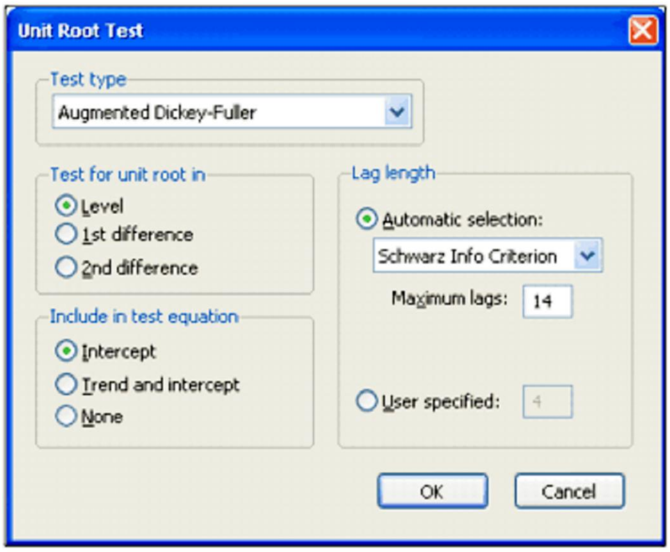
(30.2) $$y_t - y_{t-1} = (1 - L)y_t = \epsilon_t.$$

A difference stationary series is said to be *integrated* and is denoted as I(d) where d is the order of integration. The order of integration is the number of unit roots contained in the series, or the number of differencing operations it takes to make the series stationary. For the random walk above, there is one unit root, so it is an I(1) series. Similarly, a stationary series is I(0).

Standard inference procedures do not apply to regressions which contain an integrated dependent variable or integrated regressors. Therefore, it is important to check whether a series is stationary or not before using it in a regression. The formal method to test the stationarity of a series is the unit root test.

EViews provides you with a variety of powerful tools for testing a series (or the first or second difference of the series) for the presence of a unit root. In addition to Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) tests, EViews allows you to compute the GLS-detrended Dickey-Fuller (Elliot, Rothenberg, and Stock, 1996), Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992), Elliott, Rothenberg, and Stock Point Optimal (ERS, 1996), and Ng and Perron (NP, 2001) unit root tests. All of these tests are available as a view of a series.

Performing Unit Root Tests in EViews



The following discussion assumes that you are familiar with the basic forms of the unit root tests and the associated options. e provide theoretical background for these tests in asic nit Root Theory , and document the settings used when performing these tests.

To begin, double click on the series name to open the series window, and choose **View** **Unit Root Test**

ou must specify four sets of options to carry out a unit root test. The first three settings (on the left-hand side of the dialog) determine the basic form of the unit root test. The fourth set of options (on the right-hand side of the dialog) consist of test-specific advanced settings. ou only need concern yourself with these settings if you wish to customie the calculation of your unit root test.

First, you should use the topmost combo box to select the type of unit root test that you wish to perform. ou may choose one of six tests: ADF, DFGLS, PP, KPSS, ERS, and NP.

Next, specify whether you wish to test for a unit root in the level, first difference, or second difference of the series.

Lastly, choose your exogenous regressors. ou can choose to include a constant, a constant and linear trend, or neither (there are limitations on these choices for some of the tests).

ou can click on to compute the test using the specified settings, or you can customie your test using the advanced settings portion of the dialog.

The advanced settings for both the ADF and DFGLS tests allow you to specify how lagged difference terms p are to be included in the ADF test euation. ou may choose to let EViews automatically select p, or you may specify a fixed positive integer value (if you choose automatic selection, you are given the additional option of selecting both the information criterion and maximum number of lags to be used in the selection procedure).

In this case, we have chosen to estimate an ADF test that includes a constant in the test regression and employs automatic lag length selection using a Schwar Information riterion (I) and a maximum lag length of 1. Applying these settings to data on the .S. one -month Treasury bill rate for the period from March 193 to uly 1971 (ayashi92.F1), we can replicate Example 9.2 of ayashi (2000, p. 96). The results are described below.

The first part of the unit root output provides information about the form of the test (the type of test, the exogenous variables, and lag length used), and contains the test output, associated critical values, and in this case, the *p*-value:

Null Hypothesis: TBILL has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic based on SIC, MAXLAG=14)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.417410	0.5734
Test critical values:	1% level	-3.459898	
	5% level	-2.874435	
	10% level	-2.573719	

*MacKinnon (1996) one-sided p-values.

The ADF statistic value is -1.17 and the associated one -sided *p*-value (for a test with 221 observations) is .73. In addition, EViews reports the critical values at the 1, and 10 levels. Notice here that the statistic t_α value is greater than the critical values so that we do not reect the null at conventional test sies.

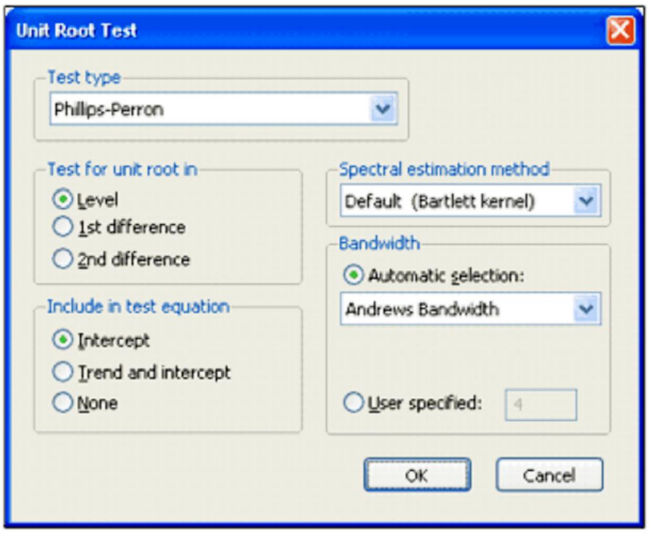
The second part of the output shows the intermediate test euation that EViews used to calculate the ADF statistic:

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(TBILL)
Method: Least Squares
Date: 08/08/06 Time: 13:55
Sample: 1953M03 1971M07
Included observations: 221

	Coefficient	Std. Error	t-Statistic	Prob.
TBILL(-1)	-0.022951	0.016192	-1.417410	0.1578
D(TBILL(-1))	-0.203330	0.067007	-3.034470	0.0027
C	0.088398	0.056934	1.552626	0.1220

R-squared	0.053856	Mean dependent var	0.013826
Adjusted R-squared	0.045175	S.D. dependent var	0.379758
S.E. of regression	0.371081	Akaike info criterion	0.868688
Sum squared resid	30.01882	Schwarz criterion	0.914817
Log likelihood	-92.99005	Hannan-Quinn criter.	0.887314
F-statistic	6.204410	Durbin-Watson stat	1.976361
Prob(F-statistic)	0.002395		

If you had chosen to perform any of the other unit root tests (PP, KPSS, ERS, NP), the right side of the dialog would show the different options associated with the specified test. The options are associated with the method used to estimate the ero freuency spectrum term, f_0, that is used in constructing the particular test statistic. As before, you only need pay attention to these settings if you wish to change from the EViews defaults.



ere, we have selected the PP test in the combo box. Note that the right-hand side of the dialog has changed, and now features a combo box for selecting the spectral estimation method. ou may use this combo box to choose between various kernel or AR regression based estimators for f_0. The entry labeled Default will show you the default estimator for the specific unit root test-in this example, we see that the PP default uses a kernel sum-of-covariances estimator with artlett weights. Alternately, if you had selected a NP test, the default entry would be AR spectral -GLS.

Lastly, you can control the lag length or bandwidth used for your spectral estimator. If you select one of the kernel estimation methods (artlett, Paren, uadratic Spectral), the dialog will give you a choice between using Newey-est or Andrews automatic bandwidth selection methods, or providing a user specified bandwidth. If you choose one of the AR spectral density estimation methods (AR Spectral - OLS, AR Spectral - OLS detrended, AR Spectral - GLS detrended), the dialog will prompt you to choose from various automatic lag length selection methods (using information criteria) or to provide a user-specified lag length. See Automatic andwidth and Lag Length Selection .

Once you have chosen the appropriate settings for your test, click on the □□ button. EViews reports the test statistic along with output from the corresponding test regression. For these tests, EViews reports the uncorrected estimate of the residual variance and the estimate of the freuency ero spectrum f_0 (labeled as the A corrected variance) in addition to the basic output. Running a PP test using the TILL series using the Andrews bandwidth yields:

Null Hypothesis: TBILL has a unit root
Exogenous: Constant
Bandwidth: 3.82 (Andrews using Bartlett kernel)

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-1.519035	0.5223
Test critical values:	1% level	-3.459898	
	5% level	-2.874435	
	10% level	-2.573719	

*MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.141569
HAC corrected variance (Bartlett kernel)	0.107615

As with the ADF test, we fail to reect the null hypothesis of a unit root in the TILL series at conventional significance levels.

Note that your test output will differ somewhat for alternative test specifications. For example, the

KPSS output only provides the asymptotic critical values tabulated by KPSS:

Null Hypothesis: TBILL is stationary
Exogenous: Constant
Bandwidth: 11 (Newey-West automatic) using Bartlett kernel

		LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic		1.537310
Asymptotic critical values*:	1% level	0.739000
	5% level	0.463000
	10% level	0.347000

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Residual variance (no correction)	2.415060
HAC corrected variance (Bartlett kernel)	26.11028

Similarly, the NP test output will contain results for all four test statistics, along with the NP tabulated critical values.

A word of caution. ou should note that the critical values reported by EViews are valid only for unit root tests of a data series, and will be invalid if the series is based on estimated values. For example, Engle and Granger (1987) proposed a two-step method of testing for cointegration which looks for a unit root in the residuals of a first-stage regression. Since these residuals are estimates of the disturbance term, the asymptotic distribution of the test statistic differs from the one for ordinary series. See ointegration Testing for EViews routines to perform testing in this setting.

□□si□ Unit Root T□eor□

The following discussion outlines the basics features of unit root tests. y necessity, the discussion will be brief. sers who reuire detail should consult the original sources and standard references (see, for example, Davidson and MacKinnon, 1993, hapter 20, amilton, 199, hapter 17, and ayashi, 2000, hapter 9).

onsider a simple AR(1) process:

$$y_t = \rho y_{t-1} + x_t'\delta + \epsilon_t, \quad (30.3)$$

where x_t are optional exogenous regressors which may consist of constant, or a constant and trend, ρ and δ are parameters to be estimated, and the ϵ_t are assumed to be white noise. If $|\rho| \geq 1$, y is a nonstationary series and the variance of y increases with time and approaches infinity. If $|\rho| < 1$, y is a (trend-)stationary series. Thus, the hypothesis of (trend-)stationarity can be evaluated by testing whether the absolute value of ρ is strictly less than one.

The unit root tests that EViews provides generally test the null hypothesis $H_0\colon \rho = 1$ against the one-sided alternative $H_1\colon \rho < 1$. In some cases, the null is tested against a point alternative. In contrast, the KPSS Lagrange Multiplier test evaluates the null of $H_0\colon \rho < 1$ against the alternative $H_1\colon \rho = 1$.

T□e □□gmente□ □i□□e□□□□□er □□□□Test

The standard DF test is carried out by estimating Euation (30.3) after subtracting y_{t-1} from both sides of the euation:

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \epsilon_t$$

$\alpha = \rho - 1$

$$H_0: \alpha = 0$$
$$H_1: \alpha < 0$$

t α

$$t_\alpha = \hat{\alpha}/(se(\hat{\alpha}))$$

$\hat{\alpha}$ α $se(\hat{\alpha})$

t

p

ϵ_t

y p p

y

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \dots + \beta_p \Delta y_{t-p} + v_t$$

t

t α

y

y_t a

$$d(y_t|a) = \begin{cases} y_t & \text{if } t = 1 \\ y_t - a y_{t-1} & \text{if } t > 1 \end{cases}$$

$d(y_t|a)$

$d(x_t|a)$

$$d(y_t|a) = d(x_t|a)'\delta(a) + \eta_t$$

x_t $\hat{\delta}(a)$

a $a = \bar{a}$

$$\bar{a} = \begin{cases} 1 - 7/T & \text{if } x_t = \{1\} \\ 1 - 13.5/T & \text{if } x_t = \{1, t\} \end{cases}$$

GLS detrended data, y_t^d $\bar{a}$

$$y_t^d \equiv y_t - x_t'\hat{\delta}(\bar{a})$$

y_t^d y_t:

$$\Delta y_t^d = \alpha y_{t-1}^d + \beta_1 \Delta y_{t-1}^d + \ldots + \beta_p \Delta y_{t-p}^d + v_t$$

y_t^d x_t

t $\hat{\alpha}$

t

$T = \{50, 100, 200, \infty\}$

t α

$$\tilde{t}_\alpha = t_\alpha\left(\frac{\gamma_0}{f_0}\right)^{1/2} - \frac{T(f_0-\gamma_0)(se(\hat{\alpha}))}{2f_0^{1/2}s}$$

$\hat{\alpha}$ t_α t α $se(\hat{\alpha})$ s

γ_0

$(T-k)s^2/T$ k

f_0

f_0 f_0

t

p

y_t

y_t x_t

$$y_t = x_t{}'\delta + u_t$$

$$LM = \sum_t S(t)^2/(T^2 f_0)$$

f_0 $S(t)$

$$S(t) = \sum_{r=1}^{t} \hat{u}_r$$

$\hat{u}_t = y_t - x_t{}'\tilde{\delta}(0)$ δ

$\tilde{\delta}$

x_t

f_0

$$\hat{\eta}_t(a) = d(y_t|a) - d(x_t|a)'\hat{\delta}(a)$$

$$\text{SSR}(a) = \sum \hat{\eta}_t^2(a)$$

$\alpha = 1$ $\alpha = \bar{a}$

$$P_T = (\text{SSR}(\bar{a}) - \bar{a}\text{SSR}(1))/f_0$$

f_0

x_t

f_0

$$T = \{50, 100, 200, \infty\}$$

y_t^d

Z_α Z_t

R_1

$$\kappa = \sum_{t=2}^{T} (y_{t-1}^d)^2 / T^2$$

$$MZ_\alpha^d = (T^{-1}(y_T^d)^2 - f_0)/(2\kappa)$$

$$MZ_t^d = MZ_\alpha \times MSB$$

$$MSB^d = (\kappa/f_0)^{1/2}$$

$$MP_T^d = \begin{cases} (\bar{c}^2\kappa - \bar{c}T^{-1}(y_T^d)^2)/f_0 & \text{if } x_t = \{1\} \\ (\bar{c}^2\kappa + (1-\bar{c})T^{-1}(y_T^d)^2)/f_0 & \text{if } x_t = \{1, t\} \end{cases}$$

$$\bar{c} = \begin{cases} -7 & \text{if } x_t = \{1\} \\ -13.5 & \text{if } x_t = \{1, t\} \end{cases}$$

x_t f_0

f_0

Kernel Sum-of-Covariances Estimation

$$\hat{f}_0 = \sum_{j=-(T-1)}^{T-1} \hat{\gamma}(j) \cdot K(j/l)$$

l K

$\hat{\gamma}(j)$ j $\tilde{u}_t$

$$\hat{\gamma}(j) = \sum_{t=j+1}^{T} (\tilde{u}_t \tilde{u}_{t-j}) / T$$

$\tilde{u}_t$

	$\tilde{u}_t$
	not applicable

	$K(x) = \begin{cases} 1 - \lvert x \rvert & \text{if } \lvert x \rvert \le 1.0 \\ 0 & \text{otherwise} \end{cases}$
	$K(x) = \begin{cases} 1 - 6x^2(1 - \lvert x \rvert) & \text{if } 0.0 \le \lvert x \rvert \le 0.5 \\ 2(1 - \lvert x \rvert)^3 & \text{if } 0.5 < \lvert x \rvert \le 1.0 \\ 0 & \text{otherwise} \end{cases}$
	$K(x) = \frac{25}{12\pi^2 x^2}\left(\frac{\sin(6\pi x/5)}{6\pi x/5} - \cos(6\pi x/5)\right)$

l

Autoregressive Spectral Density Estimator

(30.23) $$\Delta\bar{y}_t = \alpha\bar{y}_{t-1} + \varphi\cdot\bar{x}_t{}'\delta + \beta_1\Delta\bar{y}_{t-1} + \dots + \beta_p\Delta\bar{y}_{t-p} + u_t$$

EViews provides three autoregressive spectral methods: OLS, OLS detrending, and GLS detrending, corresponding to difference choices for the data $\bar{y}_t$. The following table summaries the auxiliary euation estimated by the various AR spectral density estimators:

OLS	$\bar{y}_t = y_t$, and $\varphi = 1$, $\bar{x}_t = x_t$.
OLS detrended	$\bar{y}_t = y_t - x_t{}'\hat{\delta}(0)$, and $\varphi = 0$.
GLS detrended	$\bar{y}_t = y_t - x_t{}'\hat{\delta}(\bar{a}) = y_t^d$. and $\varphi = 0$.

where $\hat{\delta}(\bar{a})$ are the coefficient estimates from the regression defined in (30.9).

The AR spectral estimator of the freuency ero spectrum is defined as:

(30.2) $$\hat{f}_0 = \hat{\sigma}_u^2/(1-\hat{\beta}_1-\hat{\beta}_2-\dots-\hat{\beta}_p)$$

where $\hat{\sigma}_u^2 = \sum\tilde{u}_t^2/T$ is the residual variance, and $\hat{\beta}$ are the estimates from (30.23). e note here that EViews uses the non-degree of freedom estimator of the residual variance. As a result, spectral estimates computed in EViews may differ slightly from those obtained from other sources.

Not surprisingly, the spectrum estimator is sensitive to the number of lagged difference terms in the auxiliary euation. ou may either specify a fixed parameter or have EViews automatically select one based on an information criterion. Automatic lag length selection is examined in Automatic andwidth and Lag Length Selection .

Default Settings

y default, EViews will choose the estimator of f_0 used by the authors of a given test specification. ou may, of course, override the default settings and choose from either family of estimation methods. The default settings are listed below:

ADF, DFGLS	*not appli□a□le*
PP, KPSS	Kernel (artlett) sum -of-covariances
ERS Point Optimal	AR spectral regression (OLS)
NP	AR spectral regression (GLS-detrended)

There are three distinct situations in which EViews can automatically compute a bandwidth or a lag length parameter.

The first situation occurs when you are selecting the bandwidth parameter l for the kernel-based estimators of f_0. For the kernel estimators, EViews provides you with the option of using the Newey-est (199) or the Andrews (1991) data-based automatic bandwidth parameter methods. See the original sources for details. For those familiar with the Newey-est procedure, we note that EViews uses the lag selection parameter formulae given in the corresponding first lines of Table II-. The Andrews method is based on an AR(1) specification. (See Automatic andwidth Selection for discussion.)

The latter two situations occur when the unit root test reuires estimation of a regression with a parametric correction for serial correlation as in the ADF and DFGLS test euation regressions, and in the AR spectral estimator for f_0. In all of these cases, p lagged difference terms are added to a regression euation. The automatic selection methods choose p (less than the specified maximum) to minimie one of the following criteria:

Akaike (AI)	$-2(l/T)+2k/T$
Schwar (SI)	$-2(l/T)+k\log(T)/T$
annan -uinn ()	$-2(l/T)+2k\log(\log(T))/T$
Modified AI (MAI)	$-2(l/T)+2(k+\tau)/T$
Modified SI (MSI)	$-2(l/T)+(k+\tau)\log(T)/T$
Modified annan -uinn (M)	$-2(l/T)+2(k+\tau)\log(\log(T))/T$

where the modification factor τ is computed as:

(30.2) $$\tau = \alpha^2 \sum_t \tilde{y}_{t-1}^2 / \hat{\sigma}_u^2$$

for $\tilde{y}_t = y_t$, when computing the ADF test euation, and for $\tilde{y}_t$ as defined in Autoregressive Spectral Density Estimator , when estimating f_0. Ng and Perron (2001) propose and examine the modified criteria, concluding with a recommendation of the MAI.

For the information criterion selection methods, you must also specify an upper bound to the lag length. y default, EViews chooses a maximum lag of:

(30.26) $$k_{\max} = \text{int}(\min(T/3, 12) \cdot (T/100)^{1/4})$$

See ayashi (2000, p. 9) for a discussion of the selection of this upper bound.

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