unit root test, ADF with R

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Load requred packages:

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --

## v ggplot2 3.3.5     v purrr   0.3.4
## v tibble  3.1.6     v dplyr   1.0.7
## v tidyr   1.1.4     v stringr 1.4.0
## v readr   2.1.1     v forcats 0.5.1

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(urca)
```

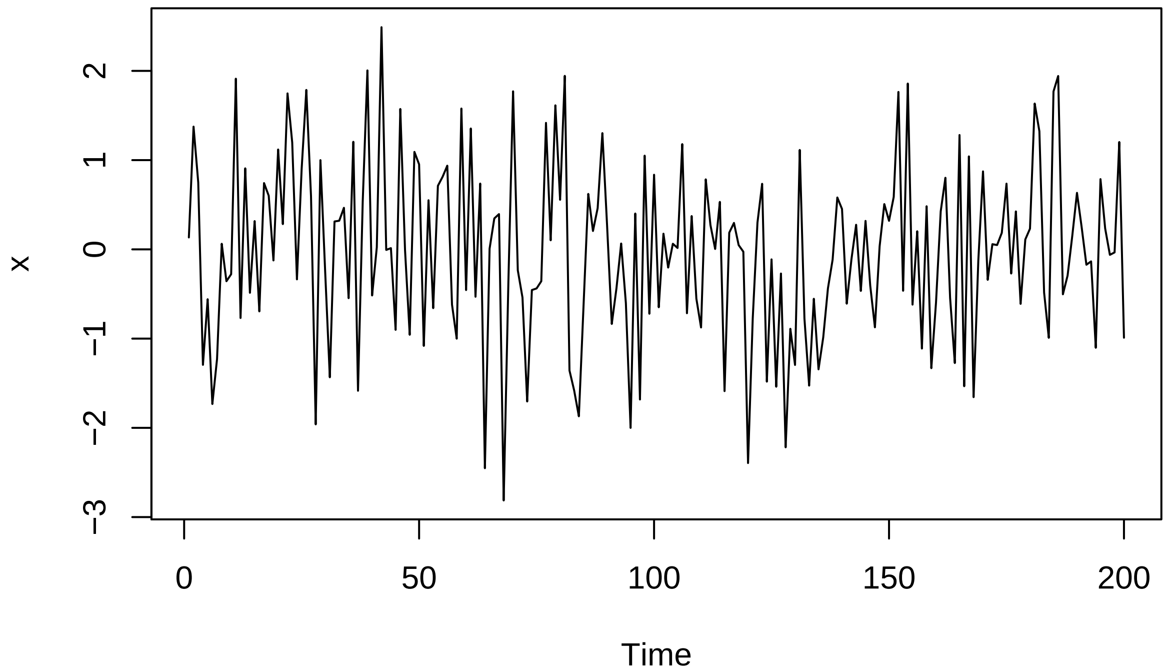
The augmented Dickey–Fuller test (ADF) test the null hypothesis

$$H_0 : timeserieshasaunitroot$$

thus time series is not stationary. It means that its properties like mean and variance varies over time.

For example let's have a look at simulated time series on white noise:

```
x <- as.ts(rnorm(200))
plot(x)
```



mean values of the first 100 and last 100 observations are:

```
mean(x[1:100])
```

```
## [1] 0.05042897
```

```
mean(x[101:200])
```

```
## [1] -0.09418039
```

very similar and t.test:

```
t.test(x[1:100], x[101:200])
```

```
##
##  Welch Two Sample t-test
##
## data:  x[1:100] and x[101:200]
## t = 1.034, df = 190.06, p-value = 0.3024
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.1312477  0.4204665
## sample estimates:
##   mean of x   mean of y
##  0.05042897 -0.09418039
```

cannot reject the null hypothesis that difference of means is zero.

Accordingly, variance of the two samples is:

```
var(x[1:100])
```

```
## [1] 1.1778
```

```
var(x[101:200])
```

```
## [1] 0.7779962
```

And F-testing the variances:

```
var.test(x[1:100], x[101:200], alternative = "two.side")
```

```
##
##  F test to compare two variances
##
## data:  x[1:100] and x[101:200]
## F = 1.5139, num df = 99, denom df = 99, p-value = 0.04031
## alternative hypothesis: true ratio of variances is not equal to 1
## 95 percent confidence interval:
##  1.018608 2.249993
## sample estimates:
## ratio of variances
##           1.513889
```

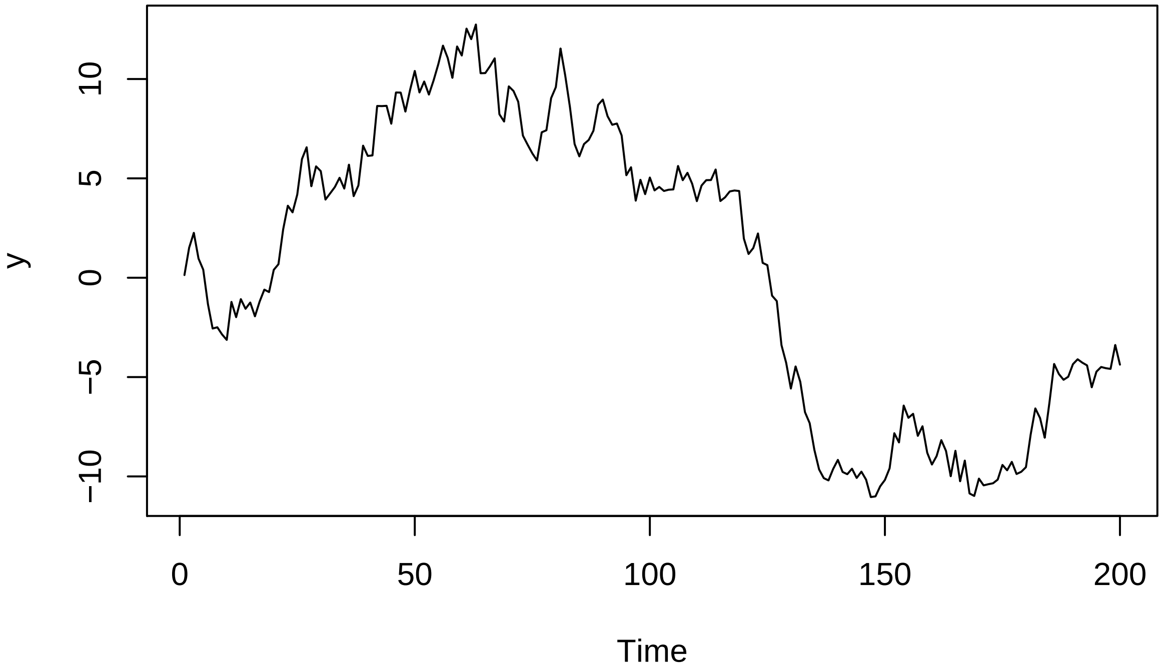
we cannot reject the null hypothesis:

$$H_0 : thetwosampleshavethesamevariance$$

This is an indication of a stationary time series, the so called weak stationarity: mean and variance are stable over different periods of time.

On the contrary, if we have a random walk:

```
y <- as.ts(cumsum(x))
plot(y)
```



Then we observe than there is a big variation over time. For example mean values of the first 100 and last 100 observations are:

```
mean(y[1:100])
```

```
## [1] 5.892578
```

```
mean(y[101:200])
```

```
## [1] -4.812354
```

And the difference of means is significantly different from zero:

```
t.test(y[1:100], y[101:200])
```

```
##
##  Welch Two Sample t-test
##
## data:  y[1:100] and y[101:200]
## t = 15.416, df = 184.42, p-value < 2.2e-16
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##   9.334908 12.074958
## sample estimates:
## mean of x mean of y
##  5.892578 -4.812354
```

Null hypothesis is rejected from t.test, mean of the first 100 observations is significantly smaller than mean of the last 100 observations.

Although the two samples do not differ in variance

```
var.test(y[1:100], y[101:200], alternative = "two.side")
```

```
##
##  F test to compare two variances
##
## data:  y[1:100] and y[101:200]
## F = 0.57317, num df = 99, denom df = 99, p-value = 0.006061
## alternative hypothesis: true ratio of variances is not equal to 1
## 95 percent confidence interval:
##  0.3856527 0.8518647
## sample estimates:
## ratio of variances
##           0.57317
```

we still see that the process is not stationary due to difference in means.

We have to declare that variability of mean (as well as variance) is a weak indication of stationarity.

In order to test it we need a specific statistical test. Among many tests that exists, augmented Dickey–Fuller test of unit root is maybe the most popular. In this section, we stick to ADF test. So, let's look at it:

```
ur.df(x)
```

```
##
## ###############################################################
## # Augmented Dickey-Fuller Test Unit Root / Cointegration Test #
## ###############################################################
##
## The value of the test statistic is: -9.5715
```

We see that we get only the statistic. In order to interpret the results is necessary to look the corresponding tables. For our convenience this can be done easily with:

```
summary(ur.df(x))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
```

```
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.8166 -0.6012 -0.0219  0.6238  2.5228
##
## Coefficients:
##            Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.98450    0.10286  -9.572   <2e-16 ***
## z.diff.lag -0.06236    0.07136  -0.874    0.383
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9888 on 196 degrees of freedom
## Multiple R-squared:  0.5278, Adjusted R-squared:  0.523
## F-statistic: 109.5 on 2 and 196 DF,  p-value: < 2.2e-16
##
##
## Value of test-statistic is: -9.5715
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

Now, we can reject the null hypothesis (existence of a unit root) because the statistic value is less than critical value at 1% level: $-10.1297 < -2.258$

On the other hand, we we test y times series (random walk):

```
summary(ur.df(y))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.70828 -0.61573 -0.00411  0.61889  2.53918
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.007905   0.009657  -0.819    0.414
## z.diff.lag -0.045325   0.071235  -0.636    0.525
##
```

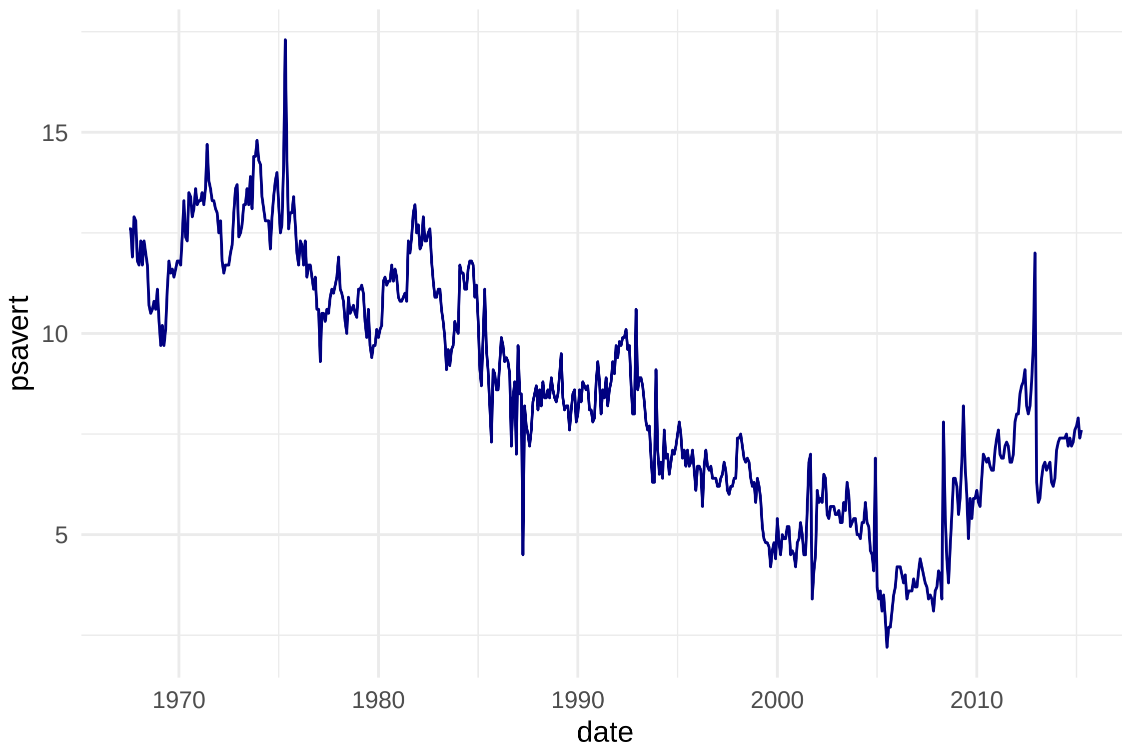
```
## Residual standard error: 0.989 on 196 degrees of freedom
## Multiple R-squared:  0.005862,   Adjusted R-squared:  -0.004283
## F-statistic: 0.5778 on 2 and 196 DF,  p-value: 0.5621
##
##
## Value of test-statistic is: -0.8186
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

We see that we cannot reject the null hypothesis, because test-statistic -0.4547 is bigger than -1.62 (critical value at 10% level).

This was a generic introduction of the augmented Dickey–Fuller test and its demonstration with simulated time series. Let's now move and examine a real world example.

The **economics** data set with ggplot package contains a column **psavert** about the personal savings rate on USA. Plot od this time series is:

```
economics %>%
  ggplot(aes(x = date, y = psavert)) +
  geom_line(color = "navyblue", size = 0.5) +
  theme_minimal()
```



Test for unit root

How can we test for unit root? Easy:

```
ur.df(economics$psavert)
```

```
##
## ###############################################################
```

```
## # Augmented Dickey-Fuller Test Unit Root / Cointegration Test #
## ###############################################################
##
## The value of the test statistic is: -1.1729
```

Or, much better to have all the information:

```r
summary(ur.df(economics$psavert, lag = 0))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.6465 -0.2679  0.0330  0.3303  4.4152
##
## Coefficients:
##          Estimate Std. Error t value Pr(>|t|)
## z.lag.1 -0.004458   0.003436  -1.298    0.195
##
## Residual standard error: 0.7457 on 572 degrees of freedom
## Multiple R-squared:  0.002935,   Adjusted R-squared:  0.001192
## F-statistic: 1.684 on 1 and 572 DF,  p-value: 0.195
##
##
## Value of test-statistic is: -1.2975
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

So we have test-statistic greater than critical value even at 10% ($-1.1729 > -1.62$), thus we reject the null hypothesis.

Let us check better the results. What is this test regression? OK, time to explain the Dickey Fuller test.

If a simple time series follows the autoregressive model:

$$y_t = \rho y_{t-1} + u_t$$

where ρ is a coefficient. If $\rho = 1$ then a unit root is present, the model is non-stationary. This is exactly what we have in random walk when we take the cumulative sum of a white noise.

We can rewrite the equation as :

$$y_t - y_{t-1} = \rho y_{t-1} - y_{t-1} + u_t \Rightarrow \Delta y_t = \delta y_{t-1} + u_t$$

where $\delta \equiv \rho - 1$. We can estimate this model and see if δ is significantly different from 0:

```r
y <- economics %>%
  pull(psavert)
dy   <- diff(y)              # first difference
y1   <- lag(y, n = 1)[-c(1)]  # omit first value (NA)
lm.1 <- lm(dy ~ 0 + y1)       # OLS with no constant
summary(lm.1)
```

```
##
## Call:
## lm(formula = dy ~ 0 + y1)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.6465 -0.2679  0.0330  0.3303  4.4152
##
## Coefficients:
##     Estimate Std. Error t value Pr(>|t|)
## y1 -0.004458   0.003436  -1.298    0.195
##
## Residual standard error: 0.7457 on 572 degrees of freedom
## Multiple R-squared:  0.002935,   Adjusted R-squared:  0.001192
## F-statistic: 1.684 on 1 and 572 DF,  p-value: 0.195
```

```r
confint(lm.1)
```

```
##          2.5 %      97.5 %
## y1 -0.01120648 0.002290211
```

Coefficient δ of y_{t-1} is not significantly different than 0 ($p > 0.05$). These results are the same as here:

```r
summary(ur.df(economics$psavert, type = "none", lags = 0))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.6465 -0.2679  0.0330  0.3303  4.4152
##
## Coefficients:
##          Estimate Std. Error t value Pr(>|t|)
## z.lag.1 -0.004458   0.003436  -1.298    0.195
##
## Residual standard error: 0.7457 on 572 degrees of freedom
## Multiple R-squared:  0.002935,   Adjusted R-squared:  0.001192
## F-statistic: 1.684 on 1 and 572 DF,  p-value: 0.195
##
##
```

```
## Value of test-statistic is: -1.2975
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

We have to know that Dickey-Fuller test is actually a test based on a regression. But we cannot rely on t-distribution for critical values. Authors of the test have provided critical values based on simulation runs. We use these critical values.

```
# z.lag.1 -0.004458   0.003436  -1.298    0.195
```

We can choose different number of lags, for example:

```
summary(ur.df(economics$psavert, type = "none", lags = 1))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.1062 -0.2916  0.0360  0.3387  4.2707
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.003929   0.003350  -1.173    0.241
## z.diff.lag -0.237688   0.040641  -5.849 8.36e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7256 on 570 degrees of freedom
## Multiple R-squared:  0.05939,    Adjusted R-squared:  0.05609
## F-statistic: 17.99 on 2 and 570 DF,  p-value: 2.641e-08
##
##
## Value of test-statistic is: -1.1729
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

```
summary(ur.df(economics$psavert, type = "none", lags = 2))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
```

```
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.8682 -0.3218  0.0190  0.3213  4.2287
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## z.lag.1     -0.003537   0.003312  -1.068    0.286
## z.diff.lag1 -0.277739   0.041308  -6.724 4.33e-11 ***
## z.diff.lag2 -0.167236   0.041309  -4.048 5.87e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7161 on 568 degrees of freedom
## Multiple R-squared:  0.08566,    Adjusted R-squared:  0.08083
## F-statistic: 17.74 on 3 and 568 DF,  p-value: 5.115e-11
##
##
## Value of test-statistic is: -1.0678
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

Or, we can allow the routine to automatically choose the best number of lags. Selection is based either to AIC:

```
summary(ur.df(economics$psavert, type = "none", selectlags = "AIC"))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.1062 -0.2916  0.0360  0.3387  4.2707
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.003929   0.003350  -1.173    0.241
## z.diff.lag -0.237688   0.040641  -5.849 8.36e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 0.7256 on 570 degrees of freedom
## Multiple R-squared:  0.05939,    Adjusted R-squared:  0.05609
## F-statistic: 17.99 on 2 and 570 DF,  p-value: 2.641e-08
##
##
## Value of test-statistic is: -1.1729
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

or to BIC selection criterion:

```
summary(ur.df(economics$psavert, type = "none", selectlags = "BIC"))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.1062 -0.2916  0.0360  0.3387  4.2707
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -0.003929   0.003350  -1.173    0.241
## z.diff.lag -0.237688   0.040641  -5.849 8.36e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7256 on 570 degrees of freedom
## Multiple R-squared:  0.05939,    Adjusted R-squared:  0.05609
## F-statistic: 17.99 on 2 and 570 DF,  p-value: 2.641e-08
##
##
## Value of test-statistic is: -1.1729
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

Another option we have is to allow for a drift, either with a fixed number of lags, for example:

```
summary(ur.df(economics$psavert, type = "drift", lags = 0))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
```

```
##
## Test regression drift
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.5773 -0.3268 -0.0068  0.2895  4.2371
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.27584    0.09468   2.913  0.00372 **
## z.lag.1     -0.03321    0.01044  -3.180  0.00155 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7409 on 571 degrees of freedom
## Multiple R-squared:  0.0174, Adjusted R-squared:  0.01568
## F-statistic: 10.11 on 1 and 571 DF,  p-value: 0.001551
##
##
## Value of test-statistic is: -3.1802 5.0966
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau2 -3.43 -2.86 -2.57
## phi1  6.43  4.59  3.78
```

or by allowing an automatically selected number of lags:

```
summary(ur.df(economics$psavert, type = "drift", selectlags = "AIC"))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression drift
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.0771 -0.3306 -0.0023  0.3104  4.1383
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.21574    0.09309   2.318   0.0208 *
## z.lag.1     -0.02646    0.01028  -2.574   0.0103 *
## z.diff.lag  -0.22658    0.04077  -5.558 4.21e-08 ***
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7228 on 569 degrees of freedom
## Multiple R-squared:  0.06806,    Adjusted R-squared:  0.06478
## F-statistic: 20.78 on 2 and 569 DF,  p-value: 1.955e-09
##
##
## Value of test-statistic is: -2.5742 3.3785
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau2 -3.43 -2.86 -2.57
## phi1  6.43  4.59  3.78
```

In the above test, test-statistic is -3.18. What does this mean?

Since $-3.18 < -2.86$ we reject the null hypothesis of unit at 5% level. But since $-3.18 > -3.43$ we cannot reject the null hypothesis at 1% level. Remember that in most of cases in empirical econometrics we are happy to reject the null at 5%. Here, we can say that time series is drift stationary.

Sometimes we need also to test stationarity in presence of trend. This can be done as follows, again either with a fixed number of lags, or by automatic selection of lags:

```
summary(ur.df(economics$psavert, type = "trend", lags = 1))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression trend
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.6525 -0.3363 -0.0061  0.2958  4.1055
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.0270465  0.2543677   4.038 6.14e-05 ***
## z.lag.1     -0.0819853  0.0191554  -4.280 2.19e-05 ***
## tt          -0.0011674  0.0003411  -3.422 0.000665 ***
## z.diff.lag  -0.1971119  0.0412977  -4.773 2.31e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7161 on 568 degrees of freedom
## Multiple R-squared:  0.08689,    Adjusted R-squared:  0.08206
## F-statistic: 18.02 on 3 and 568 DF,  p-value: 3.515e-11
##
##
## Value of test-statistic is: -4.28 6.199 9.232
##
```

```
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau3 -3.96 -3.41 -3.12
## phi2  6.09  4.68  4.03
## phi3  8.27  6.25  5.34
```

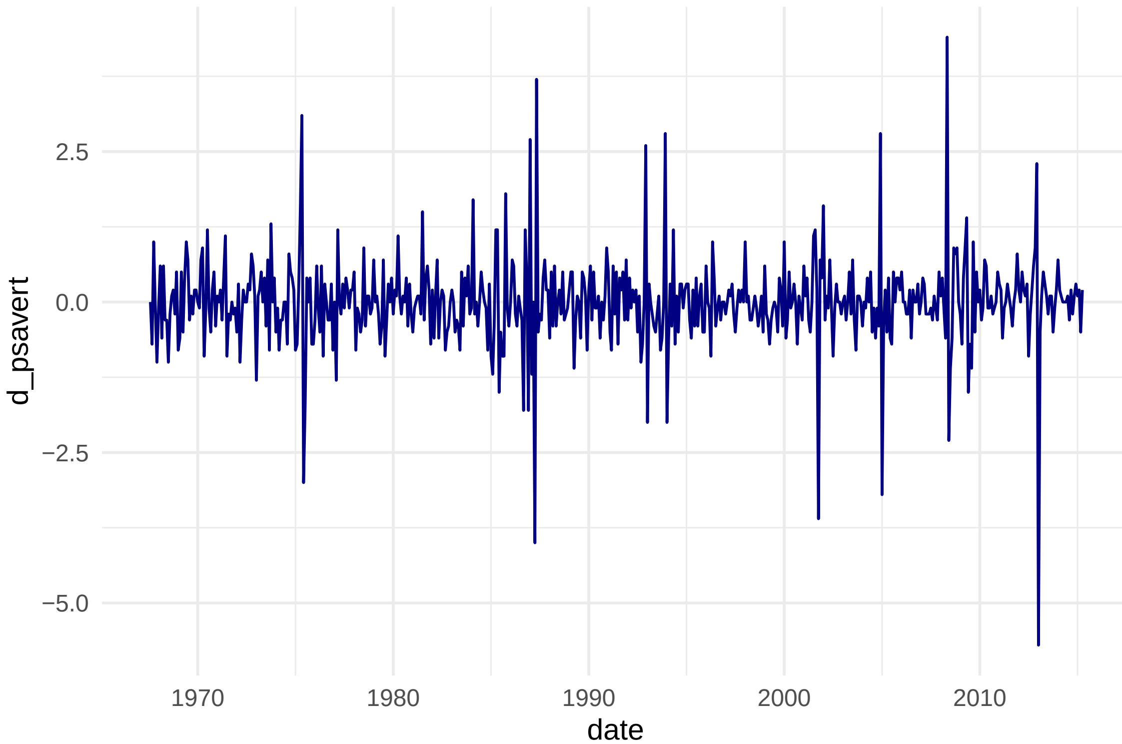
```
summary(ur.df(economics$psavert, type = "trend", selectlags = "AIC"))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression trend
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.6525 -0.3363 -0.0061  0.2958  4.1055
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.0270465  0.2543677   4.038 6.14e-05 ***
## z.lag.1     -0.0819853  0.0191554  -4.280 2.19e-05 ***
## tt          -0.0011674  0.0003411  -3.422 0.000665 ***
## z.diff.lag  -0.1971119  0.0412977  -4.773 2.31e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7161 on 568 degrees of freedom
## Multiple R-squared:  0.08689,    Adjusted R-squared:  0.08206
## F-statistic: 18.02 on 3 and 568 DF,  p-value: 3.515e-11
##
##
## Value of test-statistic is: -4.28 6.199 9.232
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau3 -3.96 -3.41 -3.12
## phi2  6.09  4.68  4.03
## phi3  8.27  6.25  5.34
```

Here, because $-4.28 < -3.96$ we reject the null hypothesis even at 1% level.

Practically this also means that in order to further use the **psavert** time series we should use it without trend. We thus would *detrend* time series. How? The most common approach is to use the first differences. Thus:

```
economics %>%
  mutate(d_psavert = c(NA, diff(psavert))) %>%
  ggplot(aes(x = date, y = d_psavert)) +
  geom_line(color = "navyblue", size = 0.5) +
  theme_minimal()
```



If we run the test on the first differences we get:

```
summary(ur.df(diff(economics$psavert), type = "none", selectlags = "AIC"))
```

```
##
## ###############################################
## # Augmented Dickey-Fuller Test Unit Root Test #
## ###############################################
##
## Test regression none
##
##
## Call:
## lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.9069 -0.3553 -0.0070  0.2942  4.2157
##
## Coefficients:
##            Estimate Std. Error t value Pr(>|t|)
## z.lag.1    -1.44705    0.06501 -22.259  < 2e-16 ***
## z.diff.lag  0.16795    0.04131   4.066 5.46e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7162 on 569 degrees of freedom
## Multiple R-squared:  0.6306, Adjusted R-squared:  0.6293
## F-statistic: 485.6 on 2 and 569 DF,  p-value: < 2.2e-16
##
##
```

```
## Value of test-statistic is: -22.2591
##
## Critical values for test statistics:
##       1pct  5pct 10pct
## tau1 -2.58 -1.95 -1.62
```

All in all: **psavert** is non-stationary at levels, but stationary at first differences.

What exactly we should test when we have a time series? How do we know what to do? Which test is appropriate? Ladies and gentlemen, welcome to applied econometrics and time series analysis.