Education and Culture
TEMPUS

# Time Series Analysis

## Course description

▷ The course will show how to build time series models for univariate and multivariate time series. It brings together material previously available only in the professional literature and presents a unified view of the most advanced procedures available for time series model building.

▷ The course begins basic concepts in univariate time series, providing an up–to–date presentation of ARIMA models, including Kalman filter, outlier analysis, automatic methods for building ARIMA models, and signal extraction. Then, it move on to advanced topics, focusing on nonlinear time series, non parametric time series analysis, vector ARMA models, cointegration and multivariate linear system.

## Basic bibliography

- *Time Series*, Daniel Peña, 2008.

## Additional bibliography


- *Time Series Analysis: Forecasting and Control*, by G.E.P. Box, G.M. Jenkins, and G. Reinsel, Prentice-Hall, 1994.
- *Introduction to Time Series Analysis and Forecasting*, by P.J. Brockwell and R.A. Davis, Springer-Verlag, 1996.
- *Time Series Analysis by State Space Methods*, by J. Durbin and S.J. Koopman, Oxford University Press, 2001.
- *Forecasting in Business and Economics*, by C.W.J. Granger, Academic Press, 1989.
- *Time Series Analysis*, by J. Hamilton, Princeton University Press, 1994.
- *A Course in Time Series Analysis*, by D. Peña, G.C. Tiao and R.S. Tsay, Wiley, 2001.
- *Analysis of Financial Time Series*, by R.S. Tsay, Wiley, 2005.

# Syllabus for the Module 1

1. Introduction to time series
2. Descriptive analysis of a time series
3. Time series and stochastic processes
4. Autoregressive, MA and ARMA processes
5. Integrated and long memory processes
6. Seasonal ARIMA processes
7. Forecasting with ARIMA models
8. Identifying possible ARIMA models
9. Estimation and selection of ARMA models
10. Model diagnosis and prediction

# 1. Introduction to time series

**Outline:**

- Examples of univariate time series
- Examples of multivariate time series
- Software for time series analysis

**Recommended readings:**

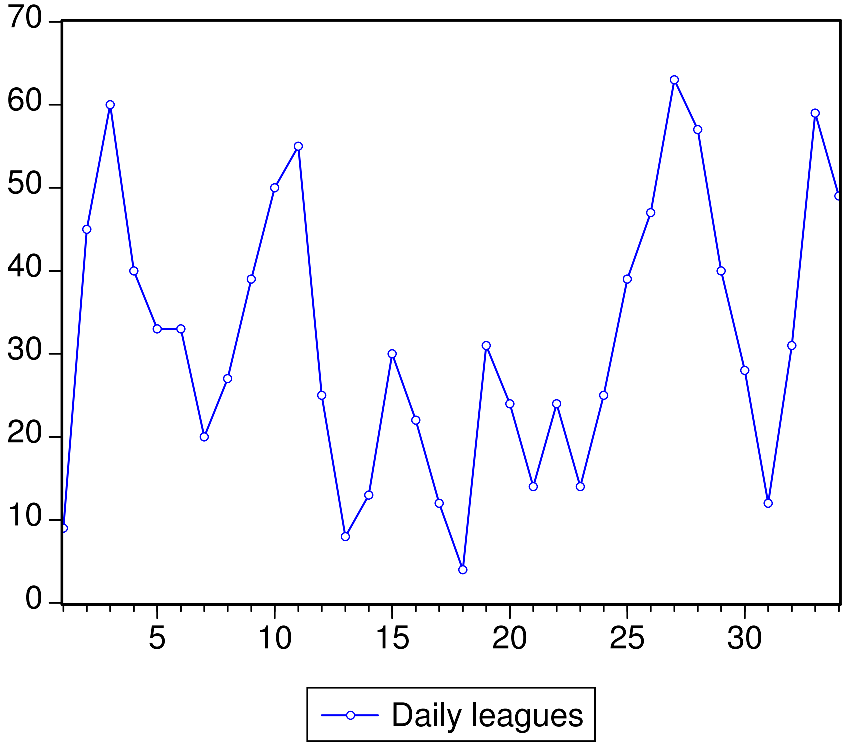
▷ Chapter 1 of D. Peña (2008).

▷ Chapter 1 of P.J. Brockwell and R.A. Davis (1996).

# Examples of univariate time series

▷ A time series is the result of observing the values of a variable over time during regular intervals (every day, every month, every year, etc.).

**Example 1.** *The figure shows the daily trajectory, measured in nautical leagues, of Christopher Columbus's fleet during his first voyage to America.*



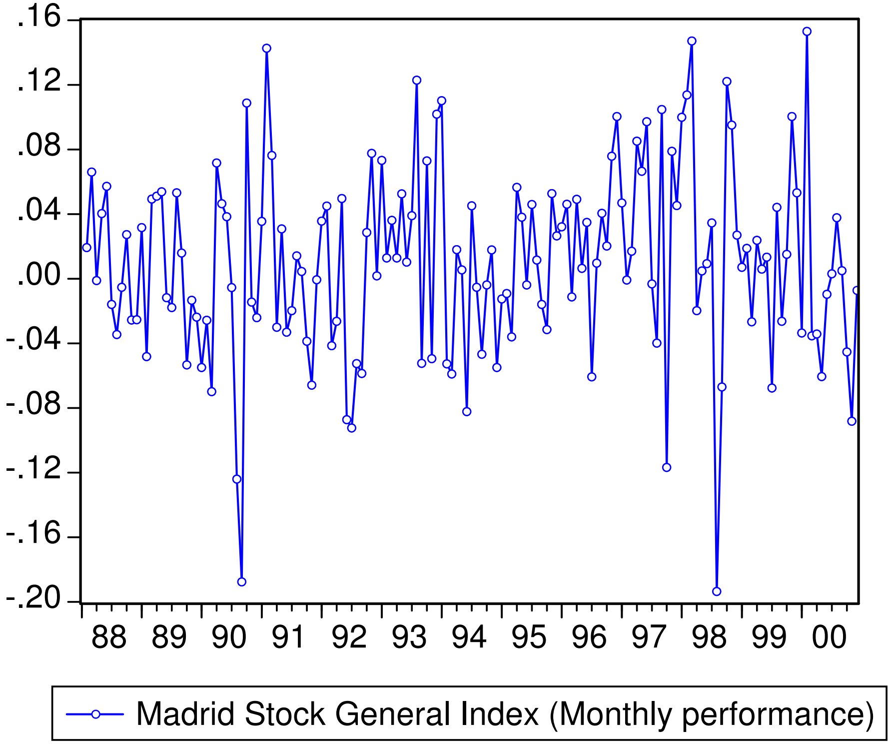

▷ Notice that the series is stable, with values that oscillate around an average daily distance of some 30 leagues.

▷ The graph of this series shows no clear increasing or decreasing trend.

Datafile `columbus.wf1`

# Examples of univariate time series

**Example 2.** *The figure gives the average monthly performance of the Madrid Stock Exchange during the period of 1988 to 2000 as measured by the General Index. Performance has been calculated as the relative difference between the average value of stocks at the beginning and end of each month.*



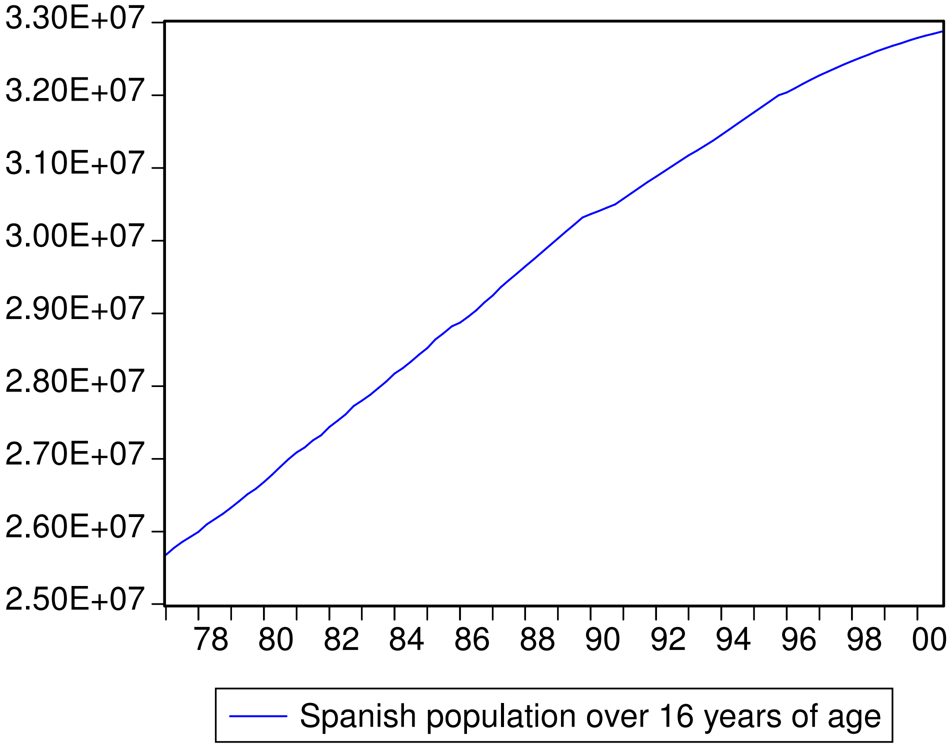

▷ Notice that the values of the series seem to move around a monthly performance of 0.00722, equivalent to 8.66% (0.00722x12=.08664) annually.

▷ As with the previous series, this one has a fixed level, with no increasing or decreasing trends over time.

Datafile `madridstockindex1988-2000.wf1`

# Examples of univariate time series

**Example 3.** *The figure shows a series which, unlike the previous two, is not clearly stable in time, and is what we call non-stationary. The series corresponds to the Spanish population over 16 years of age at the end of each quarter during the period of 1977 to 2000.*



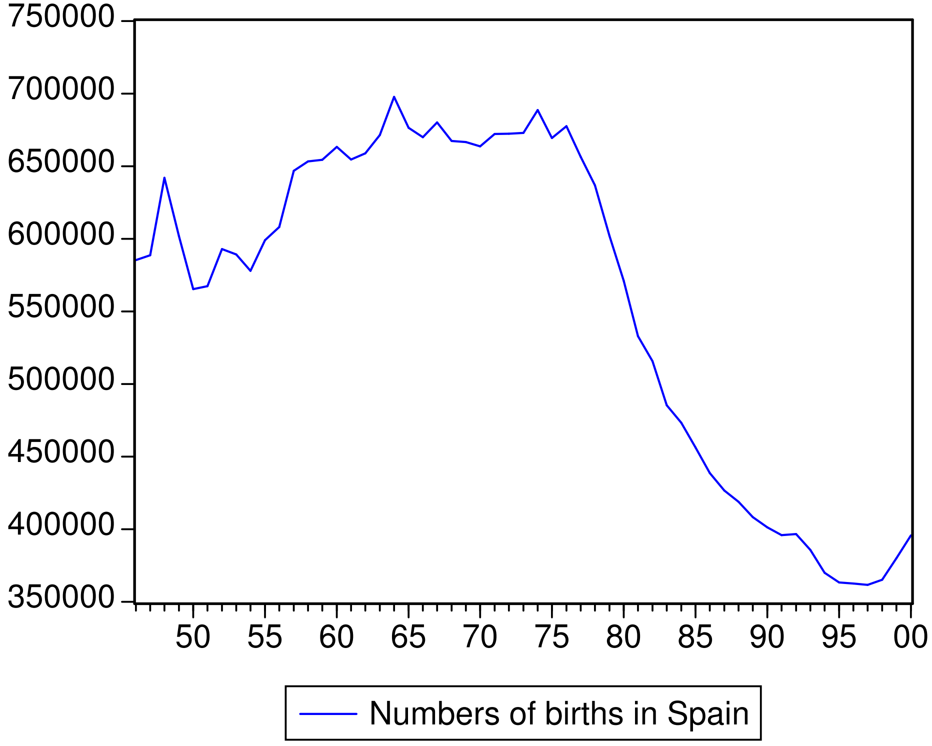

▷ Notice in the graph that the series is not stable, since its level increases over time. We say that the series has a clear, positive trend.

▷ Most economic and social series are not stationary (stable) and show trends which are more or less constant over time.

Datafile `spanishover16.wf1`

# Examples of univariate time series

**Example 4.** *The figure shows the numbers of births per year in Spain from 1946 to 2000. This annual series is not stable, since it does not oscillate around any fixed level.*



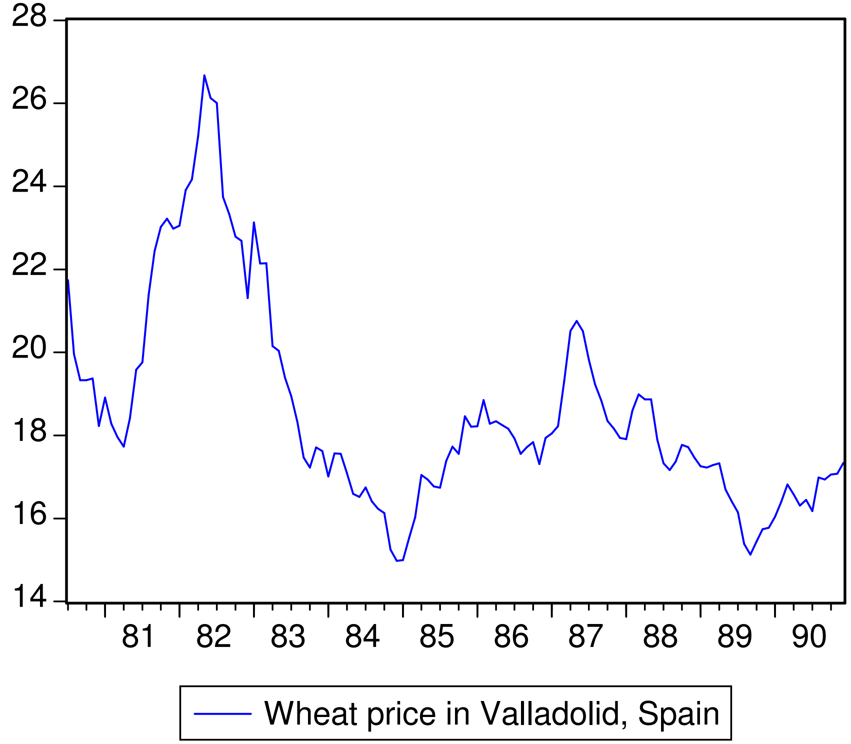

▷ The series does not show a growing or decreasing linear trend in the period: births in Spain increased in the 1950s and 1960s, then stabilized from 1965 to 1976 and after 1977 began to decrease. This drop continues until the end of the 1990s, where a slight recovery can be observed.

▷ Hence, this series shows an evolutionary trend or one that is changing over time.

Datafile `spanishbirths.wf1`

# Examples of univariate time series

**Example 5.** *The figure gives another non-stationary series: the monthly price of wheat in Valladolid (Spain) from July, 1880 to December 1890.*



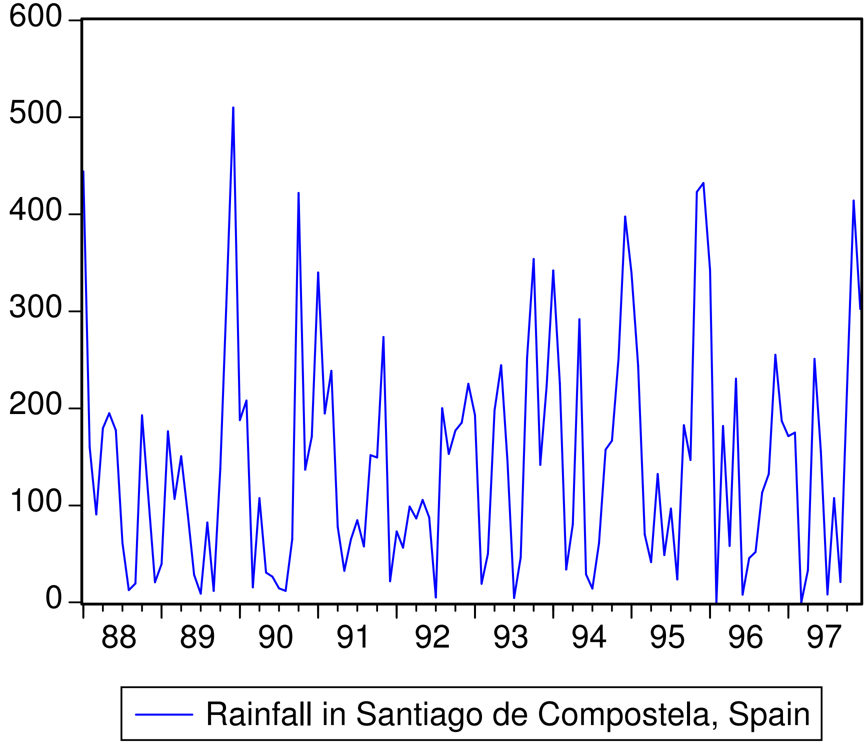

▷ Again, the series shows no evolution around a fixed level and has a variable level over time.

▷ The price of wheat rose sharply in 1882, but later dropped and in the last years experienced fewer fluctuations than in the first years of the sample.

Datafile `wheatprice.wf1`

# Examples of univariate time series

**Example 6.** *The figure shows monthly rainfall in Santiago de Compostela (Spain) over ten years and is an example of a seasonal time series.*



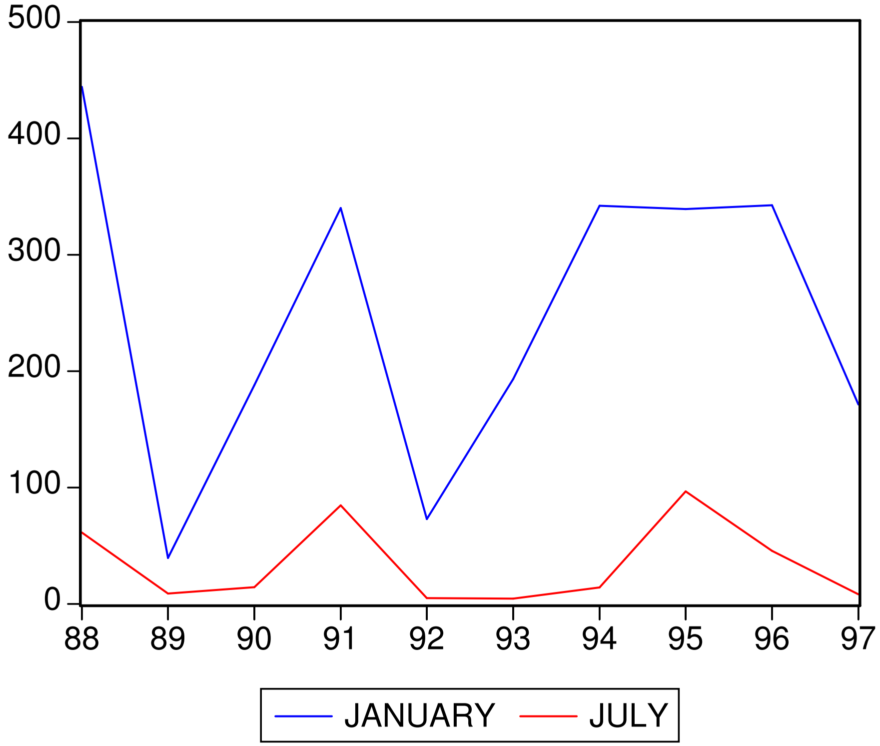

▷ Notice that the series oscillates around a central value, but with some months systematically having more rain than others.

▷ For example, the summer months have less precipitation than winter months. This effect would be visible in the graph if we marked the months, but we can see them better by plotting graphs for each month.

Datafile `rainfall.wf1`

# Examples of univariate time series

**Example 6.** *The figure gives the precipitation in January and July of different years.*

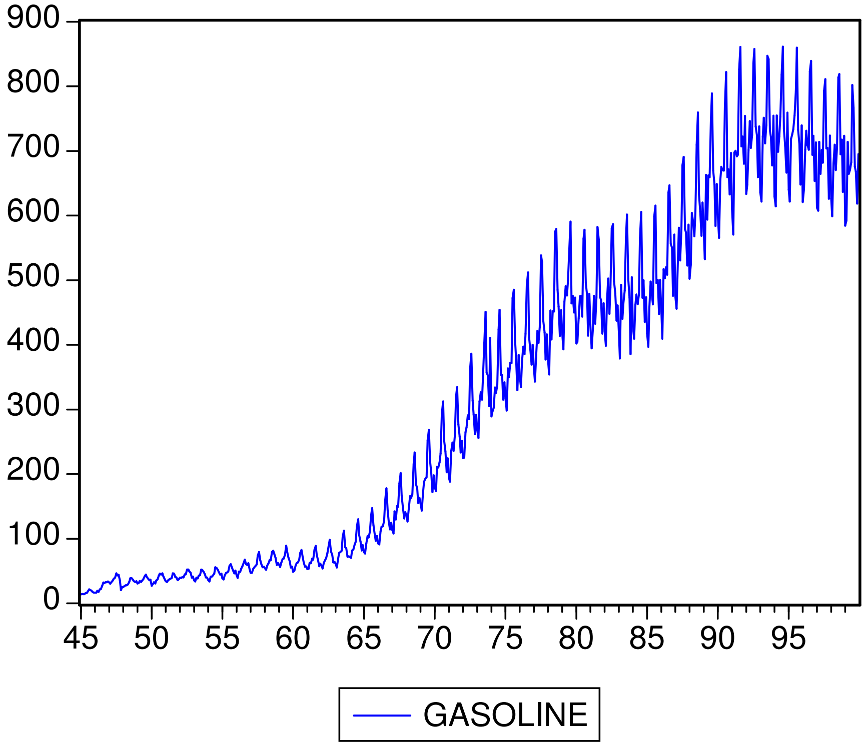



▷ Notice that in both cases the series oscillate around a central value, and that there are years where both are relatively high, wet years, compared to others where both are low, dry years.

▷ Nevertheless, what stands out most in this graph is that the average values of both series are very different. This phenomenon, where the average value of the time series depends on the month being considered, is called seasonality.

# Examples of univariate time series

**Example 7.** *This series combines trends and seasonality and corresponds to monthly gasoline consumption in Spain. We see an overall growth trend in the series, although this trend is non-linear and combines periods of growth with others of stability and decline.*



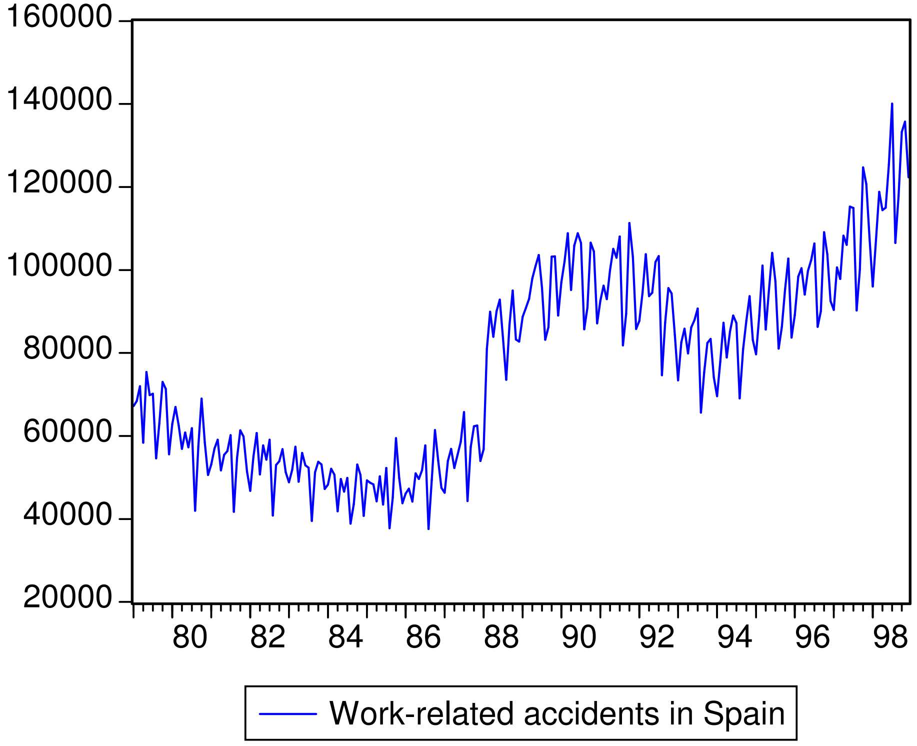

▷ Moreover, the series shows marked seasonality, with peaks and valleys in different months.

▷ The peaks in the graph correspond to the months of July and August, when gasoline consumption increases greatly due to the arrival of tourists and summer travel.

Datafile `gasoline.wf1`

# Examples of univariate time series

**Example 8.** *The figure shows both seasonality and changing level once again. This series corresponds to the number of work related accidents per month in Spain from 1979 to 1998.*




▷ Notice that the series has varied the trend: first decreasing then later increasing.

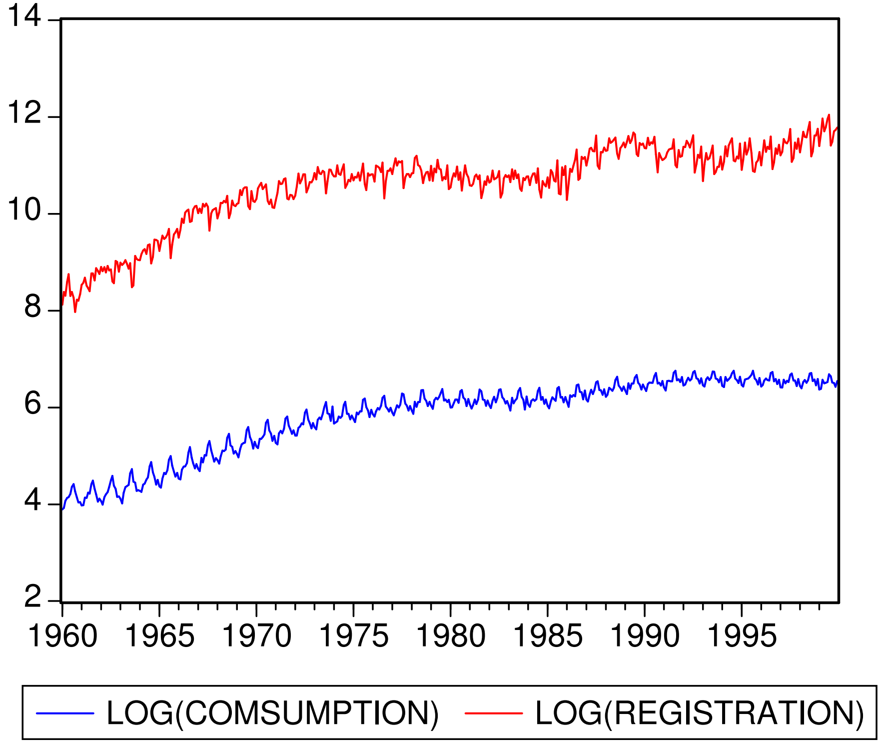
▷ The series also has a regular yearly pattern, due to seasonality.

Datafile `workaccident.wf1`

# Examples of multivariate time series

▷ In addition to studying the historical evolution of a single series, the time series models that we are going to look at allow us to study the dynamic relationship between two or more series.

**Example 9.** *The figure presents the vehicle registration and gasoline consumption in Spain from 1960 to 1999.*




▷ Notice that the increase in registration during the first years of the sample generated a clear increase in gasoline consumption. But, this is not observed in the last period.

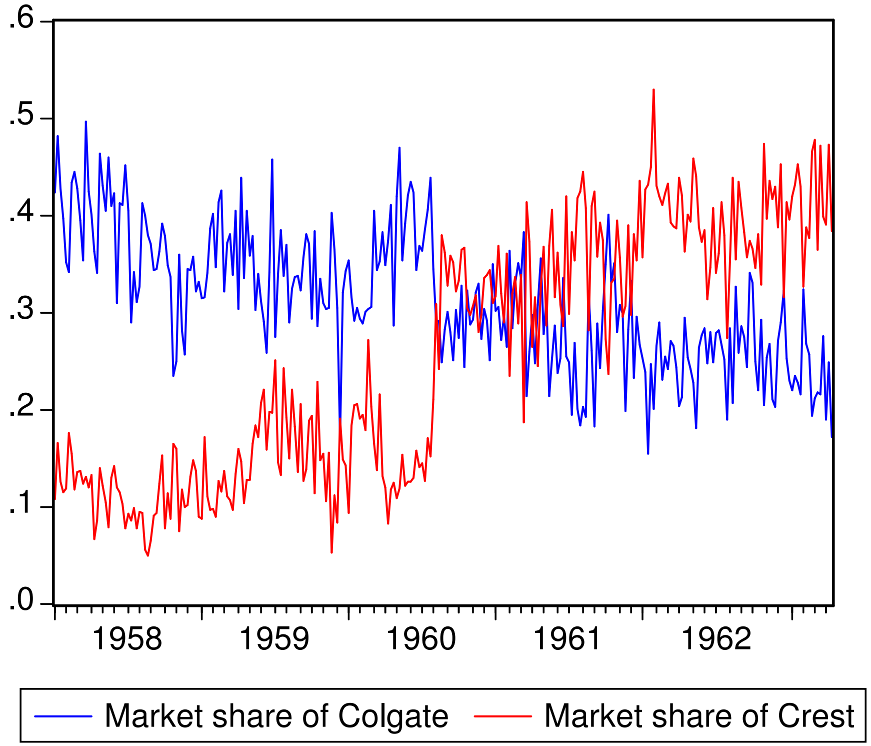
▷ In these two series we expect there to be a relationship that goes from the number of automobiles to gasoline consumption but not in the reverse way.

Datafile `registrationVSconsumption.wf1`

# Examples of multivariate time series

▷ The relationships between dynamic variables can go in both directions.

**Example 10.** *The figure shows the evolution of weekly market share of Crest and Colgate toothpaste taken during the weeks between January 1958 and April 1963. Both series are non-stationary with a level that changes over time.*



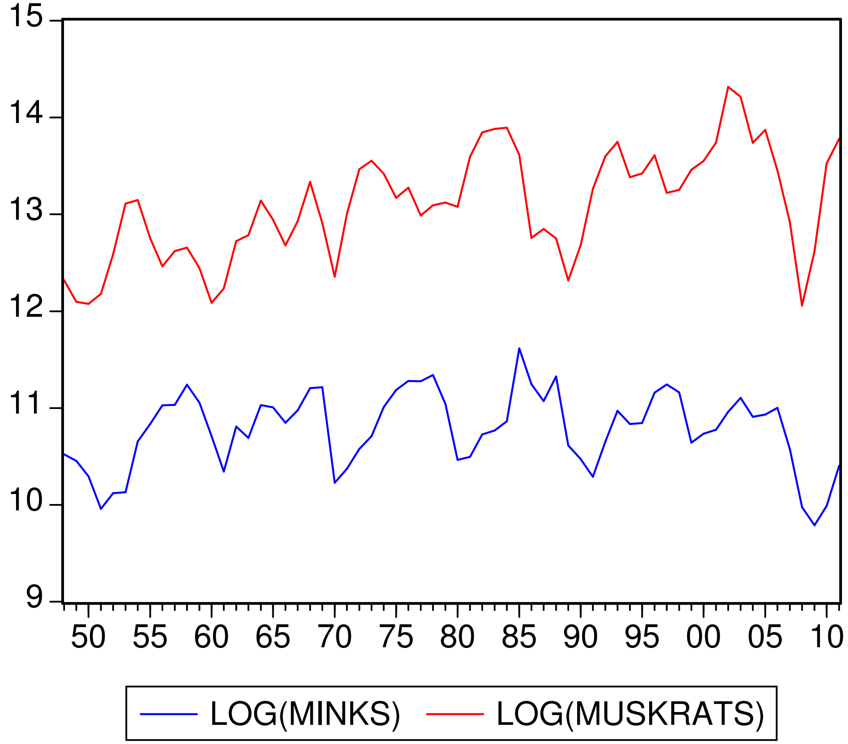

▷ In the first period we observe an increase in Crest's market share, which is accompanied by a drop in Colgate's share.
▷ Around observation 136 a sharp rise occurs in Crest's market share but this rise does not produce a similar decrease in that of Colgate, which continues a downward trend.

Datafile `crestVScolgate.wf1`

# Examples of multivariate time series

▷ Another example where the dynamic relationship goes in both directions.

**Example 11.** *The figure shows the logarithm of the yearly estimated population of muskrats and minks in Canada from 1848 to 1911. The two series are non-stationary, with a gradual increase in the muskrat population and small level shifts in the mink population.*



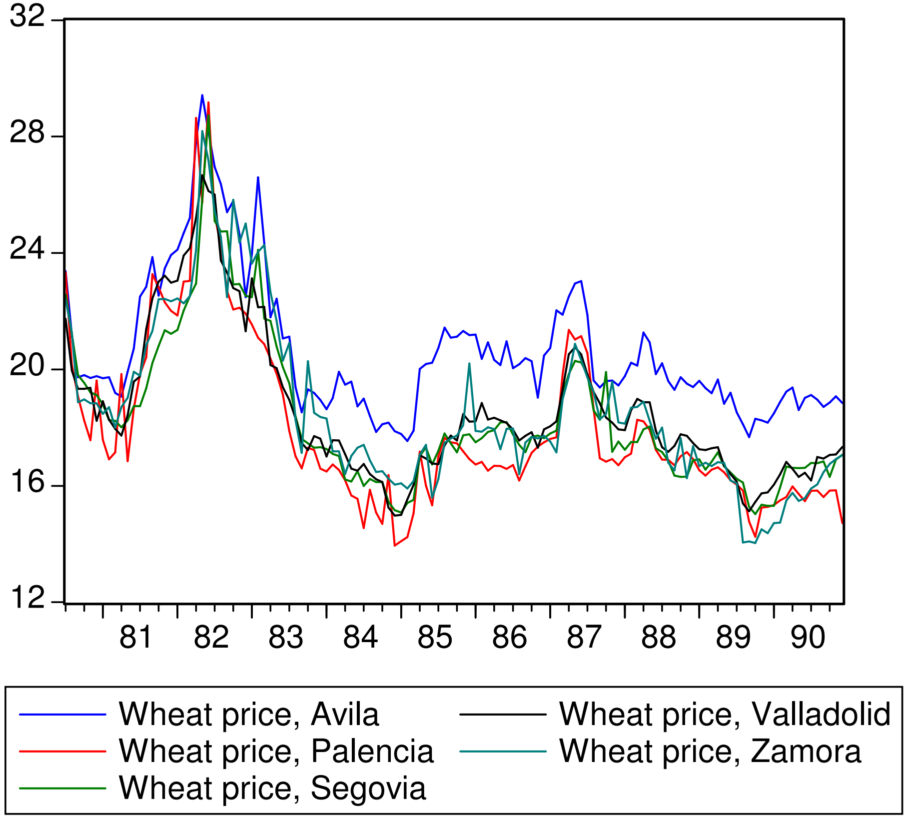

▷ The relationship between the two series is one of predator - prey; since the mink eats the muskrat, an increase in the muskrat population means more food for the minks, and their population increases as well.

▷ But, it is to be expected that the increase in the mink population will eventually produce a drop in muskrats.

Datafile `minksVSmuskrats.wf1`

# Examples of multivariate time series

**Example 12.** *The figure gives wheat prices in five Spanish provinces, Avila, Palencia, Segovia, Valladolid and Zamora. The series are non-stationary and seem to evolve with a similar pattern.*




▷ We might ask ourselves if a common evolutionary pattern exists in all of them.

▷ The identification of common factors in time series is an important question and one which will be addressed at the end of this course.

Datafile `wheatprice.wf1`

# Summary

- Time series may or may not have a stable level over time, and if they do not have one, they can present trends which are more or less constant.
  - ◇ When the level of the series is stable over time we say that the time series is stationary.
  - ◇ Otherwise we say it is non-stationary.
    - ▷ A particular case of non-stationarity is when the level varies following a cycle, which is what happens with monthly temperatures during the year.
    - ▷ We say then that the series is seasonal and this aspect can be combined with more or less noticeable trends in the general level.

- In addition to studying the evolution of a single series, a richer time series models should consider the dynamic relationship between two or more series.

- The graph of the series is always an invaluable tool for understanding its behavior.

# Software for time series analysis

▷ For modelling time series it is essential to have access to a statistical package capable of handling the necessary calculations.

▷ Unfortunately no single easily accessible program exists which allows us to apply all available procedure, and in the different applications we have used different programs.

- Statgraphics, Minitab, SPSS: provide the basic tools for identifying and estimating a univariate model for a time series, but it does not allow us to deal with outliers, nor does it permit dynamic regression or multivariate analysis.

- TSW program is based on the TRAMO/SEATS program and permits very complete analyses of univariate time series. It is specially designed for analyzing many economics series. It can be downloaded for free at the Bank of Spain (Banco de España): `http:www.bde.esserviciosoftwaretsw.htm`.

# Software for time series analysis

- The **Eviews** program is also easy to use, includes univariate and multivariate models and is oriented towards econometrics. The last version of EViews contains the routines implemented in TRAMO/SEATS.

- The **R** program includes many possibilities for more sophisticated analysis and can be programmed, which makes it more flexible. **R** is quite similar to S-plus and can be downloaded for free at: `http:www.r-project.org`.

- The Matlab program is very flexible programming languages, but are less well suited than the above programs for routine analysis of time series. There is a free version called **Octave** that can be downloaded at: `http:www.octave.org`.

- The SCA program is the most complete of those available, but it is not as easy to use, although it does include excellent algorithms for maximum likelihood estimation, processing of outliers and multivariate modeling.