# 1. An Introduction to Time Series

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## Outline

1. Some representative time series
2. Terminology
3. Objectives of time series analysis

# Examples: Economic time series

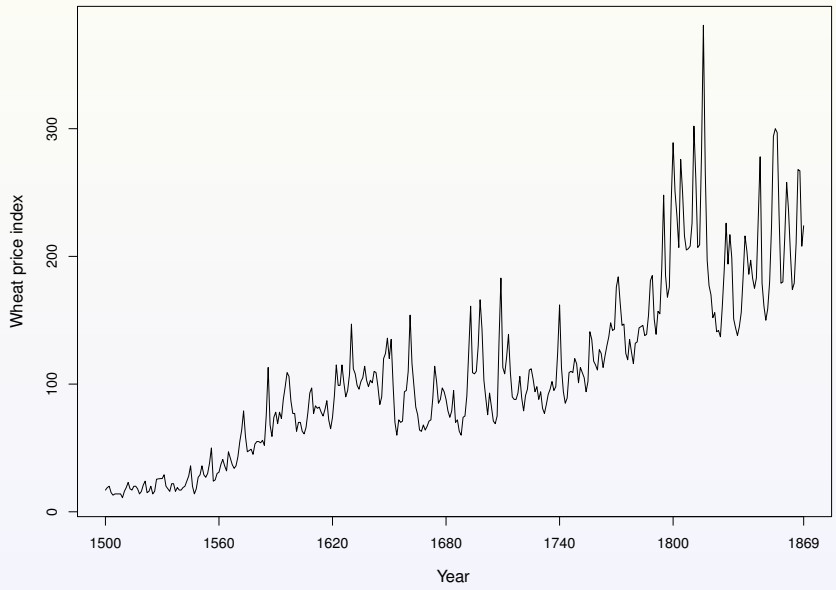


**Figure 1.1:** The Beveridge wheat price annual index series from 1500 to 1869.





# Examples: Economic time series

- The classic Beveridge wheat price index series consists of the average wheat price in nearly 50 places in various countries measured in successive years from 1500 to 1869 (Beveridge, 1921).
- To plot the data using the R statistical package, you can load the data `bev` in the `tseries` package and plot the time series (the > below are prompts):

```
> library(tseries)     # load the library
> data(bev)    # load the dataset
> plot(bev, xlab="Year", ylab="Wheat price index", xaxt="n")
> x.pos<-c(1500, 1560, 1620, 1680, 1740, 1800, 1869)
          # define x-axis labels
> axis(1, x.pos, x.pos)
```

# Examples: Financial time series

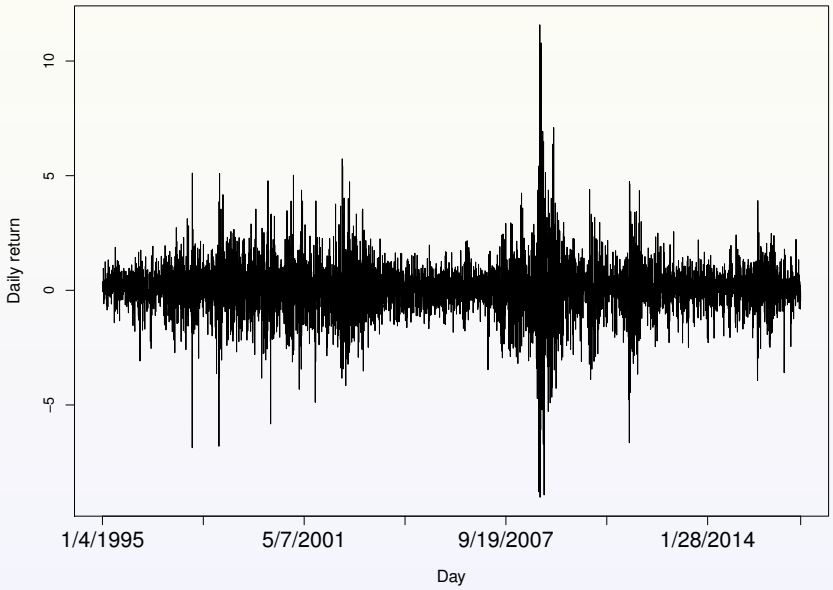


**Figure 1.2:** Daily returns of the adjusted closing prices of S&P500 index from January 4, 1995 to December 30, 2016.





# Examples: Financial time series

- The mean of the return series seems to be stable with an average return of approximately zero, but the volatility of data changes over time.
- To reproduce Figure 1.2 in R, suppose you save the data as `sp500_ret_1995-2016.csv` in the directory `mydata`. Then you can use the following command to read the data and plot the time series.

```
> sp500<-read.csv("mydata/sp500_ret_1995-2016.csv")
> n<-nrow(sp500)
> x.pos<-c(seq(1,n,800),n)
> plot(sp500$Return, type="l", xlab="Day",
     ylab="Daily return", xaxt="n")
> axis(1, x.pos, sp500$Date[x.pos])
```

# Examples: Physical time series

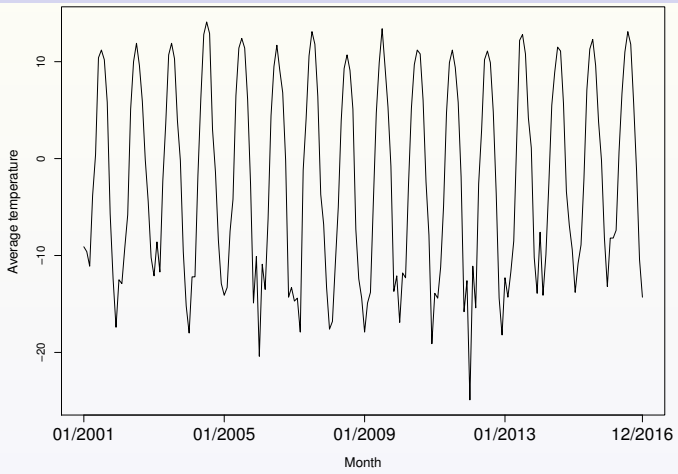


**Figure 1.3:** Monthly average air temperature (deg C) in Anchorage, Alaska, the United States, in successive months from 2001 to 2016.

Many types of time series occur in the physical sciences, particularly in meteorology, marine science and geophysics. Examples are rainfall on successive days, and air temperature measured in successive hours, days or months.





# Examples: Marketing time series

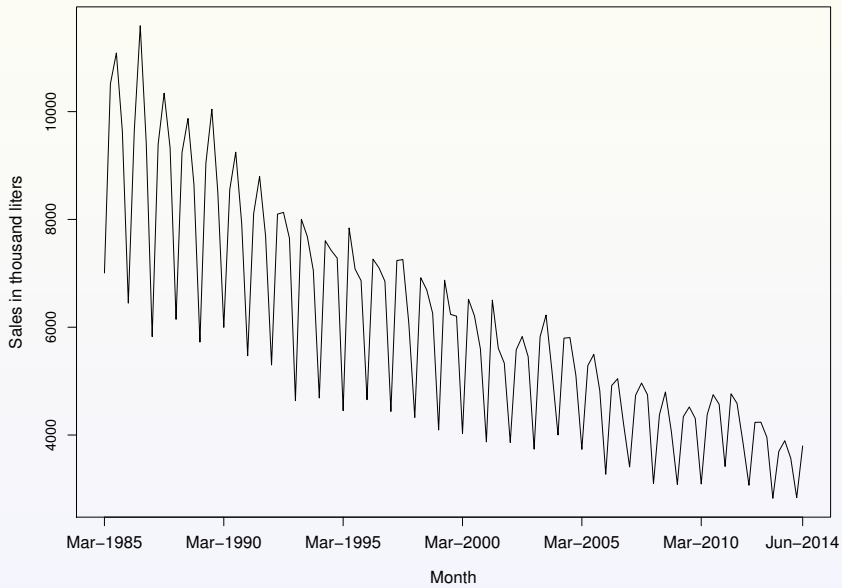


**Figure 1.4:** Domestic sales (unit: thousand liters) of Australian fortified wine by winemakers in successive quarters from March 1985 to June 2014.

## Examples: Marketing time series

- The analysis of time series arising in marketing is an important problem in commerce. Observed variables could include sales figures in successive weeks or months, monetary receipts, advertising costs and so on.
- As an example, Figure 1.4 shows the domestic sales of Australian fortified wine by winemakers in successive quarters over a 30-year period, which are available at the Australian Bureau of Statistics (`http://www.abs.gov.au/AUSSTATS/`).
- Note the trend and seasonal variation which is typical of sales data. It is often important to forecast future sales so as to plan production. It may also be of interest to examine the relationship between sales and other time series such as advertising expenditure.





## Examples: Demographic time series

- Various time series occur in the study of population change. Examples include the total population of Canada measured annually, and monthly birth totals in England.
- Figure 1.5 shows the total population and crude birth rate (per 1,000 people) for the United States from 1965 to 2015. The data are available at the U.S. Federal Reserve Bank of St. Louis (`https://fred.stlouisfed.org/`).
- Demographers want to predict changes in population for as long as 10 or 20 years into the future, and are helped by the slowly changing structure of a human population.

# Examples: Demographic time series

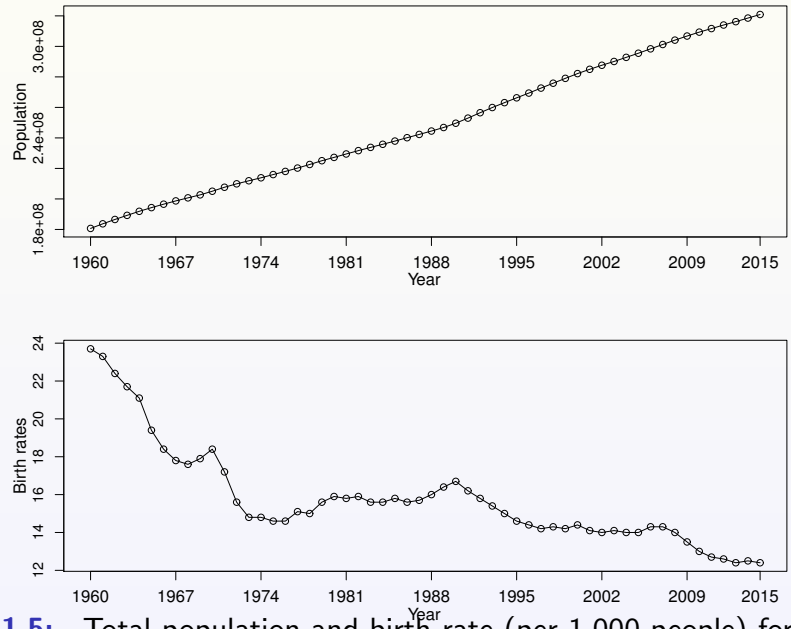


**Figure 1.5:** Total population and birth rate (per 1,000 people) for the United States from 1965 to 2015.





# Examples: Point processes

- A special type of time series occurs when we consider a series of events occurring 'randomly' through time. For example, we could record the dates of major railway disasters. A series of events of this type is usually called a **point process**.
- As an example, Figure 1.6 shows the intraday transaction data of the International Business Machines Corporation (IBM) from 9:35:00 to 9:38:00 on January 4, 2010. When a trade event occurs, the corresponding trading price and trading volume are observed. However, trades do not occur equally spaced in time; hence time intervals between trades (or trade durations) are considered as random variables.
- For observations of this type, we are interested in such quantities as the distribution of the number of events occurring in a given time period and distribution of time intervals between events. Methods of analysing point process data are generally very different from those used for analysing standard time series data.

# Examples: Point processes

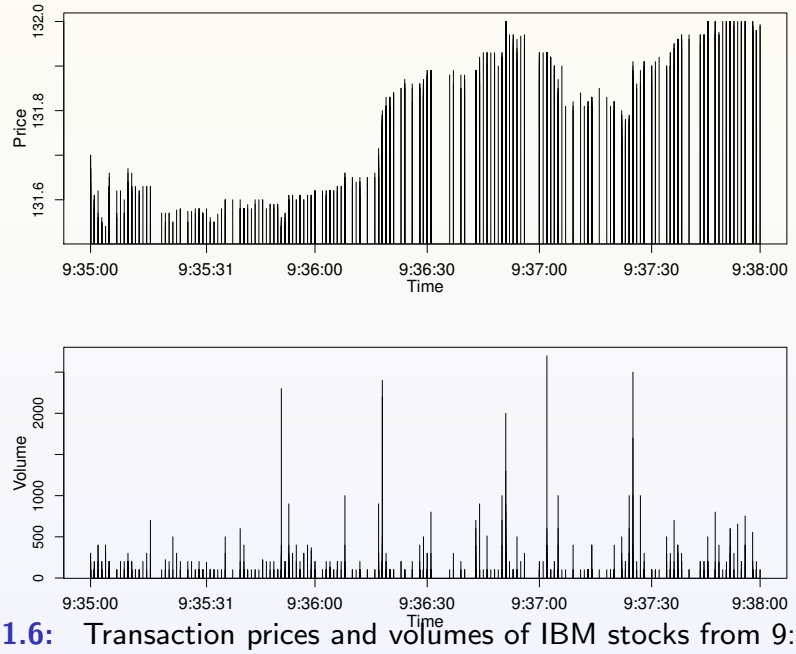


**Figure 1.6:** Transaction prices and volumes of IBM stocks from 9:35:00 to 9:38:00 on January 4, 2010.





# Terminology

- A time series is said to be **continuous** when observations are made continuously through time. A time series is said to be **discrete** when observations are taken only at specific times, usually equally spaced.
- Discrete time series can arise in several ways.
  - Given a continuous time series, we could read off (or digitise) the values at equal intervals of time to give a discrete time series, sometimes called a **sampled** series. The sampling interval between successive readings must be carefully chosen so as to lose little information.
  - A different type of discrete series arises when a variable does not have an instantaneous value but we can **aggregate** (or accumulate) the values over equal intervals of time. Examples of this type are monthly exports and daily rainfalls.
  - Some time series are inherently discrete, an example being the dividend paid by a company to shareholders in successive years.

# Objectives of time series analysis

- Description. When presented with a time series, the first step in the analysis is usually to plot the observations against time to give what is called a **time plot**, and then to obtain simple descriptive measures of the main properties of the series.
- Explanation. When observations are taken on two or more variables, it may be possible to use the variation in one time series to explain the variation in another series.
- Prediction. Given an observed time series, one may want to predict the future values of the series. This is an important task in sales forecasting, and in the analysis of economic and industrial time series.
- Control. Time series are sometimes collected or analysed so as to improve control over some physical or economic system.