

# Time Series Analysis

## Introduction

Introduction

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Introduction

# **What Are Time Series?**

# What are time series?

**Time series:** Data obtained from observations collected sequentially over time.

## **Examples:**

- Business: Yearly sales figures, monthly price indices, weekly interest rates, daily currency exchange rates, tick-by-tick stock prices, ...
- Meteorology: Daily high and low temperatures, annual precipitation and drought indices, hourly wind speeds, ...
- Ecology: Plant and animal abundance over time, ...
- Agriculture: Annual figures for crop and livestock production, soil erosion, export sales, ...
- Life sciences: Electrical activity of the heart at millisecond intervals, ...

# What are time series?

**Notation:** Observations  $Y_t$ , at time  $t = 1, \dots, T$ .

## **Distinguish:**

- univariate vs. multivariate,
- regular (equidistant) vs. irregular,
- discrete vs. continuous time.

## **Analysis goals:**

- *Explanation:* Understand or model the stochastic mechanism underlying a series.
- *Prediction:* Forecast future values of a series based on its history or other series.

Introduction

# **Time Series in Econometrics**

# Time series in econometrics

## **Examples** for economic data:

- Cross-section data: data for 5,000 households for the year 2009.
- Time series data: data for one country over 25 years.
- Panel data: 5,000 households over 5 years (“micropanel”), or 12 countries over 25 years (“macropanel”).

## **Typically:**

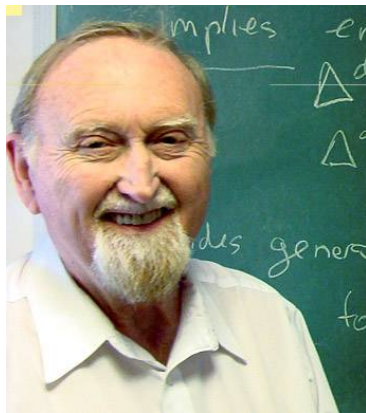
- Microeconometrics: Cross-sectional data and micropanels.
- Macroeconometrics: Time series data and macropanels.



# Time series in econometrics

- *Econometric Society*, founded 1930-12-19 in Cleveland. Co-founder Ragnar Frisch *Econometrica*, Vol. 1, 1933: “international society for the advancement of economic theory in its relation to statistics and mathematics.” (also: <http://en.wikipedia.org/wiki/Econometrics>)
- First Nobel Prize in Economics in 1969 for Ragnar Frisch and Jan Tinbergen.
- Many subsequent Nobel Prizes for econometricians or economists with strong quantitative research.
- In 2003 for two “time series econometricians”: *Robert F. Engle III* (“for methods of analyzing economic time series with time-varying volatility (ARCH)”), *Clive W.J. Granger* (“for methods of analyzing economic time series with common trends (cointegration)”). ([http://nobelprize.org/nobel\\_prizes/economics/laureates/2003/](http://nobelprize.org/nobel_prizes/economics/laureates/2003/))

# Time series in econometrics?



Introduction

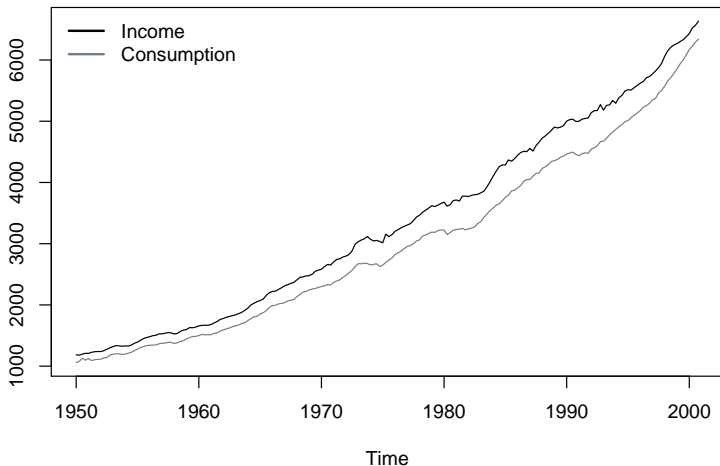
# Examples

# Examples

- USMacroG: Quarterly US macroeconomic variables (e.g., income, consumption, ...), 1950(1) to 2000(4), Greene (2003).
- EuStockMarkets: Daily closing prices (in business days) of major European stock indices: DAX, SMI, CAC, FTSE.
- UKNonDurables: Quarterly UK non-durables consumption, 1955(1) to 1988(4).
- AirPassengers: Monthly airline passenger numbers (in thousands), 1949(1) to 1960(12), Box & Jenkins (1976).
- UKDriverDeaths: Monthly totals of car drivers in Great Britain killed or seriously injured, 1969(1) to 1984(12).
- MarkPound: Daily DEM/GBP exchange rates returns (in %), 1984-01-03 through 1991-12-31.
- bev: Annual Beveridge Wheat Price Index 1500 to 1869.
- DutchAdvert: Four-weekly television and radio advertising expenditures in The Netherlands, 1978(1) to 1994(13).
- PepperPrice: Average monthly European spot prices for black and white pepper (USD/ton), 1973(10) to 1996(4).

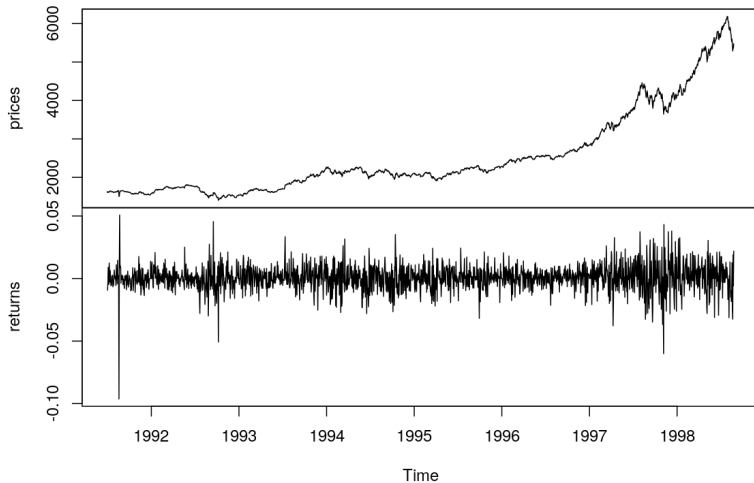
# Examples

## US macroeconomic data



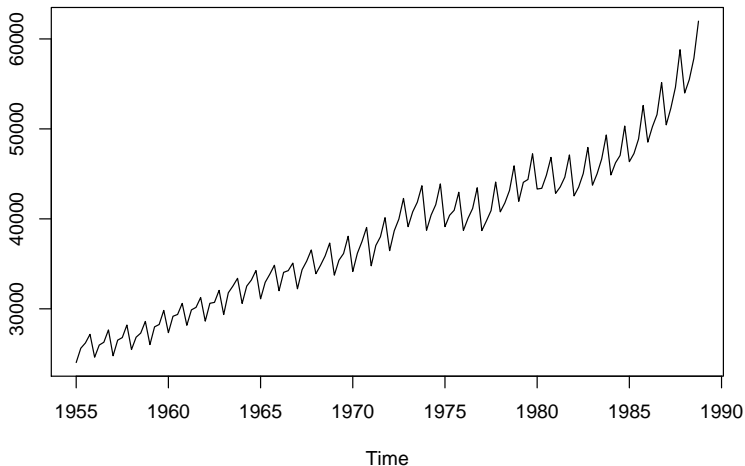
# Examples

## DAX



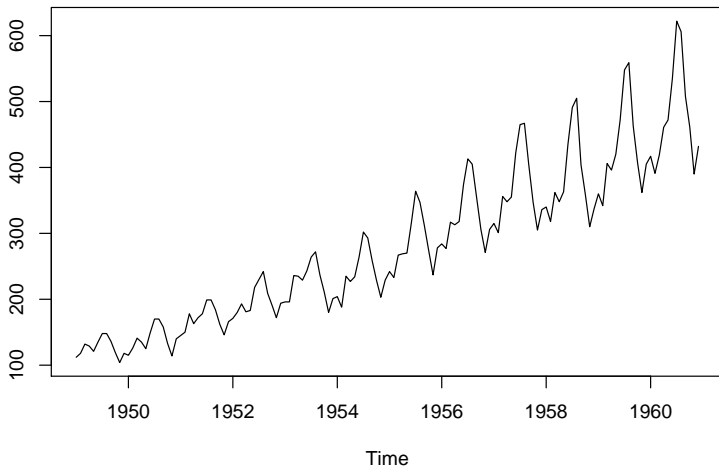
# Examples

## Consumption of non-durables in the UK



# Examples

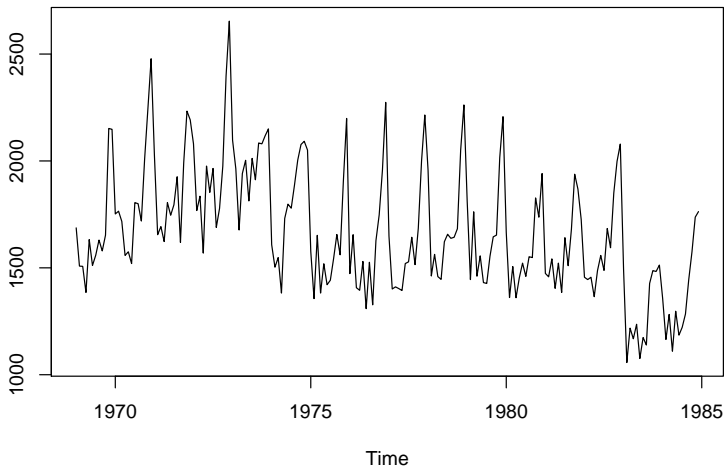
**Airline passenger totals**





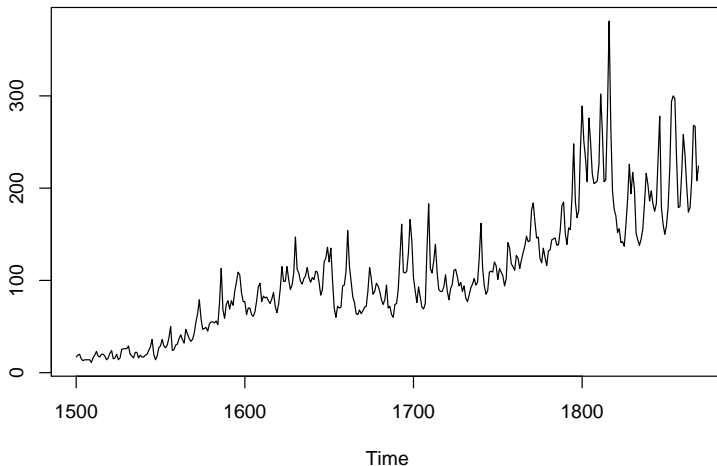
# Examples

## UK car drivers killed or seriously injured



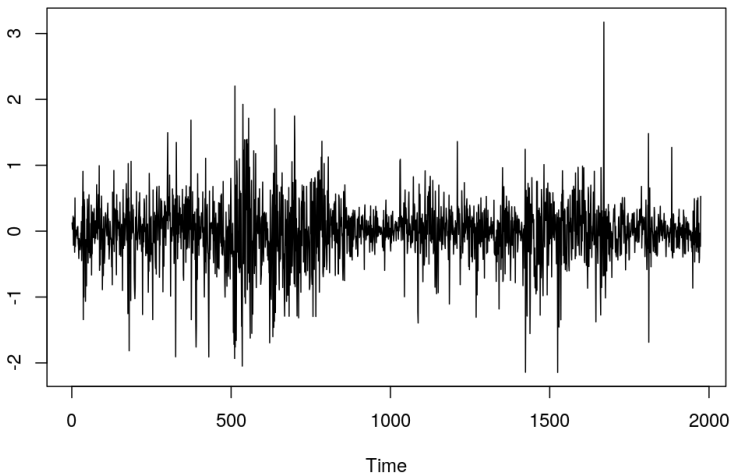
# Examples

## Beveridge Wheat Price Index



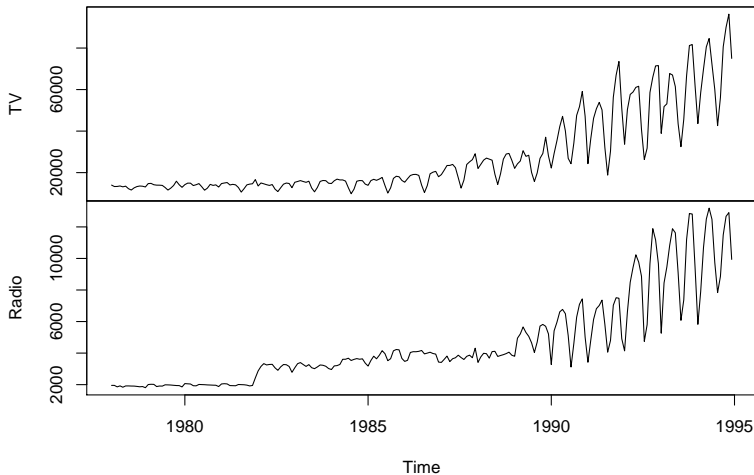
# Examples

## DEM/GBP exchange rate returns



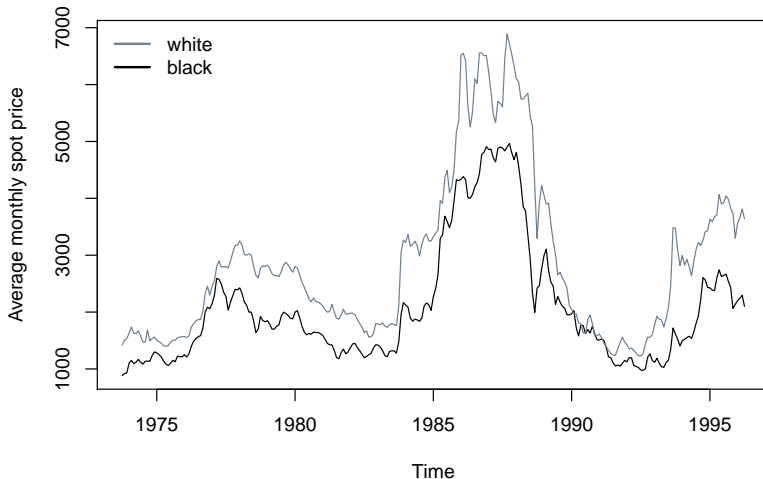
# Examples

## Dutch advertising expenditures



# Examples

**European pepper prices**



Introduction

# **A Model-Building Strategy**

# A model-building strategy

**Idea:** Based on seminal work of Box and Jenkins (1976).

**Steps:** Search for model through iteration.

- 1 *Model specification/identification:* Select classes of potentially appropriate models. Employ visualizations, summary statistics, and subject-matter knowledge. Follow principle of parsimony (“Everything should be made as simple as possible but not simpler.” attributed to Einstein).
- 2 *Model fitting:* Estimate the parameters of the model from the observed series, e.g., via least squares (LS) or maximum likelihood (ML) among others.
- 3 *Model diagnostics:* How well does the model fit the data? Are the assumptions reasonably well satisfied?

Introduction

# Software



# Software

**Pluralism:** There are many different statistics/econometrics software packages with time series functionality. Some caution (i.e., even more caution than for non-time-series software) is necessary when comparing results of computations. Differences can be due to differences in estimation methods, parametrizations, starting values, ...

**Here:** R system for statistical computing with extension packages from the Comprehensive R Archive Network (CRAN).

**Warning:** Implementations are not necessarily unified across CRAN packages, i.e., there can be differences as pointed out above.

**Base system:** The base R system ships with many classical time series methods (estimation/simulation of ARIMA models, computation of autocorrelations, ...)

# Software

## CRAN packages:

- *forecast*: Methods for (automatic) forecasting.
- *tseries*: Time series and financial econometrics.
- *urca*: Unit roots, and cointegration analysis.
- *vars*: (Structural) vector autoregression.
- *strucchange*: Testing, monitoring, and dating structural changes.
- *Rmetrics*: Large collection of packages for financial econometrics (e.g., *timeSeries*, *fGarch*).
- *AER*: Data accompanying Kleiber & Zeileis (2008).
- *TSA*: Data and functions for Cryer & Chan (2008).  
*Warning*: Redefines several base R functions!

**More:** CRAN task view on time series

<http://CRAN.R-project.org/view=TimeSeries>

# Software

**Data classes:** Standard time series class in R is “ts”.

- Aimed at regular series (annual, quarterly, monthly).
- A “ts” object is either a numeric vector (univariate series) or a numeric matrix (multivariate series).
- “tsp” attribute reflects time series properties: a vector of length 3 with start, end and frequency.
- Create via `ts()`: supply data (numeric vector or matrix) plus arguments `start`, `end`, and `frequency`.
- Methods for standard generic functions: `plot()`, `lines()`, `str()`, `summary()`, ...
- Additional time-series-specific methods: `lag()`, `diff()`,  
....

# Software

## Drawbacks:

- Only numeric time stamps (i.e., not date/time objects).
- Missing values cannot be omitted (start/end/frequency no longer sufficient for reconstructing all time stamps!) – a problem with irregular (e.g., financial) series.

**Alternatives:** Several, we (sometimes) use *zoo*.

- Generalization of “ts”: Time stamps of arbitrary type.
- Numeric vectors or matrices, “index” attribute contains *vector* of time stamps (not just “tsp” attribute!).
- Regular series can be coerced back and forth between “ts” and “zoo” via `as.zoo()` and `as.ts()`.
- “zoo” convenient for daily (e.g., “Date” time stamps) or intraday data (e.g., “POSIXct” or “chron” time stamps).
- Interfaces also to many other classes for (irregular) time series, e.g., “xts”, “timeSeries”, ...