Time Series Analysis

Basics of Time Series Analysis

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Basic Definition and Examples

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About This Lesson

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Formal Definition

A *stochastic process* is a collection of random variables $\{X_t, t \in T\}$, defined on a probability space (Ω, F, P).

A *time series* is a stochastic process in which T is a set of time points, usually

$$T = \{0, \pm 1, \pm 2, \ldots\}, \{1, 2, 3, \ldots\}, [0, \infty), \text{or } (-\infty, \infty)$$

Note: The term “time series” is also used to refer to the realization of such a process (observed time series).

Example: Time Series

- Monthly sales of Australian red wine
- Monthly accidental deaths in the U.S.
- Daily Average Temperature from La Harpe station in Hancock County, Illinois
- Daily stock price of IBM stock
- US monthly interest rates
- US yearly GDP
- 1-minute intraday S&P500 return

Time Series: Characteristics

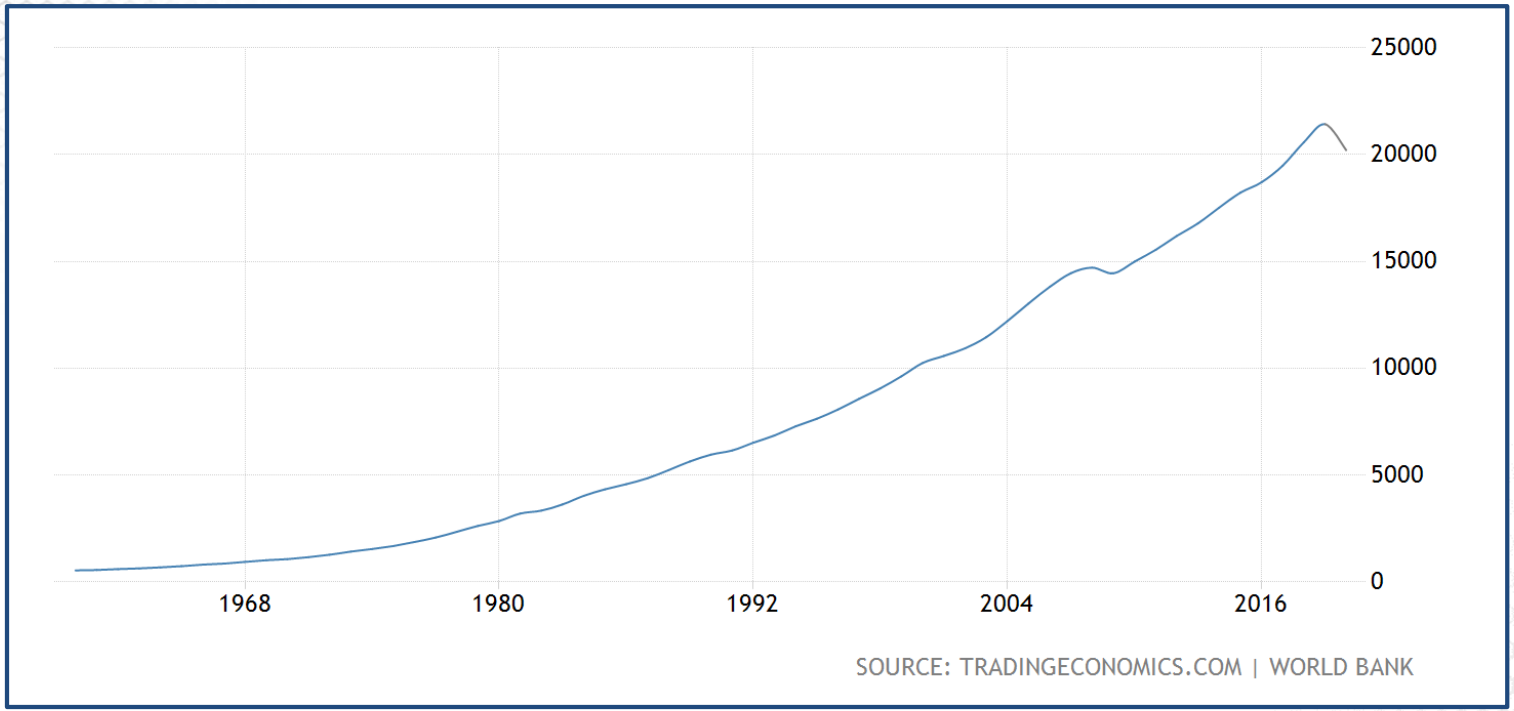
- **Trend**: long-term increase or decrease in the data over time
- **Seasonality**: influenced by seasonal factors;
- **Periodicity**: exact repetition in regular pattern
- **Cyclical trend**: rises and falls, not necessarily of a fixed/exact period
  - Seasonality vs periodicity: repeating over an exact period and modeled using seasonal models; often used interchangeably
  - Seasonality: seasonal factor ~ period of a one year
  - Periodicity: frequency of collecting measurements
  - Cyclical patterns: a dominant period, but could be very different from 'seasonality' (e.g. year) or periodicity (e.g. frequency)

Time Series: Characteristics (cont'd)

- **Varying variance** with time
  - Constant variance (also called as *homoskedasticity*)
  - Nonconstant variance (also called as *heteroskedasticity*)

- **Dependence**: positive (successive observations are similar) or negative (successive observations are dissimilar)
  - Serial correlation commonly modeled using time series analysis
  - Dependence between time series in multivariate analysis

Example: GDP in the US



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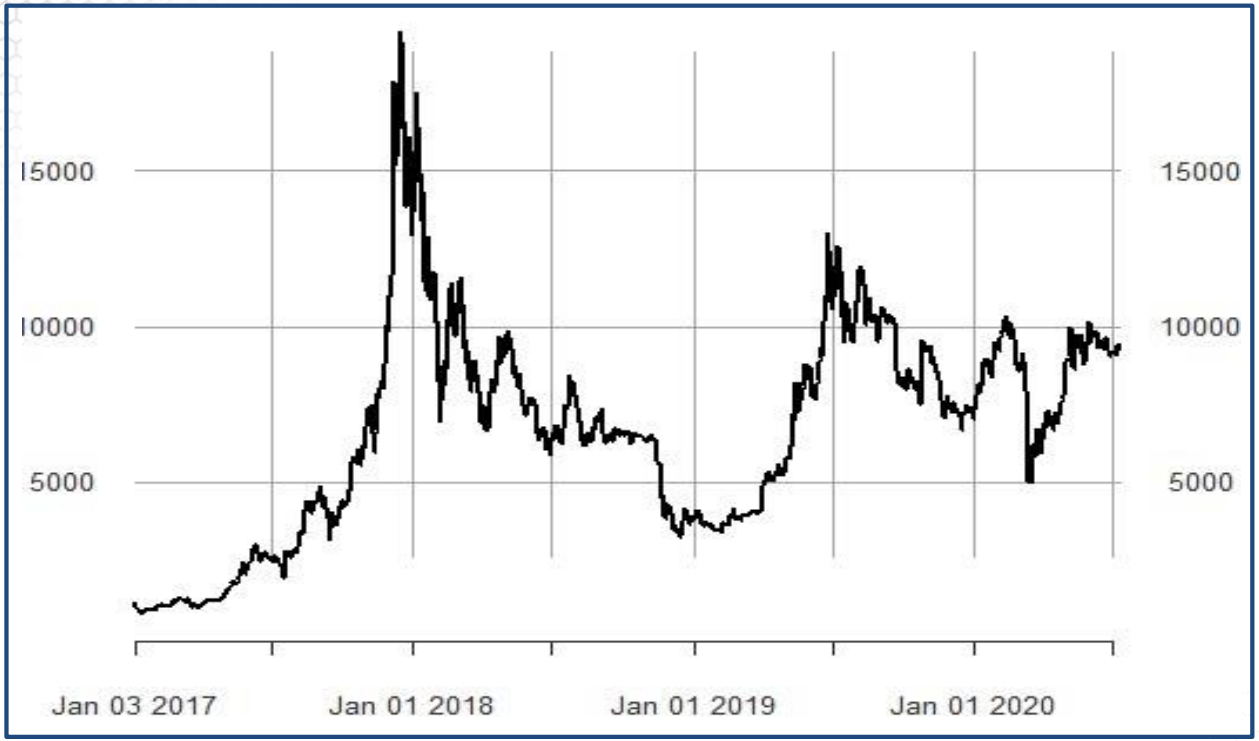
Example: Bitcoin Price



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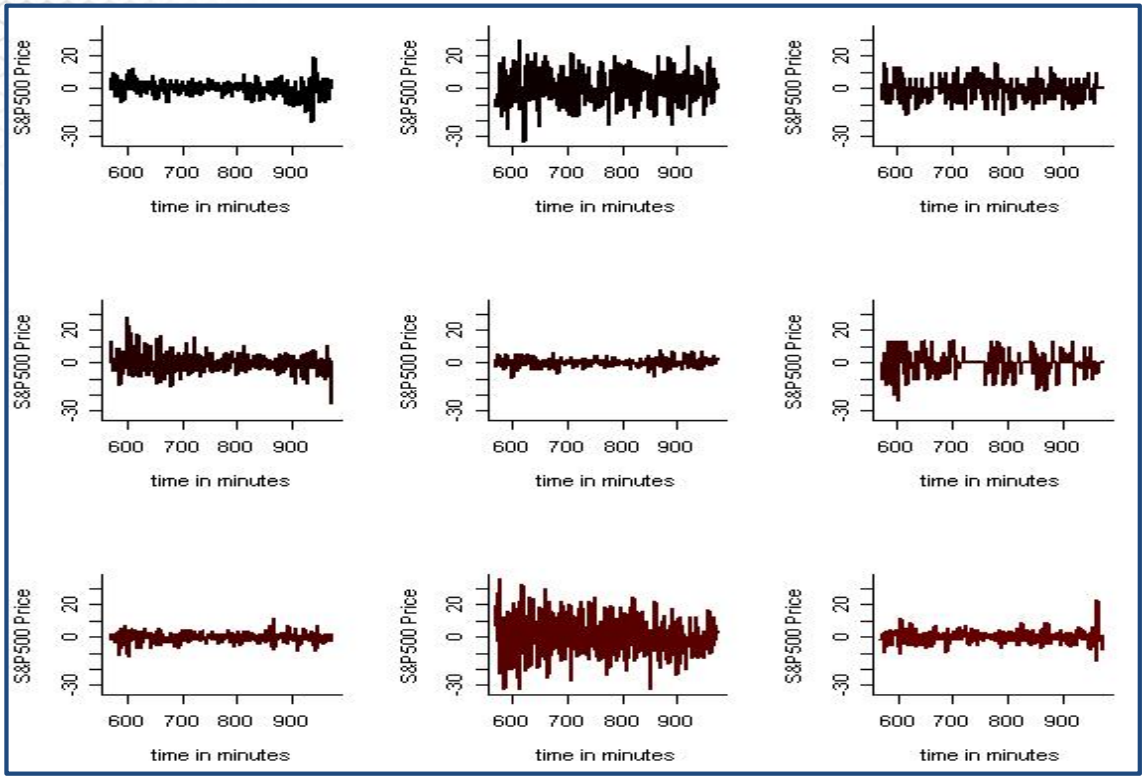
Example: S&P500 Intraday



Is Time Series Analysis Necessary?

Time Series ⇒ Dependence

- Data redundancy: number of degrees of freedom is smaller than T (T is the number of observations)
- Data sampling: $Y_t, t = 1, .., T$ concentrated about a small part of the probability space

Ignoring dependence leads to

- Inefficient estimates of regression parameters
- Poor predictions
- Standard errors unrealistically small (too narrow CI ⇒ improper inferences)

Time Series: Objectives

Description

- Plot the data and obtain simple descriptive measures of the main properties of the series.

Explanation

- Find a model to describe the time dependence in data.

Forecasting

- Given a finite sample from the series (observations), forecast the next value or the next several values.

Control/Tuning

- After forecasting, adjust various control/tune parameters.

Time Series Analysis: Approaches

Time domain approach

- Assume that correlation between adjacent points in time can be explained through dependence of the current value on past values.

Frequency domain approach

- Characteristics of interest relate to periodic (systematic) sinusoidal variations in the data, often caused by biological, physical, or environmental phenomena.

Summary

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