Forecasting Methods and Applications

Applied Data Analysis School

Lecture 1

Introduction to Forecasting

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Outline of the lecture:

- Definition of forecasting
- Objective of the forecaster
- Some applications of forecasting
- Basic considerations to successful forecasting
- Basic concepts
- Some examples of time series

References:

- Diebold, F. X. (2007), Elements of Forecasting, 4th edition, South-Western College Publishing.
- Montgomery, D. C., Jennings, C. L. and Kulahci, M. (2015), Introduction to Time Series Analysis and Forecasting, 2nd edition, Wiley.
- Brockwell, P. J. and Davis, R. A. (2002), Introduction to Time Series and Forecasting, 2nd edition, Springer-Verlag, New York.

Definition of forecasting

Definition: Forecasting is a process of making predictions of the future as accurately as possible, given all of the information available, including historical data and knowledge of any future events that might impact the forecasts. (Hyndman and Athanasopoulos, 2013).

- Forecasting is obviously a difficult activity, and some that do it well have a big advantage over those whose forecasts fail.

Examples of bad forecasts:

- “I think there is a world market for maybe five computers.”
  Thomas J. Watson, Chairman of IBM, 1943
- “There is no reason for any individual to have a computer in his home.”
  Ken Olsen, founder of Digital Equipment Corporation, 1977
- ”Apple is already dead.”
  Nathan Myhrvold, former Microsoft CTO, 1997

Objective of the forecaster

- Forecast is simply a statement about the future of a specific indicator.
- It is impossible to obtain perfect forecasts as there are too many variables that cannot be predicted with certainty.
- Instead, we should try to find and use the best statistical/econometric methods for producing and evaluating forecasts, and therefore to reduce the forecast error.
- Forecast accuracy decreases as time horizon increases. Forecasts will be less reliable the further into the future we predict.

Examples: Forecasting time of the sunrise tomorrow, forecasting electricity demand, forecasting currency exchange rates, forecasting lotto numbers.

Important: A good forecasting model captures the way in which things are changing. Good forecasts help to produce good decisions!

Some applications of forecasting

1. **Operations planning and control:** Firms forecast sales to help on decisions in inventory management, production planning, new market entry, and so on. Firms use forecasts to decide what to produce, when to produce, how much to produce, etc. One should also take into account any cyclical or seasonal effects.

2. **Marketing:** Pricing decisions and advertising expenditure decisions plays role in many marketing decisions.

3. **Economics:** Governments, central banks and policy organizations forecast the major economic variables, such as gross domestic product, unemployment, consumption, investment, interest rates or the state of future stock market activity. Such forecasts are used to guide monetary and fiscal policy.

Some applications of forecasting

4. **Financial asset and risk management:** Portfolio managers have an interest in forecasting asset returns, but asset returns are very hard to forecast. On the other hand, volatility forecasts are essential for measuring risk linked to asset portfolios.

5. **Business and government budgeting:** A large amount of firm revenues typically come from sales, and a large amount of the government revenue comes from tax receipts, both exhibiting cyclical and long-term variation.

6. **Demography:** Population forecasts are crucial for planning government expenditure on health care, infrastructure, social insurance, anti-poverty programs, etc.

Forecasting techniques

Two categories of forecasting techniques:

1. **Qualitative forecast:** It is often subjective in nature and is based on judgment of experts; They are appropriate when there is little or no historical data available. Example: Introduction of a new product.
2. **Quantitative forecast:** It is linked to the building of mathematical or statistical models; Forecasts are obtained from the underlying model or technique using observed historical data. Example: Forecasting furniture sales using house purchases as a predictor variable.

Basic approaches to generating forecasts:

1. Regression-based methods
2. Exponential smoothing techniques
3. General time series models

Basic considerations to successful forecasting

1. **Loss function:** The loss function weighs the cost of possible forecast errors, that is, it quantifies what we mean by a "good" forecast. The choice of loss function affects which forecasting models are preferred and how forecasts are evaluated and compared.

The loss functions are the form $\mathcal{L}(e)$, where

$$e = y - \widehat{y}$$

is the forecast error, i.e., the difference between the realization (true value) and the forecasted value.

Granger (1999) required the error loss function $\mathcal{L}(e)$ to satisfy three conditions:

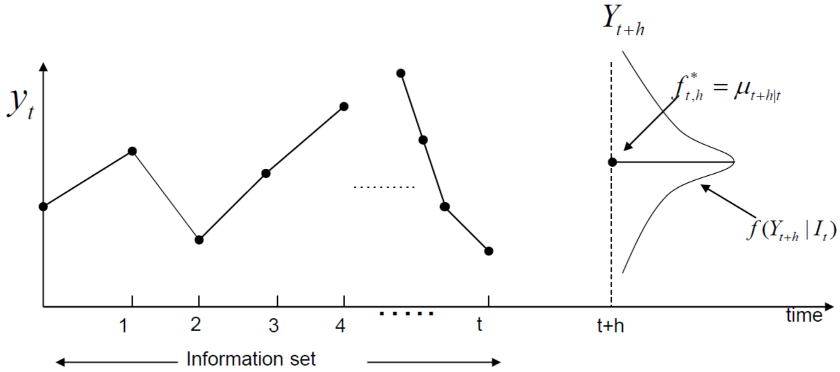
1. $\mathcal{L}(0) = 0$ (minimal loss of zero).
2. $\mathcal{L}(e) \geq 0$ for all e.
3. $\mathcal{L}(e)$ is monotonically non-decreasing in $|e|$.

Basic considerations to successful forecasting

Types of loss functions: Quadratic, absolute, asymmetric and symmetric loss functions.

2. **The forecast object:** What is the object that we need to forecast? In Economics, the forecast object is one of three types:
    - Event outcome
    - Event timing
    - Time series
3. **The forecast statement:** When forecasting, we must decide the type of forecast:
    - Point forecast
    - Interval forecast
    - Density forecast

The forecasting problem:



Example: Wage (hourly) forecast

- Suppose we take a random household in the United States and we want to forecast the wage (hourly) of the head of household.

- Mean = \$17.87; Median = \$14.76

Table 1: Percentiles of the wage distribution

1%	5%	10$	25%	50%	75%	90%	95%	99%
\$4.37	\$6.27	\$7.5	\$10.0	\$14.76	\$22.45	\$32.3	40.6	\$57.7

- What is your forecast? Will your forecast be correct?

Example: Wage (hourly) forecast

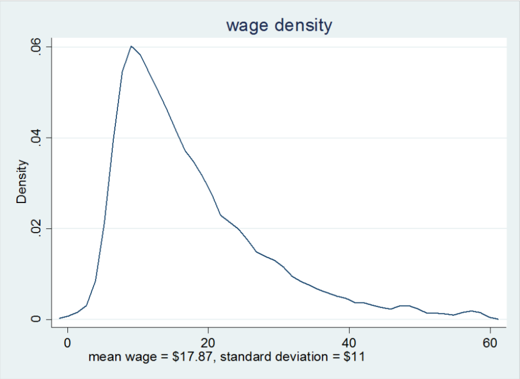


Figure 1: Wage density

Example: Wage (hourly) forecast

Figure 2: Wage distribution

Example: Wage (hourly) forecast

- It is impossible to forecast with accuracy the individual wage, but we could use a point forecast as the best guess for that wage.
- Here, the point forecast for the person's wage could be the mean \$17.87 (or the median \$14.76), but it is close to impossible that individual's wage will be exactly \$17.87.
- If we forecasted the individual's wage to be \$17.87, but it turns out that it is \$22, the forecast error is 22-17.87=4.13.
- The best guess for the point forecast depends on our loss function (how we measure the costs due to potential forecast errors).

Example: Wage (hourly) forecast

- A point forecast can be viewed as a summary of the predictive distribution.
- The most correct and accurate forecast is the entire distribution (or density).
- The forecast or predictive distribution summarizes all that is known and unknown about the potential values of the object.
- We cannot forecast with certainty the person's wage, but we know (or can estimate) the distribution:
  - The range and likelihood of possible wages.

Basic considerations to successful forecasting

4. **The forecast horizon:** The forecast horizon is the number of future periods for which forecasts must be produced. Example: If we have annual data, and it is now year T, then a forecast of the unemployment rate for year $T+2$ has a forecast horizon of 2 steps. Often, we can compute h-step-ahead and h-step-ahead extrapolation forecasts.

5. **The information set:** The quality of the forecasts is limited by the quality and quantity of information available when forecasts are made. Any forecast made is always conditional on the (past and present) information used to produce it. The information set can be univariate

$$\Omega_T = \{y_1, y_2, ..., y_T\}$$

or multivariate

$$\Omega_T = \{y_1, x_1, y_2, x_2, ..., y_T, x_T\}.$$

Basic considerations to successful forecasting

6. **Methods and complexity:** Formal statistical criteria exist to guide model selection within certain classes of models. However, practice suggests that simple models tend to be the best models in forecasting. This is known as the parsimony principle- simple models are usually preferable to complex models (other things the same).

   Reasons for preferring simple models:

   - Easier to estimate precisely
   - Easier to interpret, understand
   - Easier to communicate
   - Simplicity avoids tailoring a model "too fit" to the data

Basic concepts

Time series: It is set of observations denoted by y_t recorded sequentially over time at a specific time $t = 1, 2, ...$ The index t denotes the time period, corresponding to (equally spaced) periods of time. The time period (or data frequency) may be a year, quarter, month, week, day, or any other time unit.

Remark: In applications, a time series is a sequence of measurements of some quantity of interest taken at different points in time. In the case of a time series in discrete time, the data are observed at equally spaced time intervals. Otherwise, if t is continuous, we have a continuous time series.

Notation: A time series in discrete time is denoted by y_t, whereas $y(t)$ is the notation for the continuous time case.

Basic concepts

Lags and Leads:

- The **first lag** of y_t is y_{t-1}
  - It is the observation from the previous period
  - Example: For monthly data, the first lag of November is October of the same year.
- The **second lag** of y_t is y_{t-2}, and so on
- The ***k*th lag** of y_t is y_{t-k}
- The **first lead** of y_t is y_{t+1}
- The ***k*th lead** of y_t is y_{t+k}

Basic concepts

Time series sample:

- A historical sample of time series data is a set of T observations in contiguous time:

$$\{y_1, y_2, ..., y_T\} \text{ or } \{y_t\}, \; t = 1, 2, ..., T$$

where T is the number of observations in-sample.

Forecast period:

- In-sample period: $\{y_1, y_2, ..., y_T\}$
- Out-of-sample period: $\{y_{T+1}, y_{T+2}, ..., y_{T+h}\}$ where h is the forecast horizon.

Forecast notation:

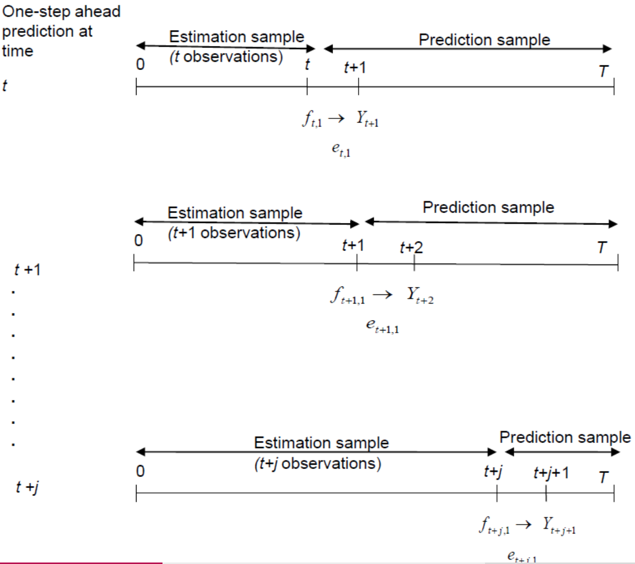
- y_t is the actual value of the series
- $\widehat{y}_t$ is the point forecast for y_t
- $\widehat{y}_{T+h}$ is the point forecast for y_{T+h}
- The notation $\widehat{y}_{T+h}$ is not clear about when the forecast is made:
  - If at time period T
  - If at time period $T+1$
  - If at time period $T+h-1$

Basic concepts

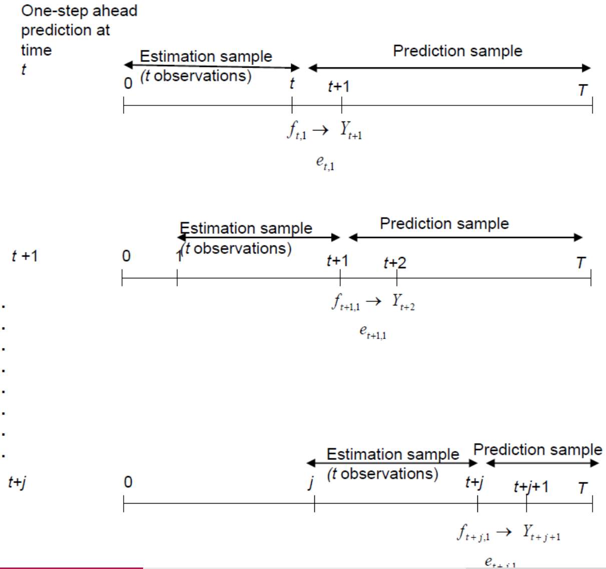
Forecast Notation:

- Hence, we use $\widehat{y}_{t+h|t}$ to refer to the forecast of y_{t+h} made at time t
- $\widehat{y}_{T+h|T}$ is the forecast of y_{T+h} made at time T
- $\widehat{y}_{T+h|T+1}$ is the forecast of y_{T+h} made at time $T+1$
- $\widehat{y}_{T+h|T+2}$ is the forecast of y_{T+h} made at time $T+2$
- etc.

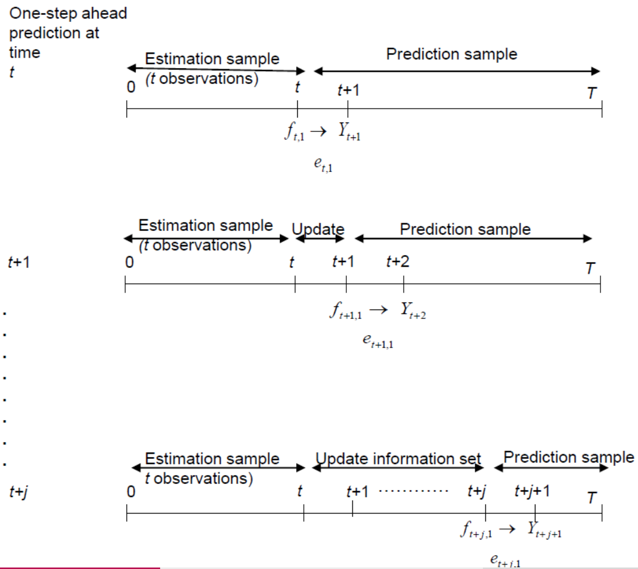
Forecasting environments: Recursive scheme



Forecasting environments: Rolling scheme



Forecasting environments: Fixed scheme



Example: Wisconsin unemployment rate

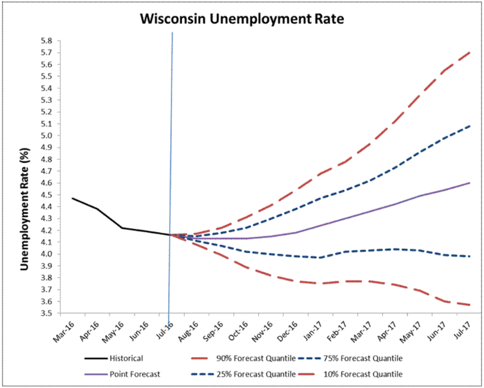


Figure 3: Forecasts for the Wisconsin unemployment rate (Source: http://www.ssc.wisc.edu/~bhansen/forecast/)

Example: Wisconsin unemployment rate

- Figure 3 is called a fan chart
- At time T make a sequence of forecasts for $T+1$, $T+2, \ldots, T+h$
- Compute point forecasts: $\widehat{y}_{T+1|T}, \widehat{y}_{T+2|T}, \ldots, \widehat{y}_{T+h|T}$
- Add interval forecasts and plot over the forecast horizon
- The intervals tend to fan out with the forecast horizon

- Forecasts for July 2017:
  - Point Forecast: 4.6%
  - 50% Forecast Interval: (4.0%, 5.1%)
  - 80% Forecast Interval: (3.6%, 5.7%)

Some examples of time series

Examples:

- Economics/Finance: Quarterly GDP, monthly advertising expenditures, weekly interest rates, tick-by-tick stock prices, daily currency exchange rates, etc.
- Meteorology: Daily high and low temperatures, annual precipitation, hourly wind speeds, etc.
- Medicine: Electrical activity of the heart at millisecond intervals, etc.

Some examples of time series

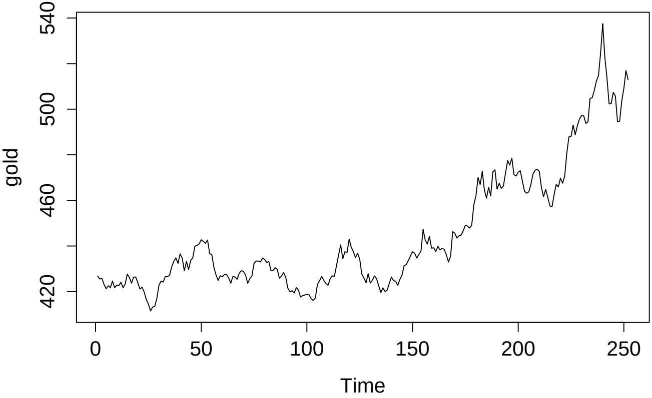


Figure 4: Daily price of gold (in dollars per ounce) for the 252 trading days of 2005

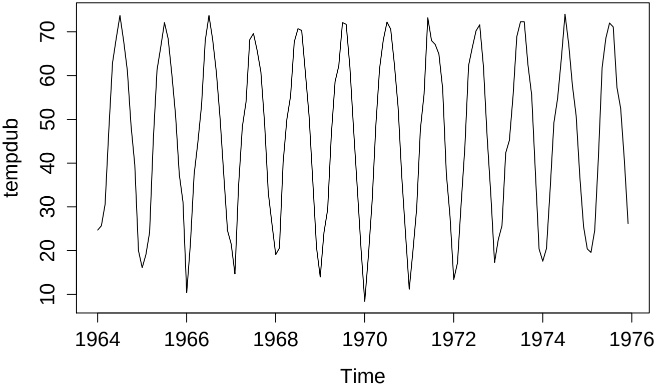


Figure 5: Monthly average temperature (in degrees Fahrenheit) in Dubuque

Some examples of time series

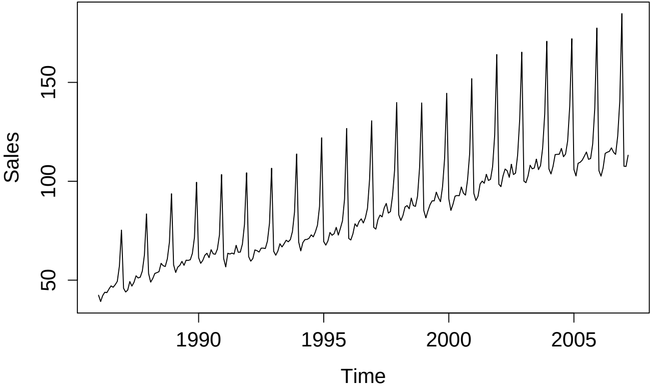


Figure 6: Annual sales of certain large equipment

Some examples of time series

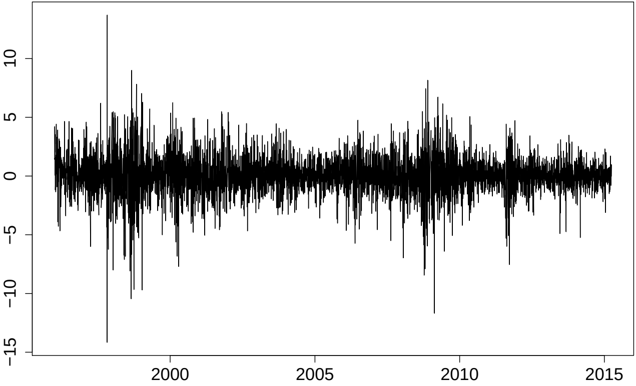


Figure 7: Daily returns of the WIG20 index from January 2, 1996 until March 31, 2015