

ETC3550/ETC5550

Applied forecasting

Week 6: Simple Exponential smoothing



Historical perspective

- Developed in the 1950s and 1960s as methods (algorithms) to produce point forecasts.
- Combine a “level”, “trend” (slope) and “seasonal” component to describe a time series.
- The rate of change of the components are controlled by “smoothing parameters”: α , β and γ respectively.
- Need to choose best values for the smoothing parameters (and initial states).
- Equivalent ETS state space models developed in the 1990s and 2000s.

Big idea: control the rate of change

α controls the flexibility of the **level**

- If $\alpha = 0$, the level never updates (mean)
- If $\alpha = 1$, the level updates completely (naive)

β controls the flexibility of the **trend**

- If $\beta = 0$, the trend is linear
- If $\beta = 1$, the trend changes suddenly every observation

γ controls the flexibility of the **seasonality**

- If $\gamma = 0$, the seasonality is fixed (seasonal means)
- If $\gamma = 1$, the seasonality updates completely (seasonal naive)

Models and methods

Methods

- Algorithms that return point forecasts.

Models

- Generate same point forecasts but can also generate forecast distributions.
- A stochastic (or random) data generating process that can generate an entire forecast distribution.
- Allow for “proper” model selection.

Simple Exponential Smoothing

Iterative form

$$\hat{y}_{t+1|t} = \alpha y_t + (1 - \alpha) \hat{y}_{t|t-1}$$

Simple Exponential Smoothing

Iterative form

$$\hat{y}_{t+1|t} = \alpha y_t + (1 - \alpha) \hat{y}_{t|t-1}$$

Weighted average form

$$\hat{y}_{T+1|T} = \sum_{j=0}^{T-1} \alpha(1 - \alpha)^j y_{T-j} + (1 - \alpha)^T \ell_0$$

Simple Exponential Smoothing

Iterative form

$$\hat{y}_{t+1|t} = \alpha y_t + (1 - \alpha) \hat{y}_{t|t-1}$$

Weighted average form

$$\hat{y}_{T+1|T} = \sum_{j=0}^{T-1} \alpha(1 - \alpha)^j y_{T-j} + (1 - \alpha)^T \ell_0$$

Component form

Forecast equation
Smoothing equation

$$\hat{y}_{t+h|t} = \ell_t$$

$$\ell_t = \alpha y_t + (1 - \alpha) \ell_{t-1}$$

Simple Exponential Smoothing

Component form

Forecast equation

$$\hat{y}_{t+h|t} = l_t$$

Smoothing equation

$$l_t = \alpha y_t + (1 - \alpha)l_{t-1}$$

Simple Exponential Smoothing

Component form

Forecast equation

$$\hat{y}_{t+h|t} = l_t$$

Smoothing equation

$$l_t = \alpha y_t + (1 - \alpha)l_{t-1}$$

Forecast error: $e_t = y_t - \hat{y}_{t|t-1} = y_t - l_{t-1}$.

Simple Exponential Smoothing

Component form

Forecast equation

$$\hat{y}_{t+h|t} = l_t$$

Smoothing equation

$$l_t = \alpha y_t + (1 - \alpha)l_{t-1}$$

Forecast error: $e_t = y_t - \hat{y}_{t|t-1} = y_t - l_{t-1}$.

Error correction form

$$y_t = l_{t-1} + e_t$$

$$l_t = l_{t-1} + \alpha(y_t - l_{t-1})$$

$$= l_{t-1} + \alpha e_t$$

Simple Exponential Smoothing

Component form

Forecast equation

$$\hat{y}_{t+h|t} = l_t$$

Smoothing equation

$$l_t = \alpha y_t + (1 - \alpha)l_{t-1}$$

Forecast error: $e_t = y_t - \hat{y}_{t|t-1} = y_t - l_{t-1}$.

Error correction form

$$y_t = l_{t-1} + e_t$$

$$l_t = l_{t-1} + \alpha(y_t - l_{t-1})$$

$$= l_{t-1} + \alpha e_t$$

Specify probability distribution: $e_t = \varepsilon_t \sim \text{NID}(0, \sigma^2)$.

ETS(A,N,N): SES with additive errors

ETS(A,N,N) model

Observation equation

$$y_t = l_{t-1} + \varepsilon_t$$

State equation

$$l_t = l_{t-1} + \alpha \varepsilon_t$$

where $\varepsilon_t \sim \text{NID}(0, \sigma^2)$.

- “innovations” or “single source of error” because equations have the same error process, ε_t .
- Observation equation: relationship between observations and states.
- State equation(s): evolution of the state(s) through time.

ETS(M,N,N): SES with multiplicative errors.

- Specify relative errors $\varepsilon_t = \frac{y_t - \hat{y}_{t|t-1}}{\hat{y}_{t|t-1}} \sim \text{NID}(0, \sigma^2)$
- Substituting $\hat{y}_{t|t-1} = l_{t-1}$ gives:
 - ▶ $y_t = l_{t-1} + l_{t-1}\varepsilon_t$
 - ▶ $e_t = y_t - \hat{y}_{t|t-1} = l_{t-1}\varepsilon_t$

ETS(M,N,N): SES with multiplicative errors.

- Specify relative errors $\varepsilon_t = \frac{y_t - \hat{y}_{t|t-1}}{\hat{y}_{t|t-1}} \sim \text{NID}(0, \sigma^2)$
- Substituting $\hat{y}_{t|t-1} = l_{t-1}$ gives:
 - ▶ $y_t = l_{t-1} + l_{t-1}\varepsilon_t$
 - ▶ $e_t = y_t - \hat{y}_{t|t-1} = l_{t-1}\varepsilon_t$

ETS(M,N,N) model

Observation equation

$$y_t = l_{t-1}(1 + \varepsilon_t)$$

State equation

$$l_t = l_{t-1}(1 + \alpha\varepsilon_t)$$

ETS(M,N,N): SES with multiplicative errors.

- Specify relative errors $\varepsilon_t = \frac{y_t - \hat{y}_{t|t-1}}{\hat{y}_{t|t-1}} \sim \text{NID}(0, \sigma^2)$
- Substituting $\hat{y}_{t|t-1} = l_{t-1}$ gives:
 - ▶ $y_t = l_{t-1} + l_{t-1}\varepsilon_t$
 - ▶ $e_t = y_t - \hat{y}_{t|t-1} = l_{t-1}\varepsilon_t$

ETS(M,N,N) model

Observation equation

$$y_t = l_{t-1}(1 + \varepsilon_t)$$

State equation

$$l_t = l_{t-1}(1 + \alpha\varepsilon_t)$$

- Models with additive and multiplicative errors with the same parameters generate the same point forecasts but different prediction intervals.