Forecasting Seasonal Time Series

Winters Exponential Smoothing

Seasonality

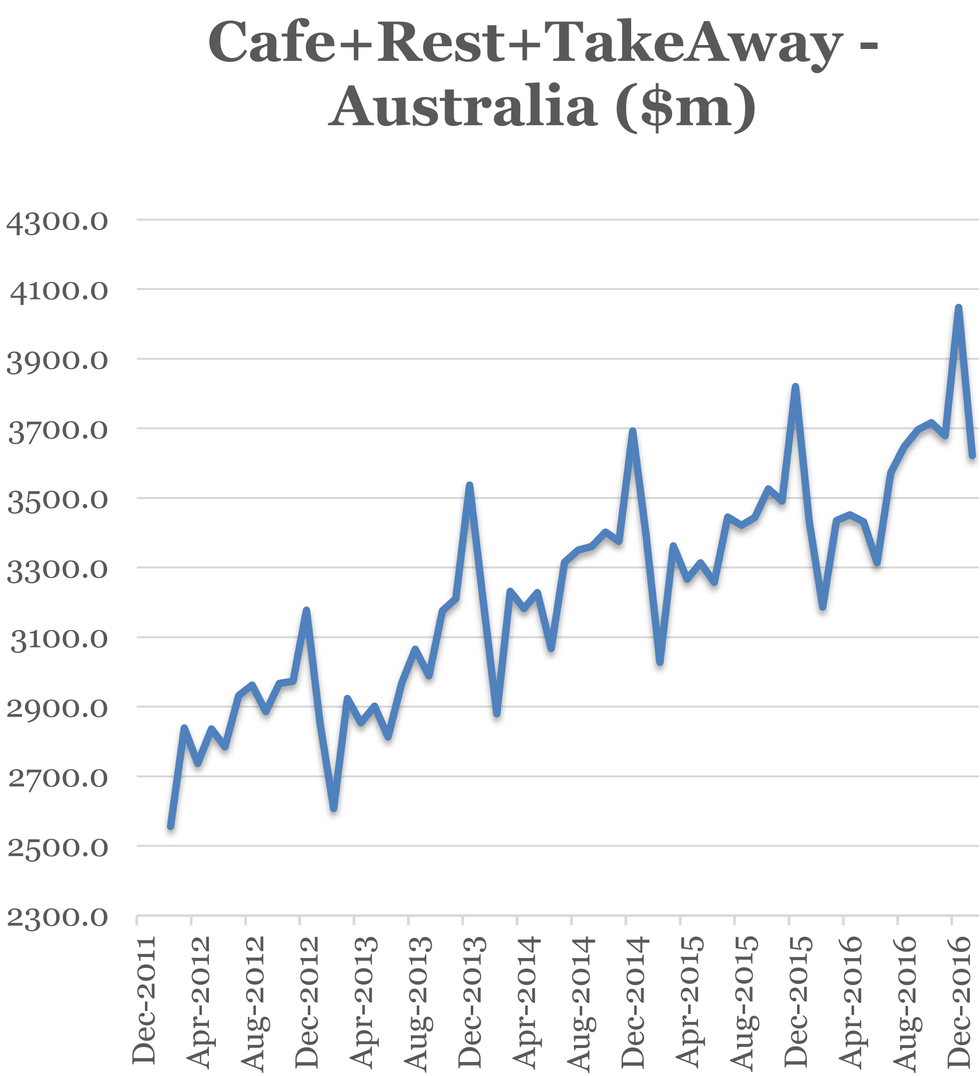
Previous smoothing models were appropriate for time series that were **horizontal** or had **trend** but not appropriate for time series with **seasonal** components

Time series may exhibit a seasonal component due to **weather, holiday periods, weekends** etc.

Seasonal components typically lead to **systematic fluctuations** of the level of the time series

The fluctuation pattern is typically **repeated for every seasonal cycle**

Seasonal Data Example



Monthly Café, Restaurant and Takeaway Sales ($m) for Aust. Feb 12 – Jan 17

Seasonal fluctuation spiking in **December** each year

Due to **weather, holidays, Christmas**

Also **trend** and **random** component

Trend due to **inflation, population, market size**

Broad Types of Seasonality

Seasonality can be classified into two broad categories; **Additive** and **Multiplicative**

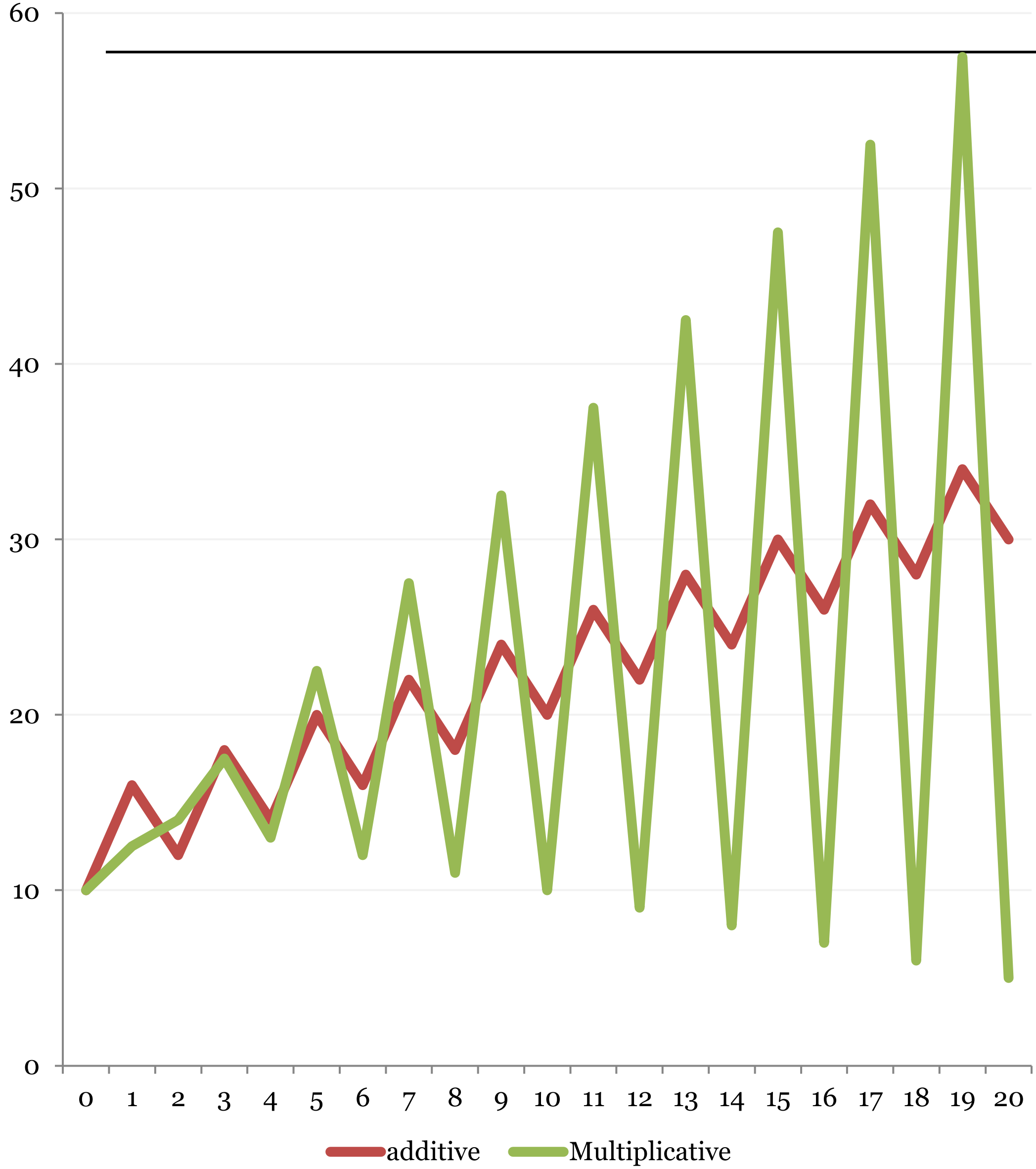
Additive is when seasonal fluctuations of the time series can be modelled by **addition** of a defined seasonal component

Multiplicative is when seasonal fluctuation of time series can be modelled by **multiplication** of a defined seasonal component

In Additive models, seasonal component size is **absolute**

In Multiplicative models, seasonal component is **relative** to the level of the time series

Additive Vs Multiplicative Seasonal Variation



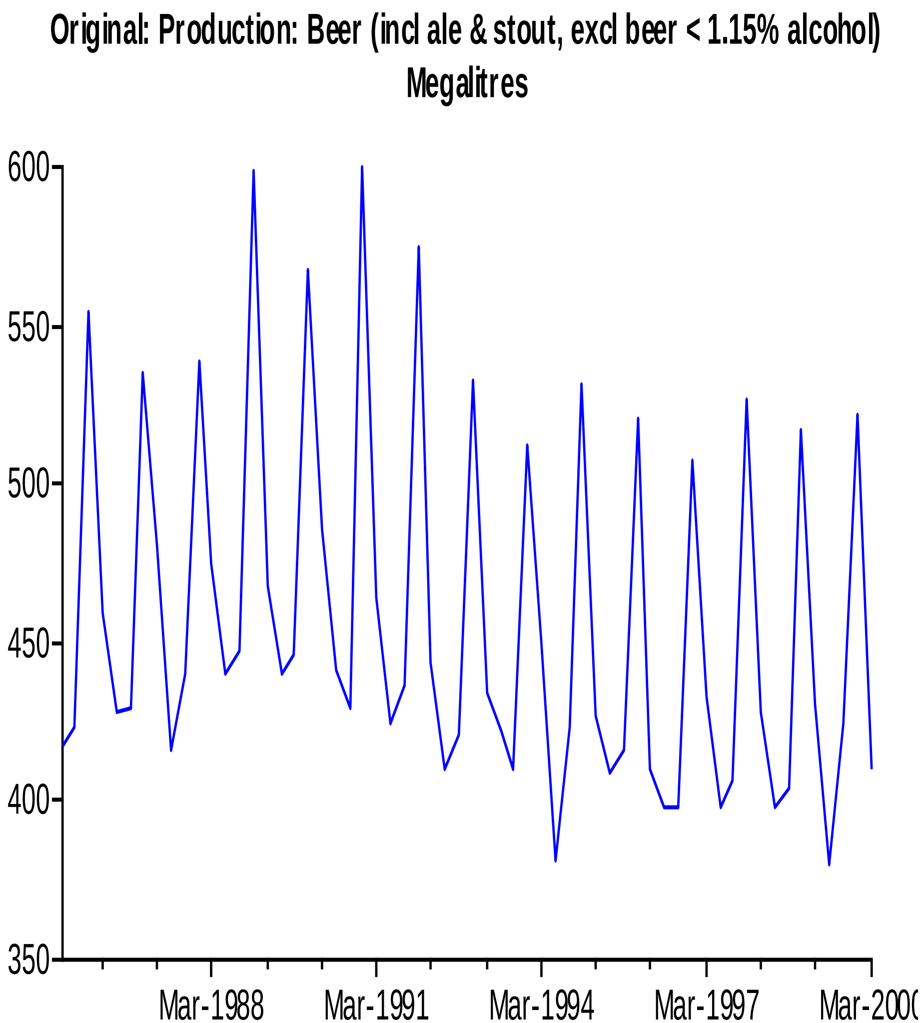
Additive → Seasonal changes are **fixed** over the time series

The magnitude of seasonal fluctuation **does not vary** with the level of the series)

Multiplicative → Seasonal changes are a **fixed percentage** of the time series

The magnitude of seasonal fluctuation **varies** with the level of the time series

Additive Seasonality



Quarterly Beer Production Aust. (megalitres)

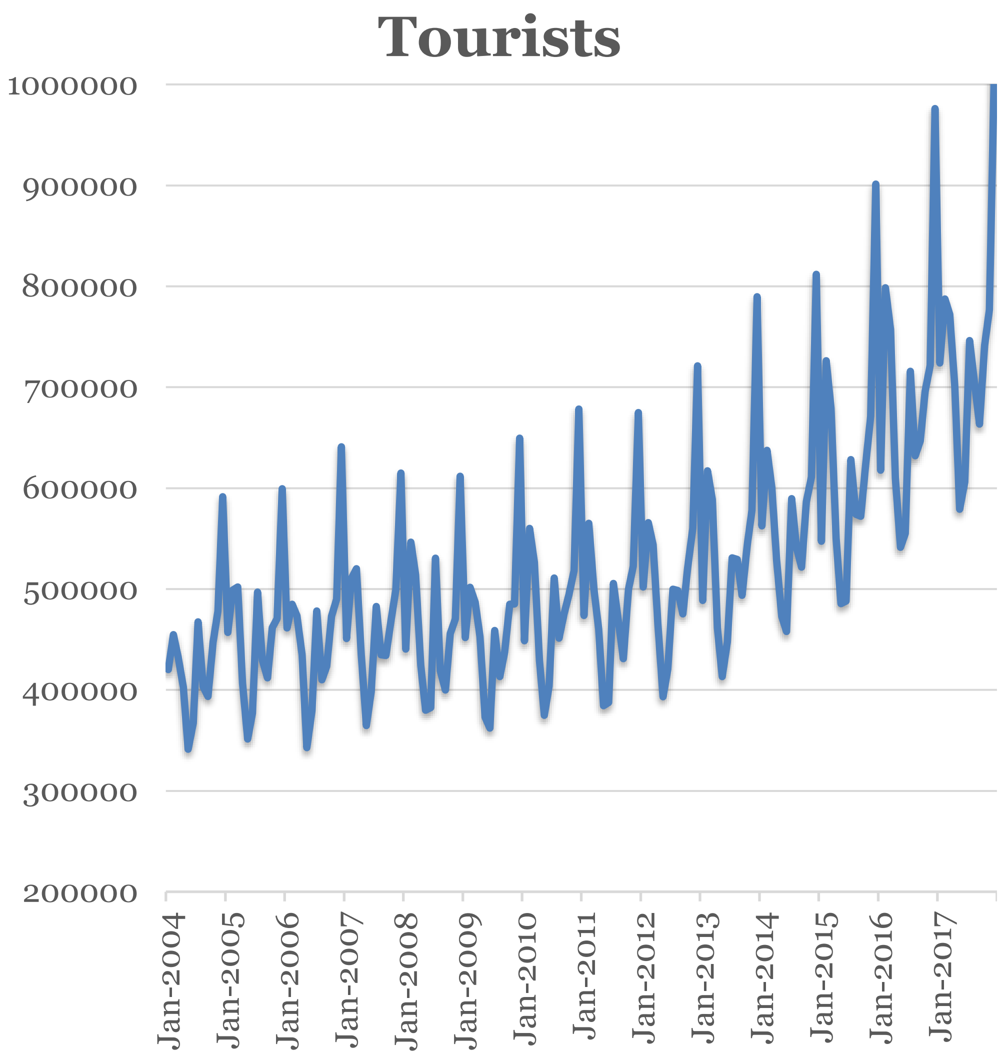
Data appears **seasonal** with some **trend** (downward) and possibly **cycle**

Due to **Christmas**, **weather**, **consumer taste** changes

Seasonal fluctuation appears **constant** and **not dependent** on level of time series

Peaks & troughs **contained within a parallel band**

Multiplicative Seasonality



Monthly visitor arrivals Australia-number

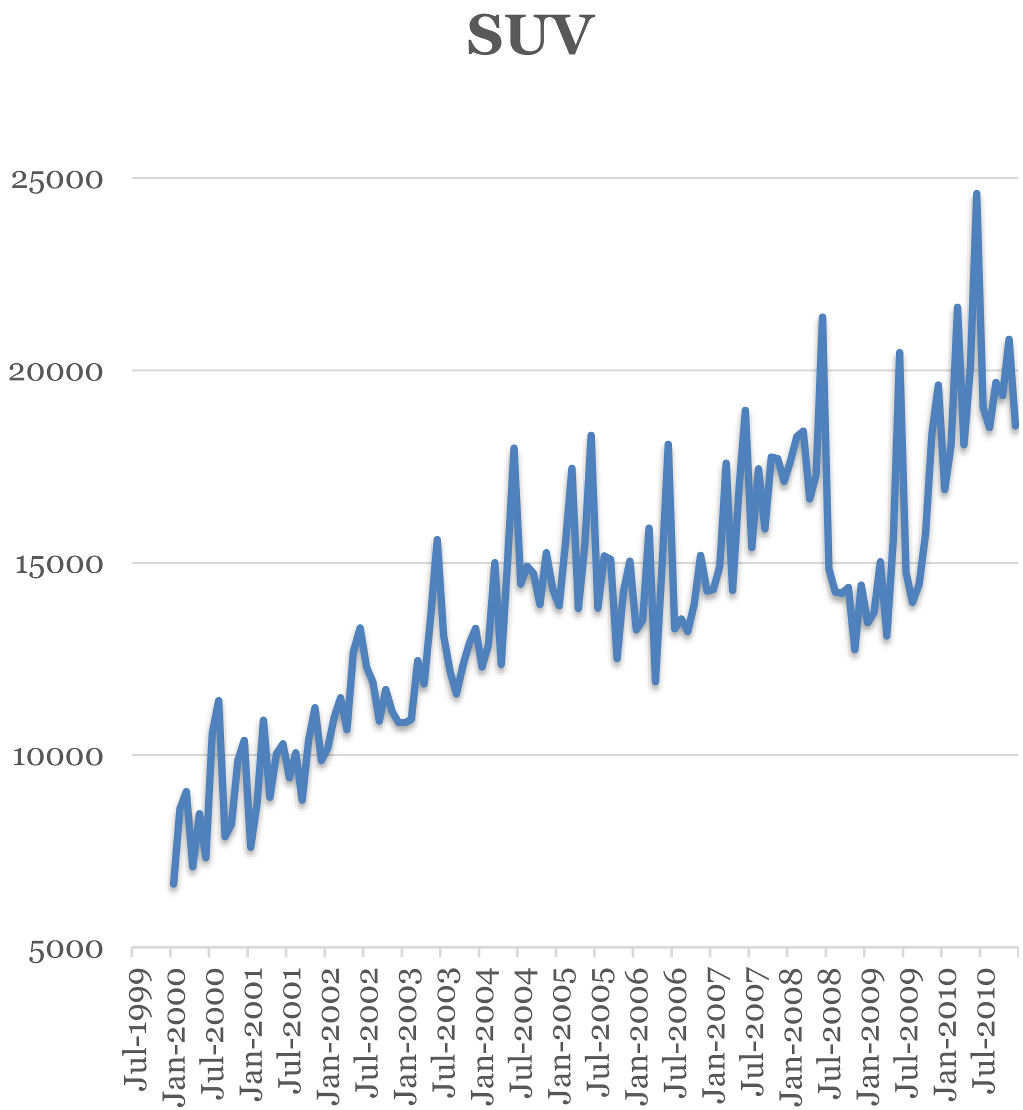
Data appears **seasonal** with **trend** (upward) and **cycle**

Due to: **Christmas**, weather, **globalisation**, tourism marketing, **Olympics**

Seasonal fluctuation appears **relative** and **dependent** on level of time series (**but constant %)**

Peaks, troughs **not contained within a parallel band**

Identifying Seasonality



It should be reasonably clear from a **time series graph** if seasonality is present

However it isn't always obvious eg. monthly SUV Sales (Jan 00 – Dec - 10)

Check the **ACF** and **PACF** for evidence of seasonality (**spikes** at **seasonal** values)

The time series may have to be **detrended** first for the seasonal spikes to appear clearly on **ACF** and **PACF**

Seasonal Models

If the time series has **seasonal components**, none of the previous models studied so far will be adequate

We will need to include a seasonal component in our models or **adjust for seasonality when forecasting**

An **extension of** Holt's method can accommodate seasonal effects

This model is the **Winters Exponential Smoothing** model

WES includes a **seasonality equation** and is a 3-parameter model with smoothing constants for **level: α** (alpha), **trend: β** (beta) and one for **seasonality: γ** (gamma)

WES (cont)

In both models, the first equation adjusts the **actual value of the time series by a seasonal estimate**

The second equation is a **trend** equation (as per Holt's)

The third equation provides an **updated** estimate of the **seasonal estimate** at each time period

The forecast equation allows for prediction **"m" periods** into the future.

The first part of the equation is a **trend projection "m" periods ahead**. The result is adjusted by an **estimate of seasonality** for that specific season **(added or multiplied)**

More on the WES Equations

The values of α, β, γ are all theoretically between 0 and 1 inclusive.

Choosing the values of the smoothing parameters is not easy. As a default, low values of α, β, γ (**0.2, 0.2, 0.2**) are used as a preliminary estimate.

The model also needs initialization values for $\mathbf{L_1}$, $\mathbf{T_1}$ and $\mathbf{S_1 - S_p}$. Can use $\mathbf{S_1 - S_p}$ = **0 (for Additive)** or **1 (for Multiplicative)**

Changes to the smoothing parameters may **reduce error levels** and **improve accuracy** (usually based on an error criterion like MSE)

As with HES and SES, **SOLVER** can be used to derive the **"optimum" combination** of the smoothing parameters