ISA 444: Business Forecasting

11 - Seasonal Decomposition and Smoothing Methods

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Fall 2020

Outline

1. **Preface**
2. Exam 1 Review
3. Time Series Components
4. Decomposition Methods
5. Recap

Quick Refresher on Chapter 03 so Far

Main Learning Outcomes Discussed in Previous Chapter

☑ Explain the difference between causal and extrapolative forecasting.

☑ Describe and apply forecasting with a cumulative average.

☑ Describe and apply forecasting with a moving average.

☑ Recognize time series that are appropriate for simple exponential smoothing (SES).

☑Use SES to forecast future observations of a time series.

☑Be able to develop an optimal forecast based on a training sample.

☑Be able to evaluate the out-of-sample performance of a forecast based on a hold-out (validation) sample.

☑Recognize time series that are appropriate for linear exponential smoothing (LES).

☑ Use LES to forecast future observations of a time series.

Learning Objectives for Today's Class

Main Learning Outcomes

- **Explain when to use an additive vs. multiplicative model for a time series.**
- **Use classic decomposition methods to detrend and deseasonalize a time series.**

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Live Walk-Through During Class

We will walk through the exam during class. Please feel free to ask me any questions as we are going through the exam solutions.

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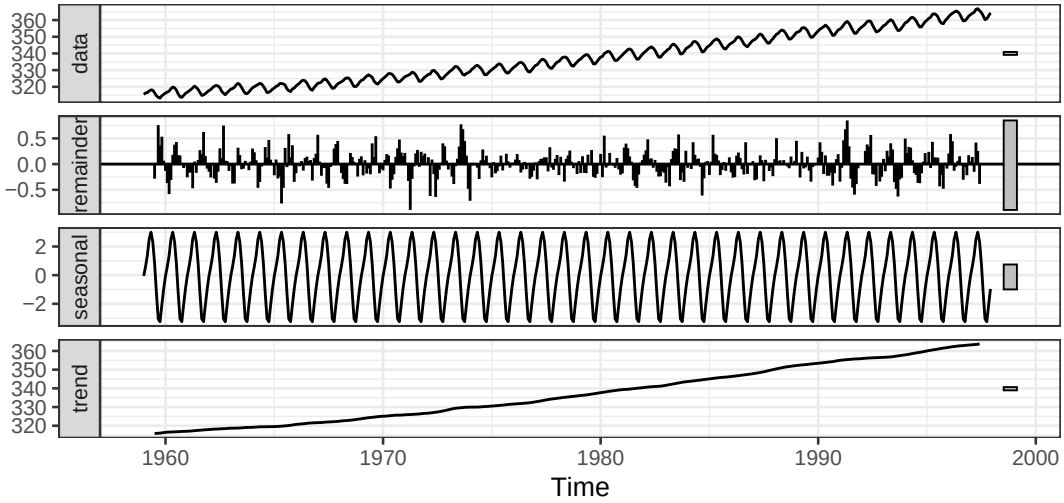
Definition and Basic Principles [1]

A time series may be made up of:

- **Trends (T)** - upward and downward movements
- **Seasonal (S) components** - regular, recurrent patterns that repeat at a fixed known duration (period)
- **Error (E) components** - irregular "noise" that is randomly distributed over time[1]

[1] A time series may also contain a cyclical component if it displays a somewhat periodic fluctuation, but the fluctuation has a periodicity of unknown duration, usually longer than a year.

Definition and Basic Principles [2]

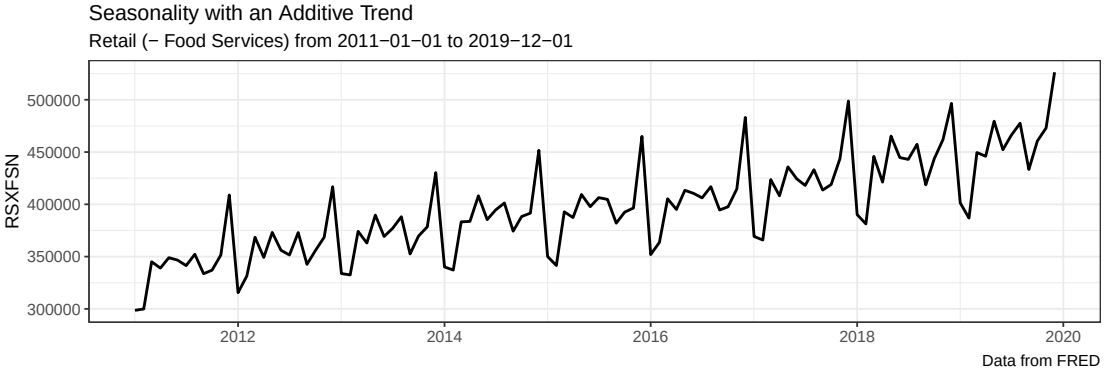


Based on C02 data in base R

Recall: Additive vs. Multiplicative Models [1]

An additive model is written as $Y = T + S + E$.

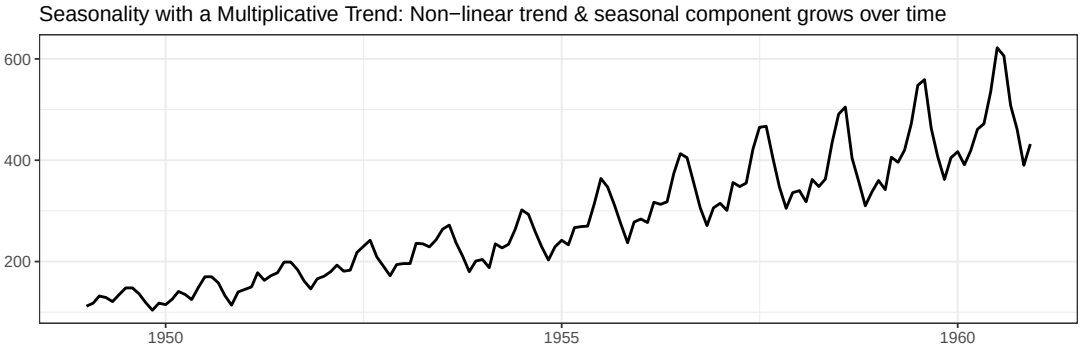
Definition: *An additive model is appropriate when the trend is approximately linear, and the seasonal components stays constant over time.*



Recall: Additive vs. Multiplicative Models [2]

A fully multiplicative model is written as Y = TSE.

Definition: *It is appropriate when the rate of change in the trend and/or the seasonal component and/or the variability in the error term increase or decrease over time.*



Some Comments

- When the trend and seasonal component are multiplied together, larger levels in the series will tend to exhibit larger peaks and troughs. When the error term is also multiplicative, the magnitude of the forecast errors will tend to rise and fall with the level of the series.[2]
- If the error variability is relatively constant over time, but the trend and/or seasonal components increase/decrease over time, a **mixed additive/multiplicative model**, $Y = TS + E$, may be more appropriate.
- An alternative to using a purely multiplicative model is to first transform the data using a logarithmic transformation.

$$\begin{aligned} Y &= TSE \\ \ln(Y) &= \ln(TSE) \\ &= \ln(T) + \ln(S) + \ln(E) \end{aligned}$$

[2] Slide is from Dr. Allison Jones-Farmer's lecture notes, Miami University, Spring 2020.

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Background: Centered Moving Averages

Calculate the CMA(3), where you center the moving average in the middle of the moving window.

Q	Bike Sales	MA3
1.00	10.00	—
2.00	31.00	—
3.00	43.00	—
4.00	16.00	—
1.00	11.00	—
2.00	33.00	—
3.00	45.00	—
4.00	17.00	—
1.00	14.00	—
2.00	36.00	—
3.00	50.00	—
4.00	21.00	—
1.00	19.00	—
2.00	41.00	—
3.00	55.00	—
4.00	25.00	—

Decomposition Methods

Decomposition methods are used to "decompose" a time series into its components.
Decomposition methods are generally poor forecasting methods, but they work well for:

- exploring and visualizing time series data
- detrending and/or deseasonalizing data

Decomposition methods may be applied to multiplicative or additive time series.

Pure Decomposition Process for an Additive Time Series

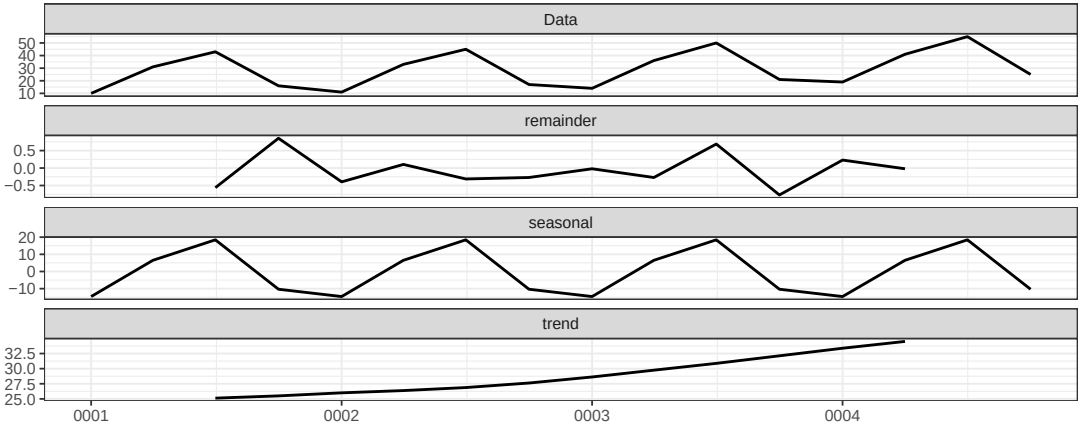
- **Estimate the trend** by calculating the centered moving average for a window of width K, denoted as CMA(K). Note you will lose $(K-1)/2$ observations at the beginning and end of the series if K is odd; suppose $K = 3$, so we lose one observation at the beginning and the end.
- **Detrend the series** by subtracting the CMA from the corresponding observations.
- **Estimate the initial seasonal factors** by calculating the average value of the detrended series for each quarter, month, day, etc. (depending on the season length).
- **Standardize the seasonal factors** by computing their averages and then setting the final seasonal factor for each season equal to the initial value minus the overall average.
- **Estimate the error term** by subtracting seasonal factor from the detrended series for each corresponding season.

A Non-Graded Class Activity: Decomposing the 11-BikeSalesR.xlsx

Based on the procedure described above, please use Excel to perform the aforementioned five steps.

A Live Demo of Using R as an alternative

In class, we will use R to decompose the series and obtain the following plot



Notes on the `decompose()` in R

- The `decompose()` function in R uses a slightly different algorithm than your textbook presents.[3]
- The MA used to compute the trend estimate is a $2 \times m$ moving average. This means that for quarterly data, a 2×4 moving average is computed. First a MA(4) is computed, then a MA(2) of the MA(4) is computed. This is used to estimate the trend.
- The seasonal components are computed as usual and centered.

[3] Slide is from Dr. Allison Jones-Farmer's lecture notes, Miami University, Spring 2020.

Pure Decomposition Process for a Multiplicative Model:

- **Estimate the trend** by calculating the centered moving average for a window of width K (i.e., CMA(K)). For now, let us assume that $k = 3$.
- **Detrend the series** dividing the observations $2, .., (n-1)$ from the their corresponding CMA(3).
- **Estimate the initial seasonal factors** by calculating the average value of the detrended series for each quarter, month, day, etc. (depending on the season length).
- **Standardize the seasonal factor** by computing their averages and then setting the final seasonal factor for each season equal to the initial value divided by the overall average.
- **Estimate the error term** by dividing the detrended series by the seasonal factor for each corresponding season.

Limitations to Decomposition

- Decomposition is widely used in practice but is not a good forecasting method.
- Decomposition methods are useful for visualizing your data and exploratory data analysis.
- Trend estimates are from moving averages and are not available for the first few and last few observations.
- Decomposition methods assume that the seasonal factors occur regularly from season to season over every period. This may not be true over the long run.
- Decomposition methods are not robust to unusual or spurious patterns that may occur in the data.

Because of these limitations, we need a better forecasting method for seasonal data![4]

[4] Slide is from Dr. Allison Jones-Farmer's lecture notes, Miami University, Spring 2020.

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Summary of Main Points

Main Learning Outcomes

- **Explain when to use an additive vs. multiplicative model for a time series.**
- **Use classic decomposition methods to detrend and deseasonalize a time series.**

Things to Do for Next Class

- Thoroughly read Chapter 4.1-4.4 of our textbook.
- Go through the slides, examples and make sure you have a good understanding of what we have covered.
- Complete the graded assignment (see details in next slide).

Graded Assignment 10: Evaluating your Retention/Focus

Please go to Canvas (click here) and answer the question. **Due Oct. 1, 2020 [11:59 PM, Ohio local time].**

What/Why/Prep? The purpose of this assignment is to evaluate your understanding and retention of the material covered up to the end of Class 11. In order to prepare for this, you should have either actively attended class and/or watched the recording from WebEx. Furthermore, you should have thoroughly read up to the end of Chapter 4.4 from your textbook.

General Guidelines:

- Individual assignment.
- This is **NOT** a timed assignment.
- Proctorio is NOT required for this assignment.
- You will need to have R installed (or accessible through the Remote Desktop)

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