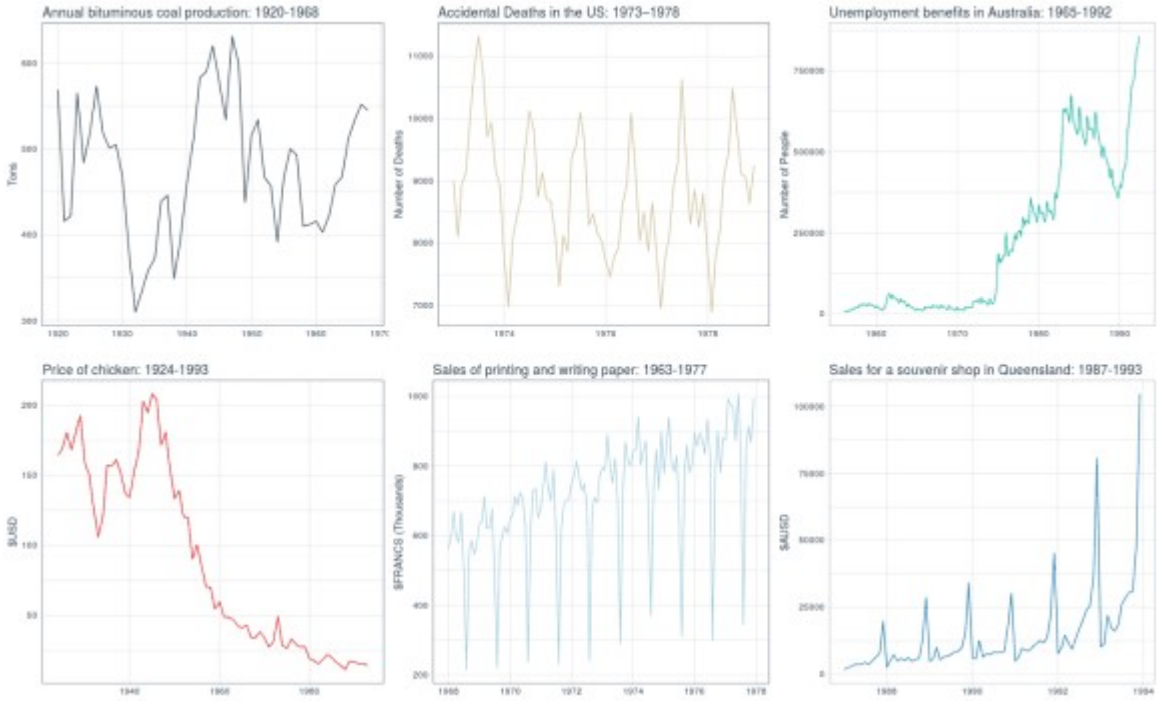
Plot time series data using the `fpp2`, `fpp3`, and `timetk` forecasting frameworks.



1. Set Up

1.1. Introduction

There are a number of forecasting packages written in R to choose from, each with their own pros and cons.

For almost a decade, the `forecast` package has been a rock-solid framework for time series forecasting. However, within the last year or so an official updated version has been released named `fable` which now follows tidy methods as opposed to base R.

More recently, `modeltime` has been released and this also follows tidy methods. However, it is strictly used for modeling. For data manipulation and visualization, the timetk package will be used which is written by the same author as `modeltime`.

The following is a code comparison of various time series visualizations between these frameworks: `fpp2`, `fpp3` and `timetk`.

A few things to keep in mind:

- Only the essential code has been provided
- Non-essential code such as plot titles and themes has been excluded
- All plots utilize the Business Science ggplot theme

1.2 Load Libraries

```
# Load libraries
library(fpp2)          # An older forecasting framework
library(fpp3)          # A newer tidy forecasting framework
library(timetk)        # An even newer tidy forecasting
```

```
framework
library(tidyverse)    # Collection of data manipulation tools
library(tidyquant)    # Business Science ggplot theme
library(cowplot)      # A ggplot add-on for arranging plots
```

2. TS vs tsibble

- The base ts object is used by `forecast` & `fpp2`
- The special tsibble object is used by `fable` & `fpp3`
- The standard tibble object is used by `timetk` & `modeltime`

2.1 Load Time Series Data

For the next few visualizations, we will utilize a dataset containing quarterly production values of certain commodities in Australia.

```
# Quarterly Australian production data as tibble
aus <- tsibbledata::aus_production %>% as_tibble()
# Check structure
aus %>% str()
```

```
Classes 'tbl_df', 'tbl' and 'data.frame':       218 obs. of  7 variables:
 $ Quarter    : yearquarter, format: "1956 Q1" "1956 Q2" "1956 Q3" "1956 Q4" ...
 $ Beer       : num  284 213 227 308 262 228 236 320 272 233 ...
 $ Tobacco    : num  5225 5178 5297 5681 5577 ...
 $ Bricks     : num  189 204 208 197 187 214 227 222 199 229 ...
 $ Cement     : num  465 532 561 570 529 604 603 582 554 620 ...
 $ Electricity: num  3923 4436 4806 4418 4339 ...
 $ Gas        : num  5 6 7 6 5 7 7 6 5 7 ...
```

Always check the class of your time series data.

2.2 fpp2 Method: From tibble to ts

```
# Convert tibble to time series object
aus_prod_ts <- ts(aus[, 2:7],  # Choose columns
                  start = c(1956, 1),  # Choose start date
                  end = c(2010, 2),    # Choose end date
                  frequency = 4)       # Choose frequency
per yr
# Check it out
aus_prod_ts %>% tail()
```

	Beer	Tobacco	Bricks	Cement	Electricity	Gas
2009 Q1	415	NA	NA	1963	58368	196
2009 Q2	398	NA	NA	2160	57471	238
2009 Q3	419	NA	NA	2325	58394	252
2009 Q4	488	NA	NA	2273	57336	210
2010 Q1	414	NA	NA	1904	58309	205
2010 Q2	374	NA	NA	2401	58041	236

2.3 fpp3 Method: From ts to tsibble

2.3.1 Pivot Wide

```
# Convert ts to tsibble and keep wide format
aus_prod_tbl_wide <- aus_prod_ts %>%    # TS object
  as_tsibble(index = "index",           # Set index column
             pivot_longer = FALSE)      # Wide format
```

```
# A tsibble: 218 x 7 [1Q]
     index  Beer Tobacco Bricks Cement Electricity   Gas
     <qtr> <dbl>   <dbl>  <dbl>  <dbl>       <dbl> <dbl>
 1 1956 Q1   284    5225    189    465        3923     5
 2 1956 Q2   213    5178    204    532        4436     6
 3 1956 Q3   227    5297    208    561        4806     7
 4 1956 Q4   308    5681    197    570        4418     6
 5 1957 Q1   262    5577    187    529        4339     5
 6 1957 Q2   228    5651    214    604        4811     7
 7 1957 Q3   236    5317    227    603        5259     7
 8 1957 Q4   320    6152    222    582        4735     6
 9 1958 Q1   272    5758    199    554        4608     5
10 1958 Q2   233    5641    229    620        5196     7
# … with 208 more rows
```

2.3.2 Pivot Long

```
# Convert ts to tsibble and pivot to long format
aus_prod_tbl_long <- aus_prod_ts %>%    # TS object
  as_tsibble(index = "index",           # Set index column
             pivot_longer = TRUE)       # Long format
```

```
# A tsibble: 1,308 x 3 [1Q]
# Key:       key [6]
      index key   value
      <qtr> <chr> <dbl>
 1 1956 Q1 Beer    284
 2 1956 Q2 Beer    213
 3 1956 Q3 Beer    227
 4 1956 Q4 Beer    308
 5 1957 Q1 Beer    262
 6 1957 Q2 Beer    228
 7 1957 Q3 Beer    236
 8 1957 Q4 Beer    320
 9 1958 Q1 Beer    272
10 1958 Q2 Beer    233
# … with 1,298 more rows
```

2.4 timetk Method: From tsibble/ts to tibble

2.4.1 Pivot Wide

```
# Convert tsibble to tibble, keep wide format
aus <- tsibbledata::aus_production %>%
    tk_tbl() %>%
    mutate(Quarter = as_date(as.POSIXct.Date(Quarter)))
```

```
# A tibble: 218 x 7
   Quarter     Beer Tobacco Bricks Cement Electricity   Gas
   <date>     <dbl>   <dbl>  <dbl>  <dbl>       <dbl> <dbl>
 1 1955-12-31   284    5225    189    465        3923     5
 2 1956-03-31   213    5178    204    532        4436     6
 3 1956-06-30   227    5297    208    561        4806     7
 4 1956-09-30   308    5681    197    570        4418     6
 5 1956-12-31   262    5577    187    529        4339     5
 6 1957-03-31   228    5651    214    604        4811     7
 7 1957-06-30   236    5317    227    603        5259     7
 8 1957-09-30   320    6152    222    582        4735     6
 9 1957-12-31   272    5758    199    554        4608     5
10 1958-03-31   233    5641    229    620        5196     7
# … with 208 more rows
```

Workaround for indexing issue with tsibble and R 4.0 and up.

2.4.2 Pivot Long

```
# Quarterly Australian production data to long format
aus_long <- aus %>%
    rename(date = Quarter) %>%
    pivot_longer(
        cols = c("Beer","Tobacco","Bricks",
                 "Cement","Electricity","Gas"))
```

```
# A tibble: 1,308 x 3
   date       name        value
   <date>     <chr>       <dbl>
 1 1955-12-31 Beer          284
 2 1955-12-31 Tobacco      5225
 3 1955-12-31 Bricks        189
 4 1955-12-31 Cement        465
 5 1955-12-31 Electricity  3923
 6 1955-12-31 Gas             5
 7 1956-03-31 Beer          213
 8 1956-03-31 Tobacco      5178
 9 1956-03-31 Bricks        204
10 1956-03-31 Cement        532
# … with 1,298 more rows
```

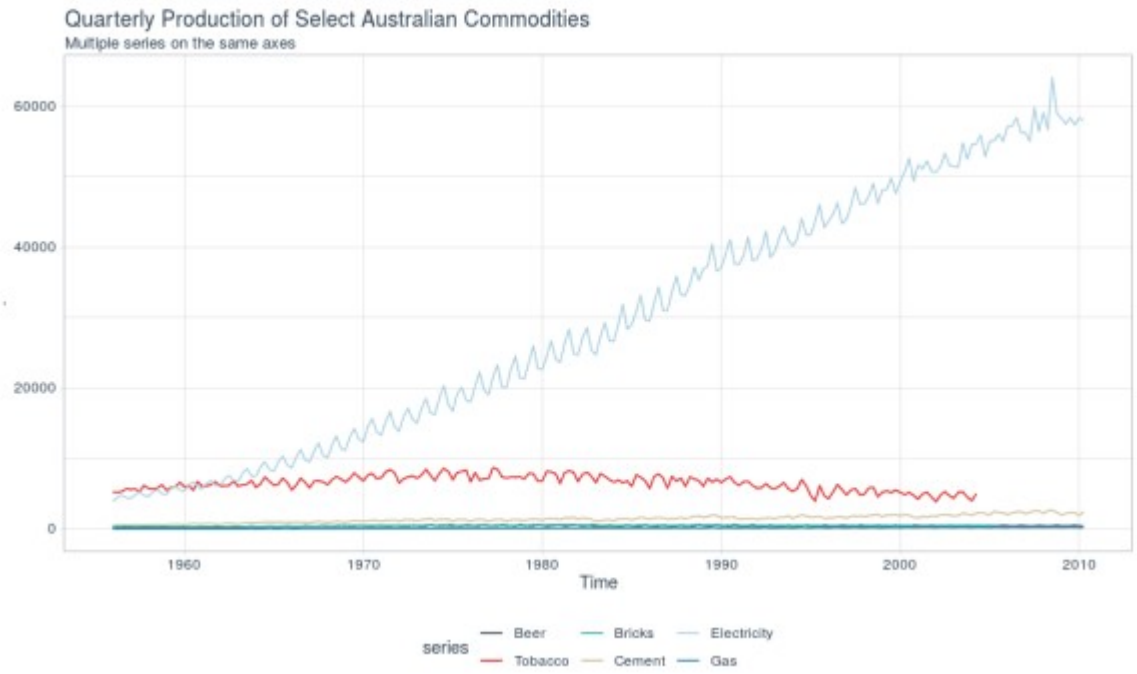
3. Time Series Plots

When analyzing time series plots, look for the following patterns:

- **Trend**: A long-term increase or decrease in the data; a “changing direction”.
- **Seasonality**: A seasonal pattern of a fixed and known period. If the frequency is unchanging and associated with some aspect of the calendar, then the pattern is seasonal.
- **Cycle**: A rise and fall pattern not of a fixed frequency. If the fluctuations are not of a fixed frequency then they are cyclic.
- **Seasonal vs Cyclic**: Cyclic patterns are longer and more variable than seasonal patterns in general.

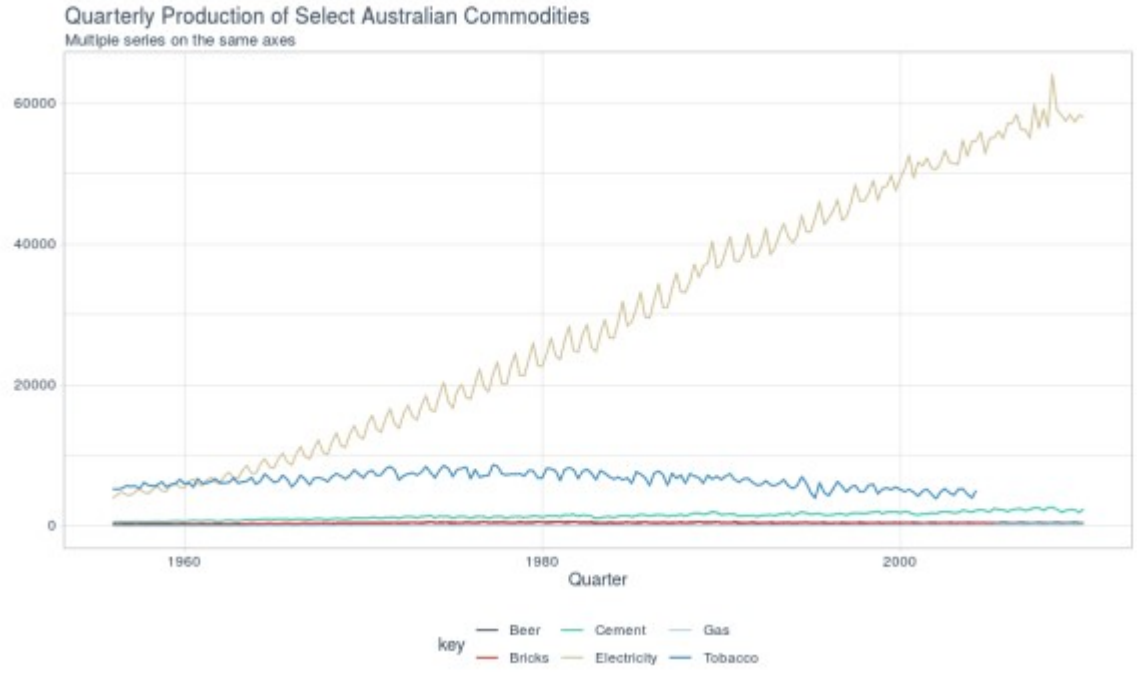
3.1 fpp2 Method: Plot Multiple Series On Same Axes

```
# Using fpp2
aus_prod_ts %>%              # TS object
  autoplot(facets=FALSE)     # No facetting
```



3.2 fpp3 Method: Plot Multiple Series On Same Axes

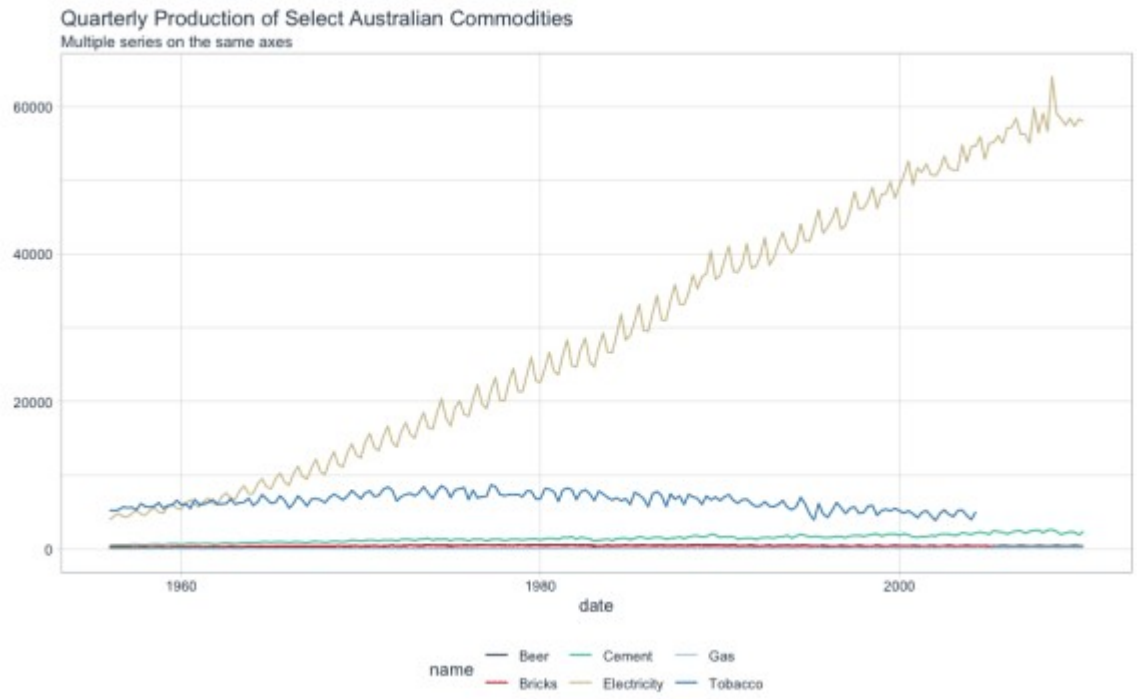
```
# Using fpp3
aus_prod_tbl_long %>%     # Data in long format
  autoplot(value)
```



3.3 ggplot Method: Plot Multiple Series On Same Axes

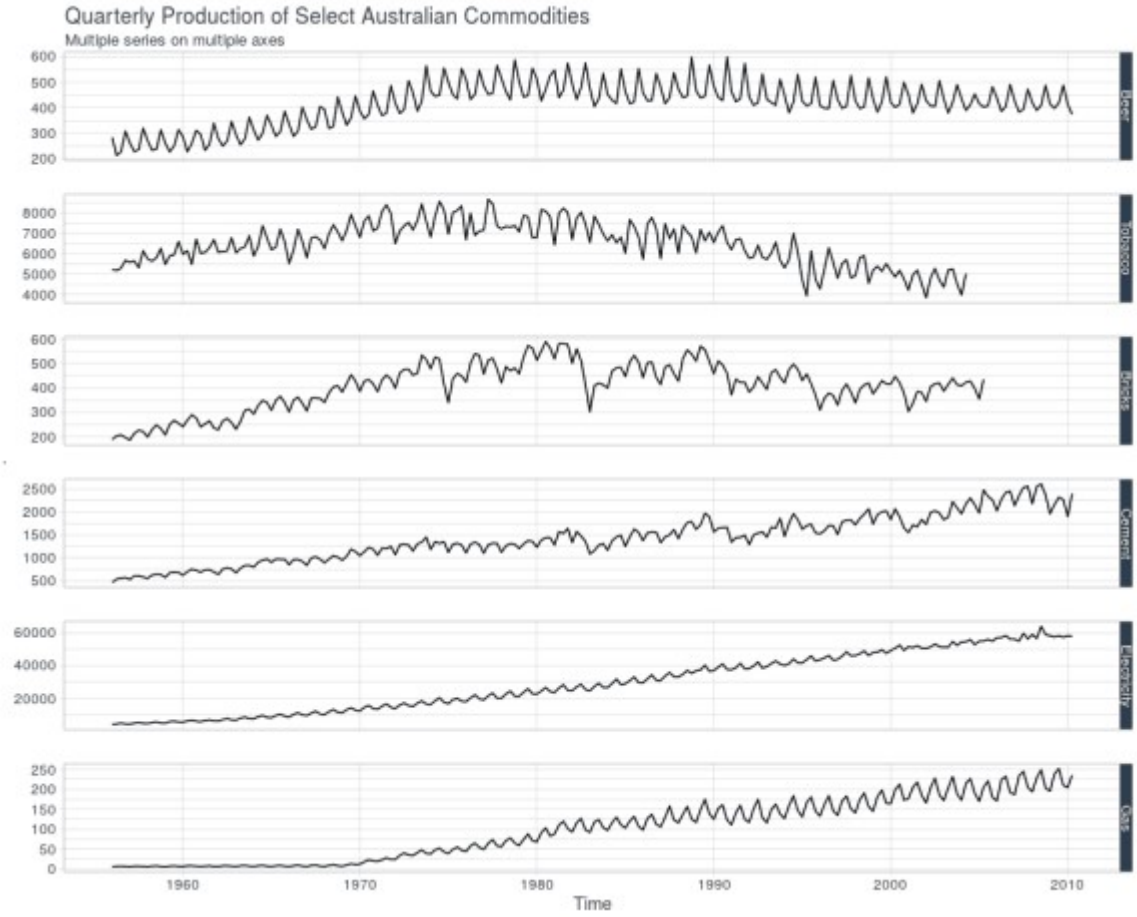
Note that plotting multiple plots on the same axes has not been implemented into `timetk`. Use `ggplot`.

```
# Using ggplot
aus_long %>%
    ggplot(aes(date, value, group = name, color = name)) +
    geom_line()
```



3.4 fpp2 Method: Plot Multiple Series On Separate Axes

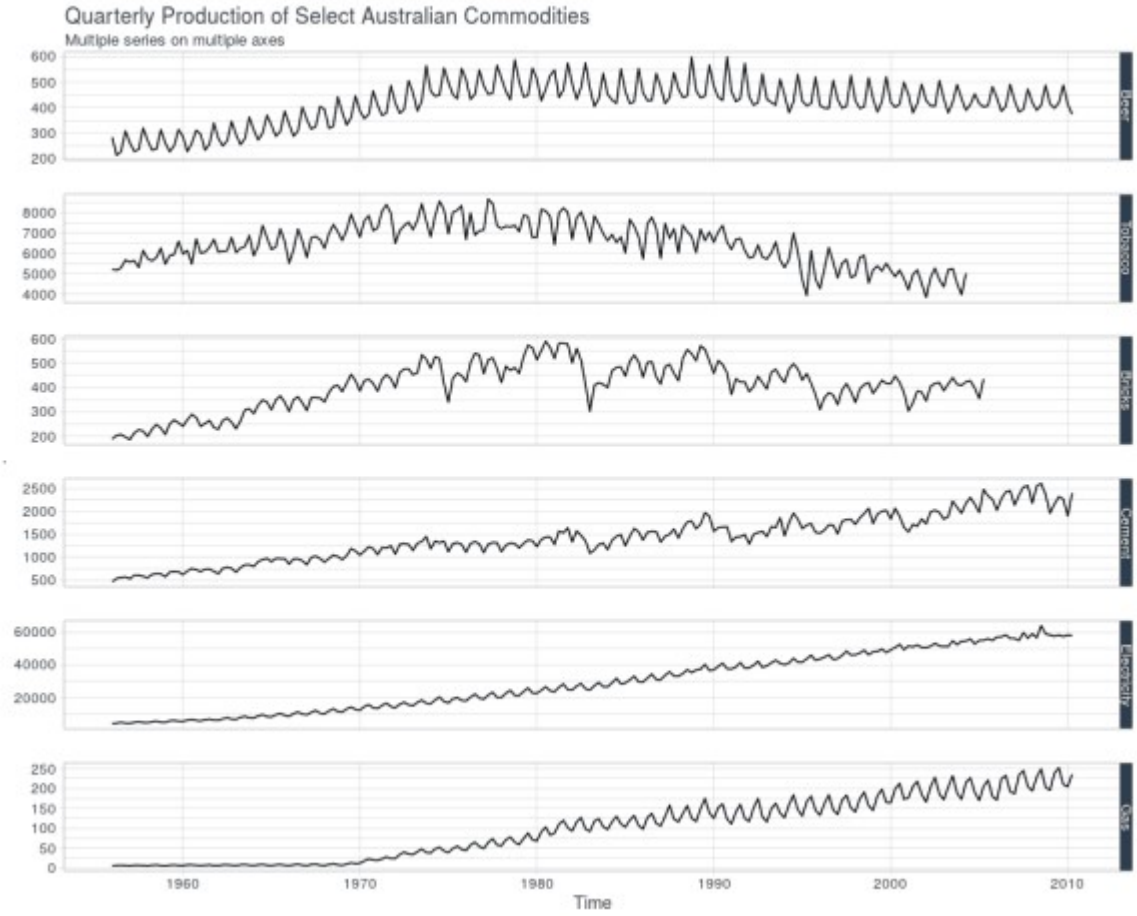
```
# Using fpp2
aus_prod_ts %>%
  autoplot(facets=TRUE)    # With facetting
```



Facetted plot with fpp2

3.5 fpp3 Method: Plot Multiple Series On Separate Axes

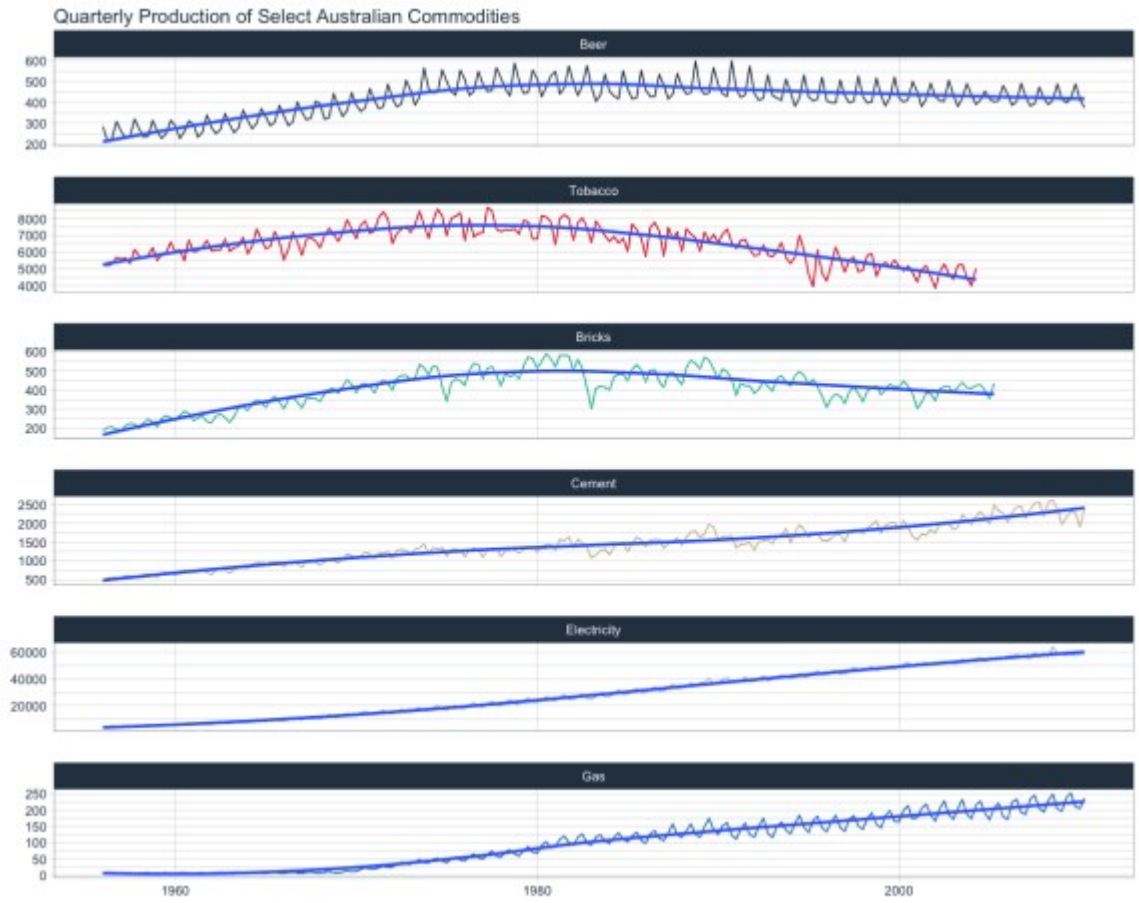
```
# Using fpp3
aus_prod_tbl_long %>%
  ggplot(aes(x = index, y = value, group = key)) +
  geom_line() +
  facet_grid(vars(key), scales = "free_y")   # With facetting
```



Facetted plot with fpp3

3.6 timetk Method: Plot Multiple Series On Separate Axes

```
# Using timetk
aus_long %>%
    plot_time_series(
        .date_var = date,
        .value = value,
        .facet_vars = c(name), # Group by these columns
        .color_var = name,
        .interactive = FALSE,
        .legend_show = FALSE
    )
```



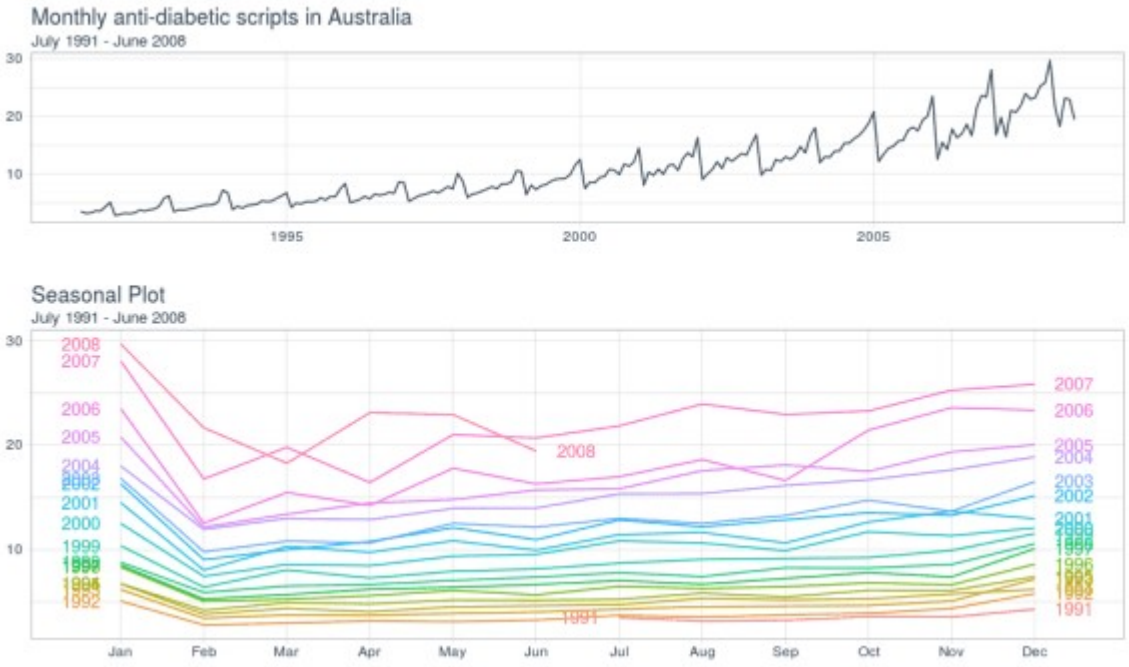
Facetted plot with timetk

4. Seasonal Plots

Use seasonal plots for identifying time periods in which the patterns change.

4.1 fpp2 Method: Plot Individual Seasons

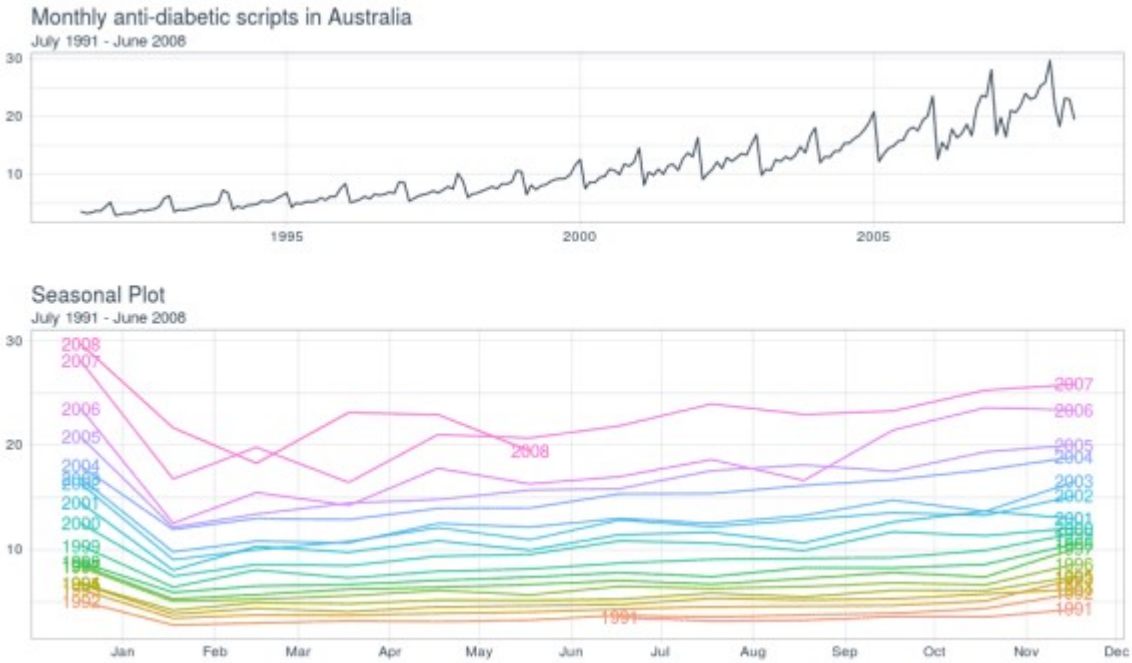
```
# Monthly plot of anti-diabetic scripts in Australia
a1 <- a10 %>%
  autoplot()
# Seasonal plot
a2 <- a10 %>%
  ggseasonplot(year.labels.left = TRUE,    # Add labels
               year.labels = TRUE)
# Arrangement of plots
plot_grid(a1, a2, ncol=1, rel_heights = c(1, 1.5))
```



Seasonal plot with fpp2

4.2 fpp3 Method: Plot Individual Seasons

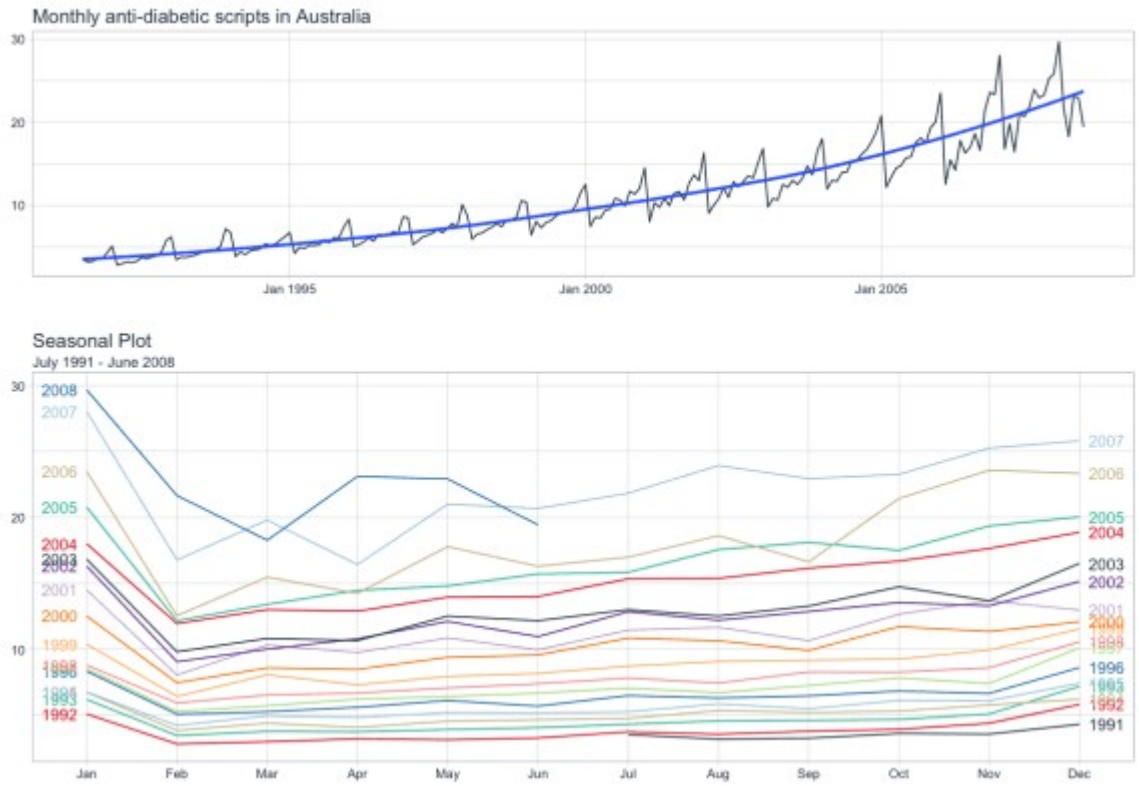
```
# Monthly plot of anti-diabetic scripts in Australia
a1 <- a10 %>%
  as_tsibble() %>%
  autoplot(value)
# Seasonal plot
a2 <- a10 %>%
  as_tsibble() %>%
  gg_season(value, labels="both")    # Add labels
# Arrangement of plots
plot_grid(a1, a2, ncol=1, rel_heights = c(1, 1.5))
```



4.3 ggplot Method: Plot Individual Seasons

Note that seasonal plots have not been implemented into `timetk`. Use ggplot to write:

```
# Convert ts to tibble
a10_tbl <- fpp2::a10 %>%
    tk_tbl()
# Monthly plot of anti-diabetic scripts in Australia
a1 <- a10_tbl %>%
    plot_time_series(
        .date_var = index,
        .value    = value,
        .smooth   = TRUE,
        .interactive = FALSE,
        .title = "Monthly anti-diabetic scripts in Australia"
    )
# New time-based features to group by
a10_tbl_add <- a10_tbl %>%
    mutate(
        month = factor(month(index, label = TRUE)),  # Plot
this
        year = factor(year(index))  # Grouped on y-axis
    )
# Seasonal plot
a2 <- a10_tbl_add %>%
    ggplot(aes(x = month, y = value,
               group = year, color = year)) +
    geom_line() +
    geom_text(
        data = a10_tbl_add %>% filter(month == min(month)),
        aes(label = year, x = month, y = value),
        nudge_x = -0.3) +
    geom_text(
        data = a10_tbl_add %>% filter(month == max(month)),
        aes(label = year, x = month, y = value),
        nudge_x = 0.3) +
    guides(color = FALSE)
# Arrangement of plots
plot_grid(a1, a2, ncol=1, rel_heights = c(1, 1.5))
```



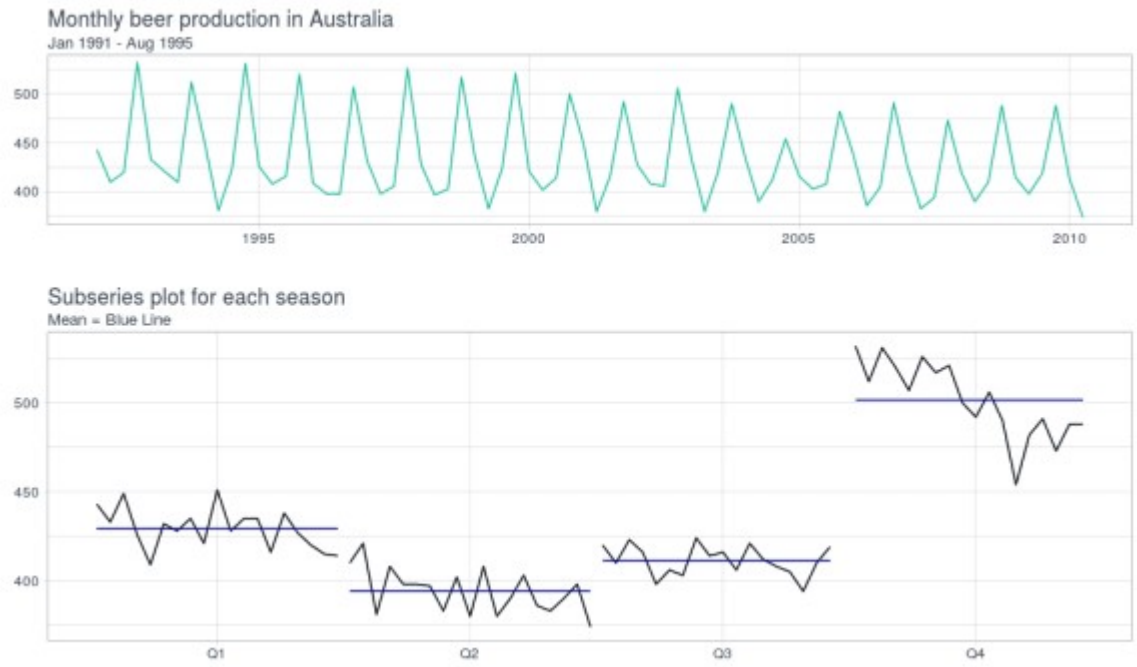
Seasonal plot with ggplot

5. Subseries Plots

Use subseries plots to view seasonal changes over time.

5.1 fpp2 Method: Plot Subseries on Same Axes

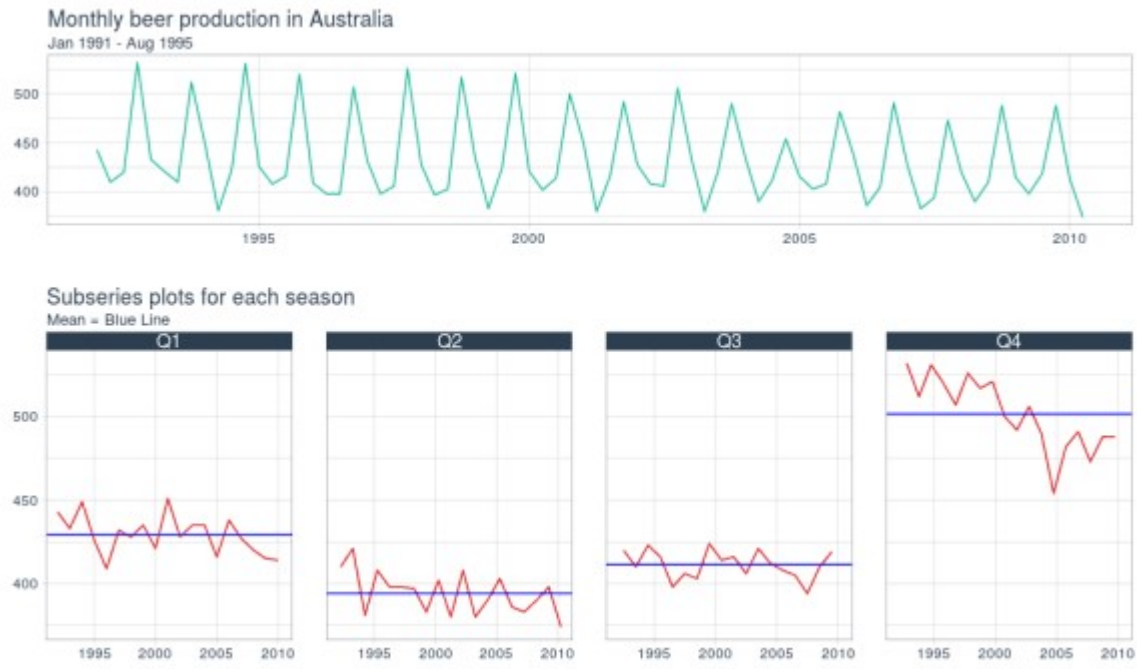
```
# Monthly beer production in Australia 1992 and after
beer_fpp2 <- fpp2::ausbeer %>%
  window(start = 1992)
# Time series plot
b1 <- beer_fpp2 %>%
  autoplot()
# Subseries plot
b2 <- beer_fpp2 %>%
  ggsubseriesplot()
# Plot it
plot_grid(b1, b2, ncol=1, rel_heights = c(1, 1.5))
```



Subseries plots on the same axes using fpp2

5.2 fpp3 Method: Plot Subseries on Separate Axes

```
# Monthly beer production in Australia 1992 and after
beer_fpp3 <- fpp2::ausbeer %>%
  as_tsibble() %>%
  filter(lubridate::year(index) >= 1992)
# Time series plot
b3 <- beer_fpp3 %>%
  autoplot(value)
# Subseries plot
b4 <- beer_fpp3 %>%
  gg_subseries(value)
# Plot it
plot_grid(b3, b4, ncol=1, rel_heights = c(1, 1.5))
```

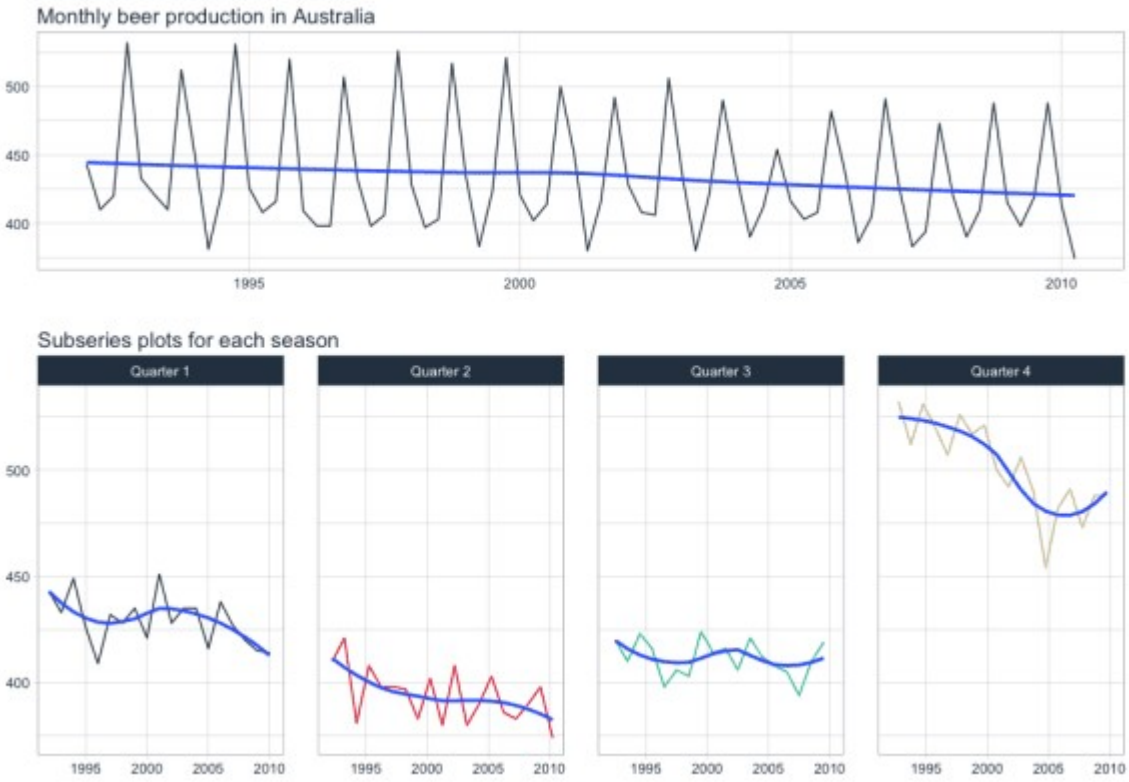


Subseries plots on the same axes using fpp3

5.3 timetk Method: Plot Subseries on Separate Axes

```
# Monthly beer production in Australia 1992 and after
ausbeer_tbl <- fpp2::ausbeer %>%
    tk_tbl() %>%
    filter(year(index) >= 1992) %>%
    mutate(index = as_date(index))
# Time series plot
b1 <- ausbeer_tbl %>%
    plot_time_series(
        .date_var = index,
        .value    = value,
        .interactive = FALSE
    )
# Subseries plot
b2 <- ausbeer_tbl %>%
    mutate(
        quarter = str_c("Quarter ",
as.character(quarter(index)))
    ) %>%
    plot_time_series(
        .date_var = index,
        .value = value,
        .facet_vars = quarter,
        .facet_ncol = 4,
        .color_var = quarter,
        .facet_scales = "fixed",
        .interactive = FALSE,
        .legend_show = FALSE
    )
# Plot it
```

```
plot_grid(b1, b2, ncol=1, rel_heights = c(1, 1.5))
```



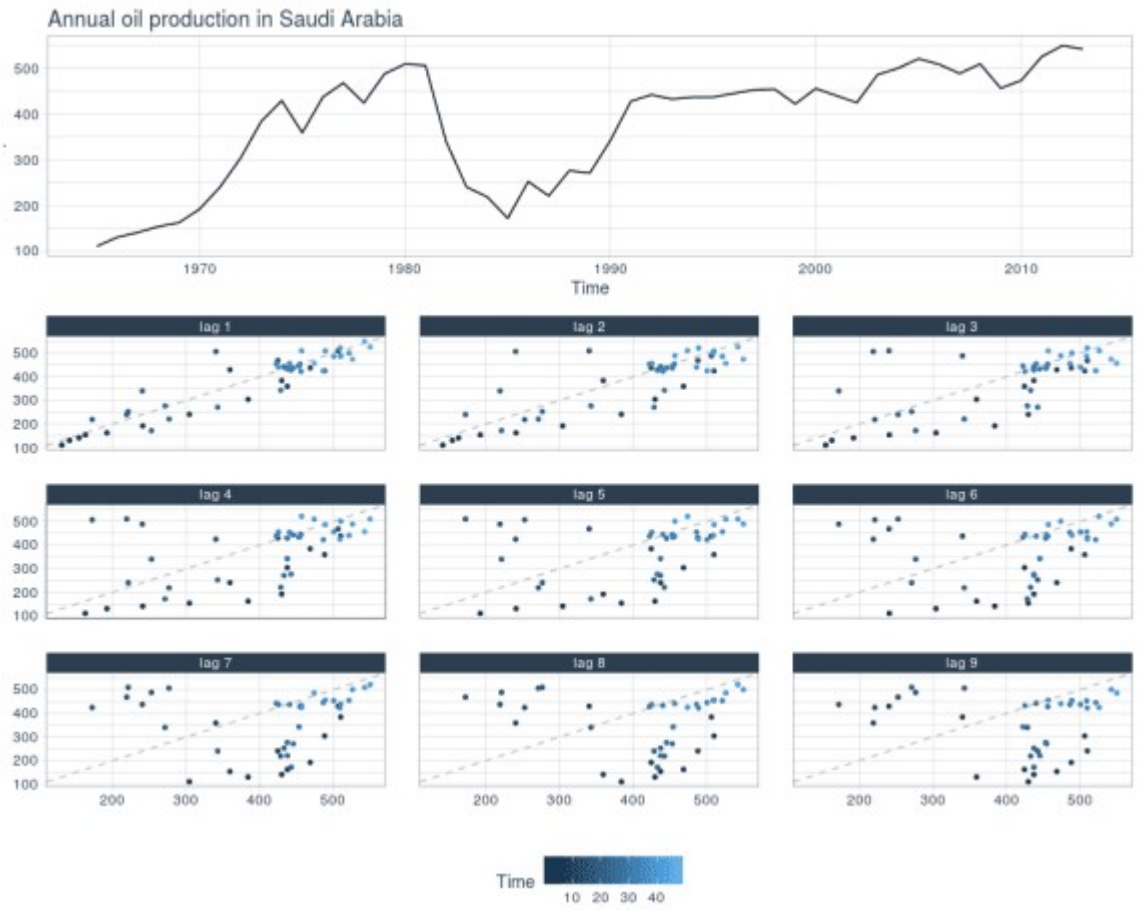
Subseries plots on the same axes using timetk

6. Lag Plots

Use lag plots to check for randomness.

6.1 fpp2 Method: Plot Multiple Lags

```
# Plot of non-seasonal oil production in Saudi Arabia
o1 <- fpp2::oil %>%
  autoplot()
# Lag plot of non-seasonal oil production
o2 <- gglagplot(oil, do.lines = FALSE)
# Plot both
plot_grid(o1, o2, ncol=1, rel_heights = c(1,2))
```



Lag plots using fpp2

6.2 fpp3 Method: Plot Multiple Lags

```
# Plot of non-seasonal oil production
o1 <- oil %>%
  as_tsibble() %>%
  autoplot(value)
# Lag plot of non-seasonal oil production
o2 <- oil %>%
  as_tsibble() %>%
  gg_lag(y=value, geom = "point")
# Plot it
plot_grid(o1, o2, ncol=1, rel_heights = c(1,2))
```

Lag plots using fpp3

6.3 timetk Method (Hack?) : Plot Multiple Lags

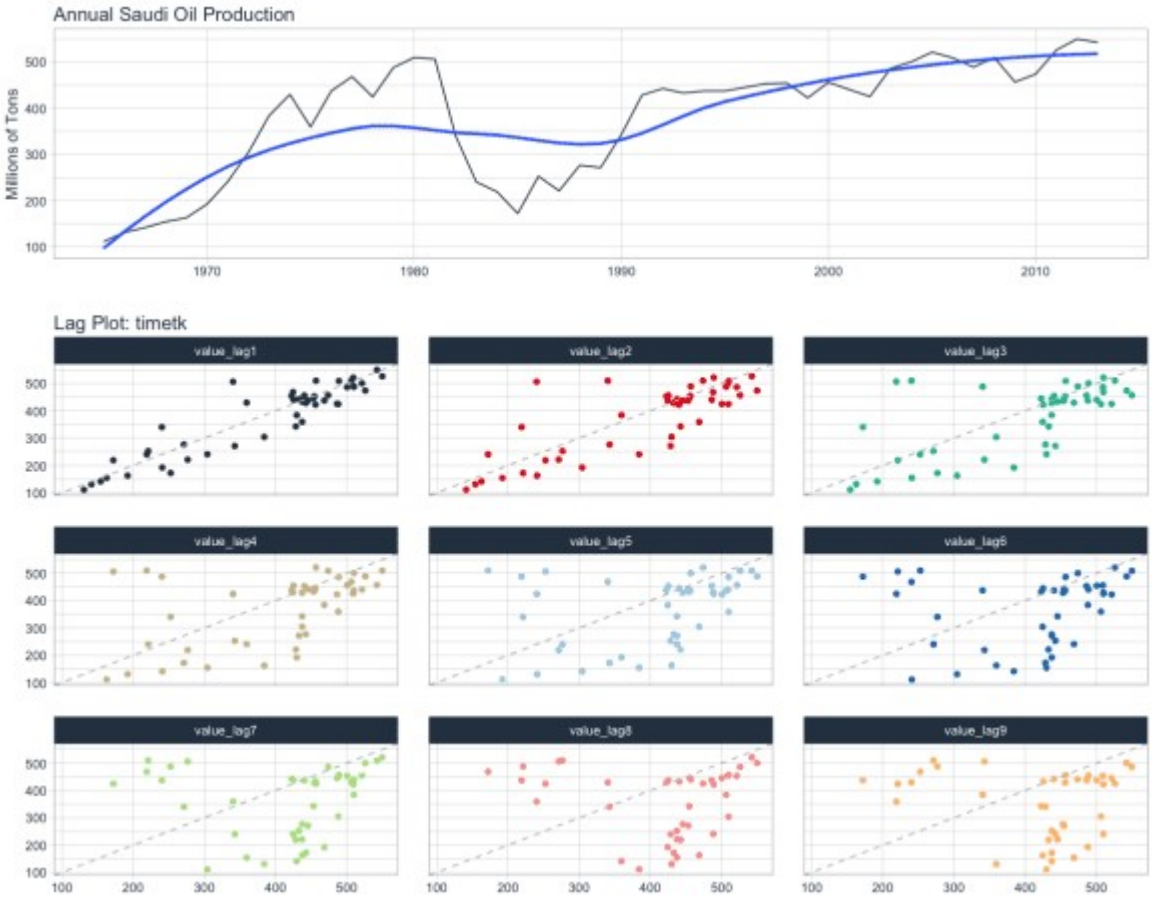
```
# Convert to tibble and create lag columns
oil_lag_long <- oil %>%
    tk_tbl(rename_index = "year") %>%
    tk_augment_lags(      # Add 9 lag columns of data
        .value = value,
        .names = "auto",
        .lags = 1:9) %>%
    pivot_longer(         # Pivot from wide to long
        names_to = "lag_id",
        values_to = "lag_value",
        cols = value_lag1:value_lag9)  # Exclude year & value
```

```
# A tibble: 441 x 4
    year value lag_id     lag_value
   <dbl> <dbl> <chr>          <dbl>
 1  1965  111. value_lag1        NA
 2  1965  111. value_lag2        NA
 3  1965  111. value_lag3        NA
 4  1965  111. value_lag4        NA
 5  1965  111. value_lag5        NA
 6  1965  111. value_lag6        NA
 7  1965  111. value_lag7        NA
 8  1965  111. value_lag8        NA
 9  1965  111. value_lag9        NA
10  1966  131. value_lag1      111.
# … with 431 more rows
```

Now you can plot value vs lag_value

```
# Time series plot
o1 <- oil %>%
    tk_tbl(rename_index = "year") %>%
    mutate(year = ymd(year, truncated = 2L)) %>%
    plot_time_series(
        .date_var = year,
        .value = value,
        .interactive = FALSE)
# timetk Method: Plot Multiple Lags
o2 <- oil_lag_long %>%
    plot_time_series(
        .date_var = value,     # Use value instead of date
        .value = lag_value,    # Use lag value to plot
against
        .facet_vars = lag_id,  # Facet by lag number
        .facet_ncol = 3,
        .interactive = FALSE,
        .smooth = FALSE,
        .line_alpha = 0,
        .legend_show = FALSE,
        .facet_scales = "fixed"
        ) +
    geom_point(aes(colour = lag_id)) +
    geom_abline(colour = "gray", linetype = "dashed")
# Plot it
```

```
plot_grid(o1, o2, ncol=1, rel_heights = c(1,2))
```



Lag plots using timetk

7. Autocorrelation Function Plots

The autocorrelation function measures the linear relationship between lagged values of a time series. The partial autocorrelation function measures the linear relationship between the correlations of the residuals.

ACF

- Visualizes how much the most recent value of the series is correlated with past values of the series (lags)
- If the data has a trend, then the autocorrelations for small lags tend to be positive and large because observations nearby in time are also nearby in size
- If the data are seasonal, then the autocorrelations will be larger for seasonal lags at multiples of seasonal frequency than other lags

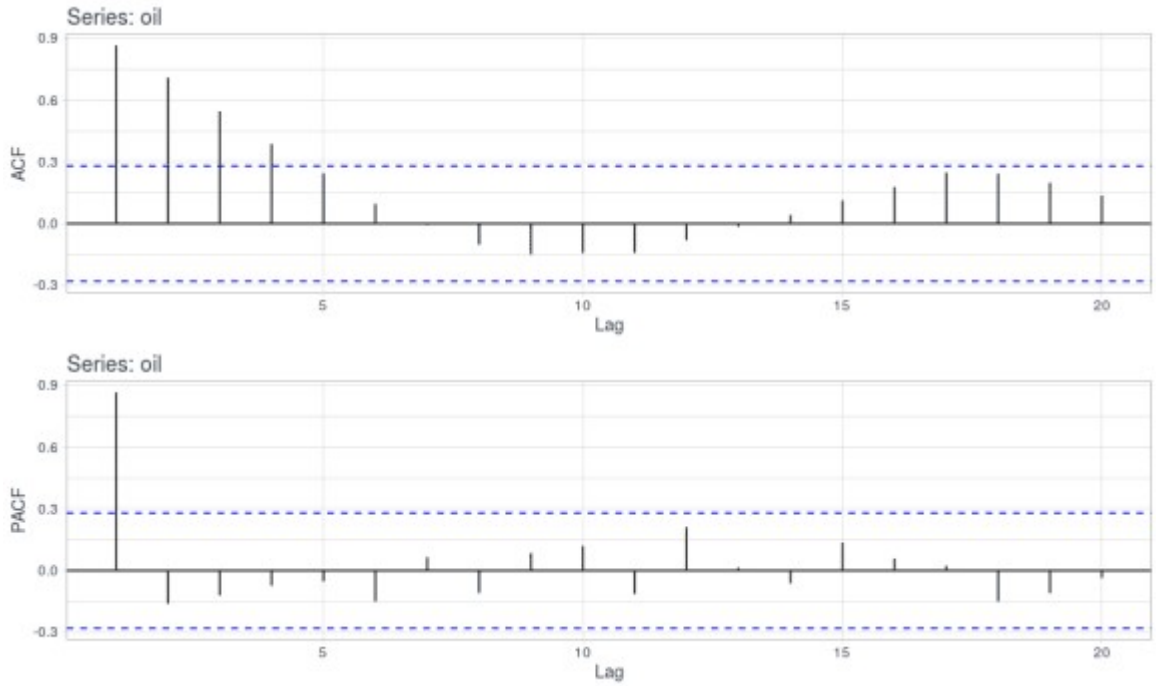
PACF

- Visualizes whether certain lags are good for modeling or not; useful for data with a seasonal pattern
- Removes dependence of lags on other lags by using the correlations of the residuals

7.1 fpp2 Method: Plot ACF + PACF

```
# ACF plot
o1 <- ggAcf(oil, lag.max = 20)
```

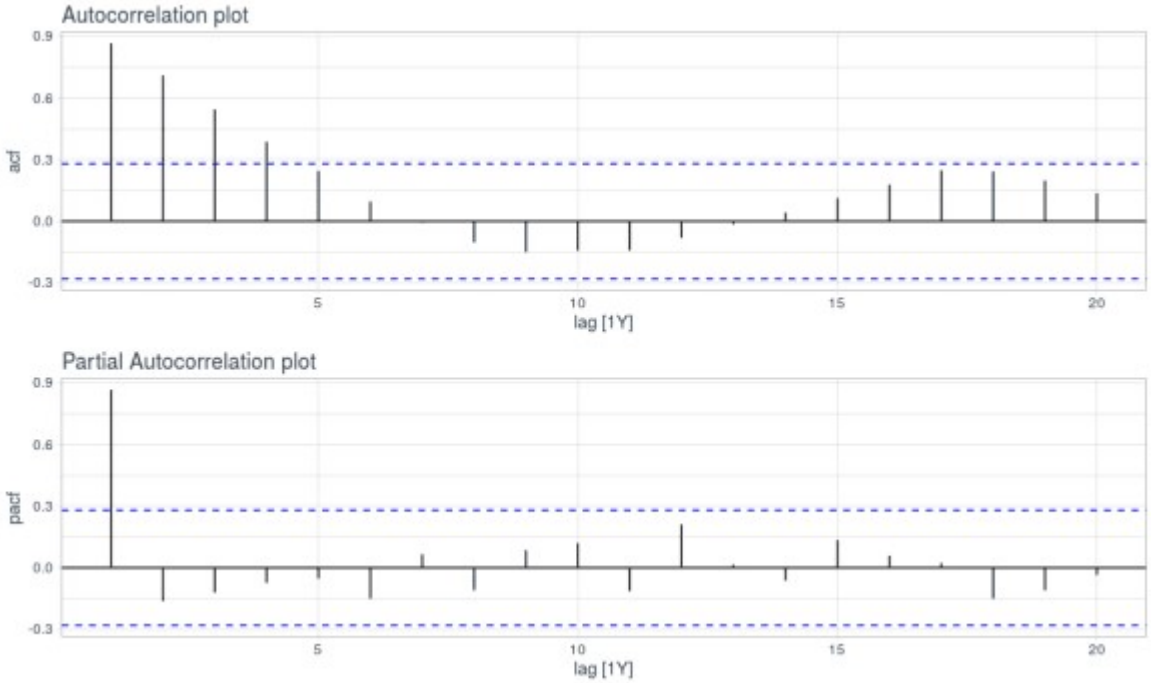
```
# PACF plot
o2 <- ggPacf(oil, lag.max = 20)
# Plot both
plot_grid(o1, o2, ncol = 1)
```



Are autocorrelations large at seasonal lags? Are the most recent lags above the white noise threshold?

7.2 fpp3 Method: Plot ACF + PACF

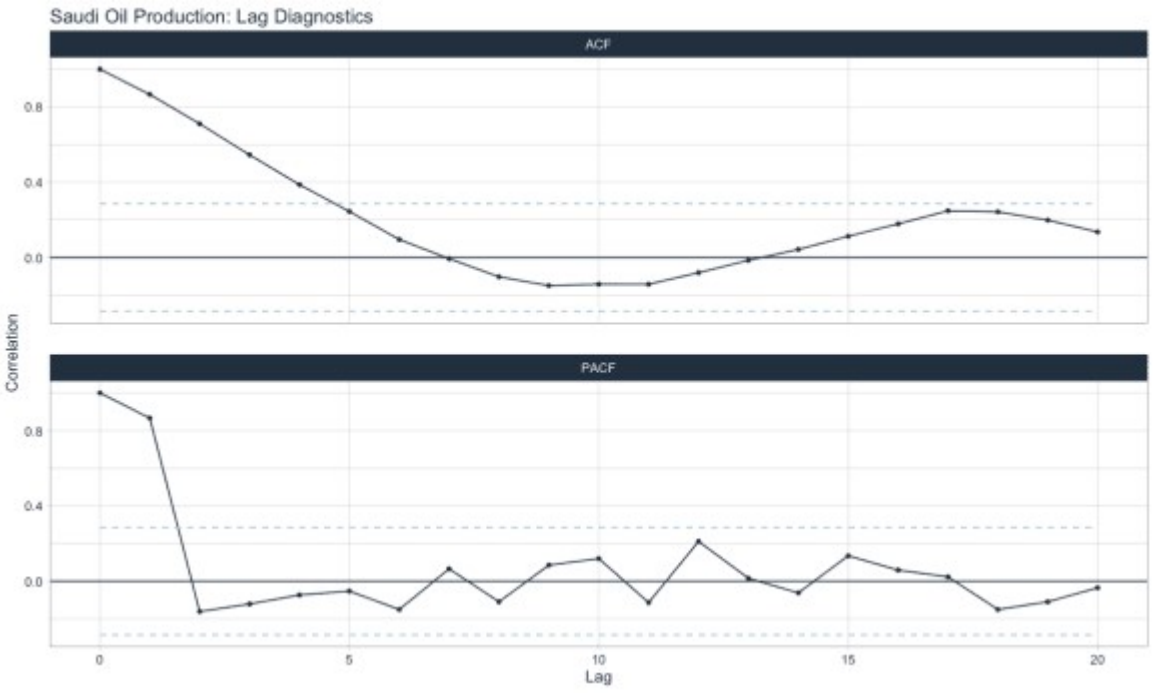
```
# Convert to tsibble
oil_tsbl <- oil %>% as_tsibble()
# ACF Plot
o1 <- oil_tsbl %>%
  ACF(lag_max = 20) %>%
  autoplot()
# PACF Plot
o2 <- oil_tsbl %>%
  PACF(lag_max = 20) %>%
  autoplot()
# Plot both
plot_grid(o1, o2, ncol = 1)
```



The autocorrelations are not large at seasonal lags so this series is non-seasonal. The most recent lags show that there is a trend.

7.3 timetk Method: Plot ACF & PACF

```
# Using timetk
oil %>%
    tk_tbl(rename_index = "year") %>%
    plot_acf_diagnostics(
        .date_var = year,
        .value    = value,
        .lags     = 20,
        .show_white_noise_bars = TRUE,
        .interactive = FALSE
    )
```



ACF shows more recent lags are above the white noise significance bars denoting a trend. PACF shows that including lag 1 would be good for modeling purposes.

8. Summary

As with all things in life, there are good and bad sides to using any of these three forecasting frameworks for visualizing time series. All three have similar functionality as it relates to visualizations.