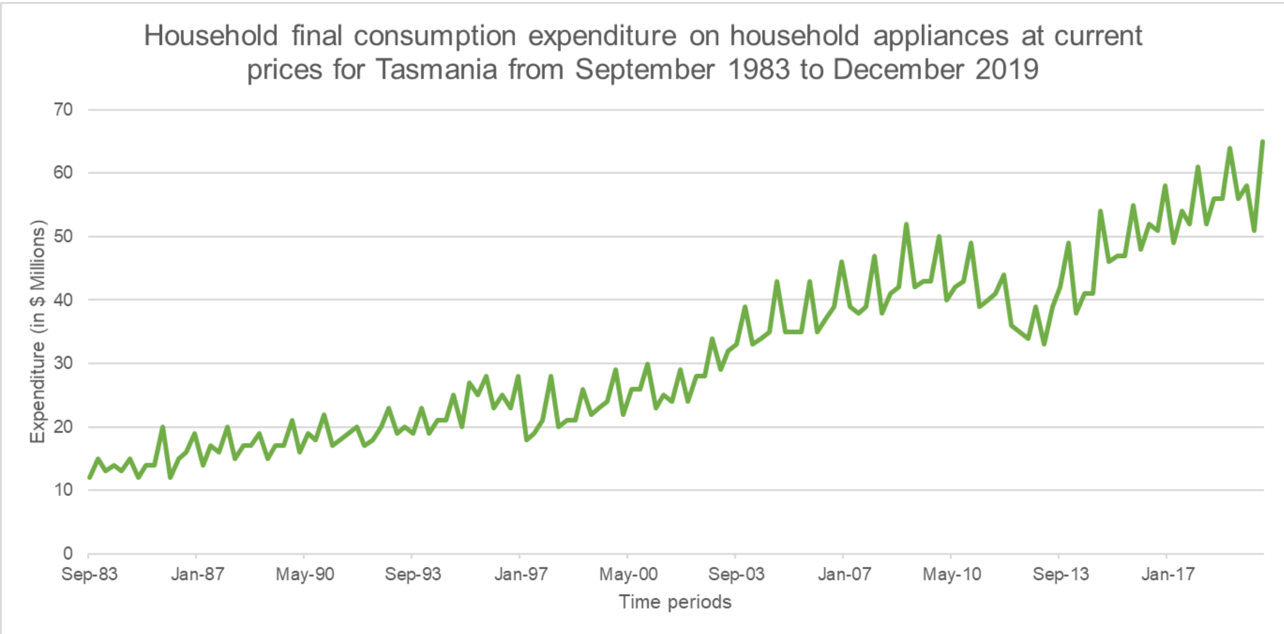
# Questions 1 & 2 (1 page) – Plot and Components

Q1) The Australian state that I have been designated is Tasmania. I identified a relevant time series for household final consumption expenditure on household appliances at current prices from September 1983 to December 2019 on the Australian Bureau of Statistics (ABS) website. I was provided a link to the relevant webpage on iLearn and downloaded the XLS file for Table 31. A reference to this webpage will be made in the "References" section of this report and in the XLS file submitted with this report.

This time series will be used to forecast the expenditure on household appliances in Tasmania to assist in the business plans that American home appliance retailer *HomeAppCo* has in terms of expanding and launching stores across Australia.

<u>Line chart of the relevant time series</u>:

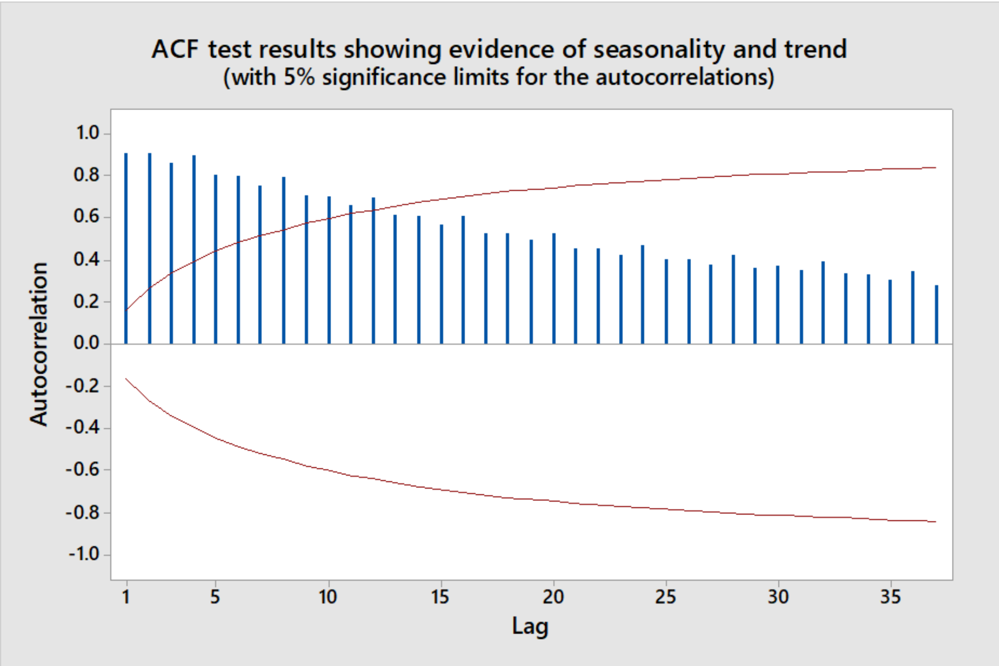



There is a structural break in the time series as there is a downward trend from December 2008 to March 2013.

Q2) The systematic components that are evident in the time series are trend and seasonal components. The trend component of the time series is evident from the upward path of the time series and the underlying trend appears to be non-linear. The seasonal component of the time series can be explained by the annual peaks in December and annual troughs in March. This seasonal pattern is relatively consistent over the time series and can also be described by some random fluctuation (non-systematic component of the time series). The environmental and economic factors that have likely impacted on the observed paths of the time series will be examined in Question 4.

# Questions 3 & 4 (1 page) – Correlogram and Factors

Q3) The ACF (autocorrelation function) correlogram confirms the presence of the systematic components (trend and seasonal) of the time series. The trend component of the time series is revealed by the lags initially being large and a relatively steady decline of the autocorrelations from lag 1 onwards. The seasonal component of the time series is revealed by the significant autocorrelations between observations that are at multiples of the seasonal period. The seasonal period of the time series data is quarterly, and you can clearly see a spike at every 4$^{th}$ lag as the seasonal cycle repeats every 4 quarters.



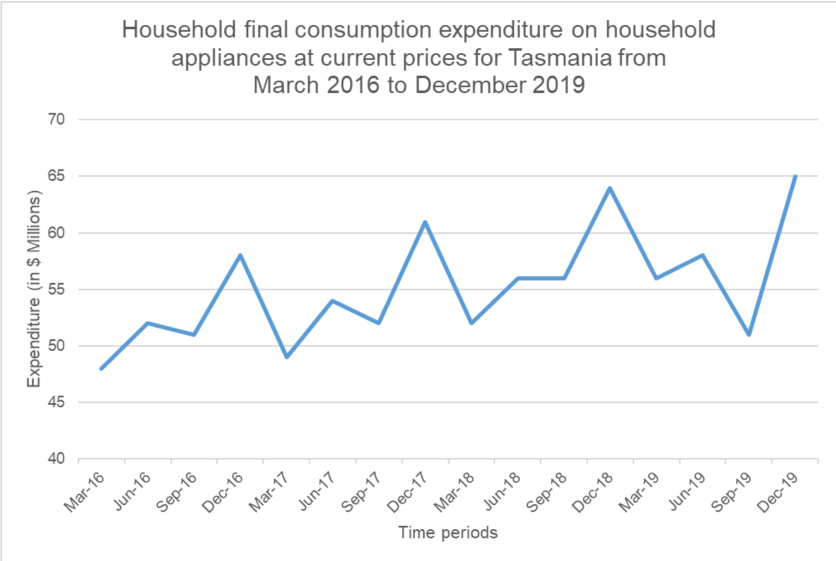

Q4) There are economic and environmental factors and circumstances which have influenced the characteristics and components of the time series. The trend component of the time series has likely been influenced by population growth (Humphries 2018) because as the population of Tasmania increases there are more people who need household appliances. People will always be need of household appliances such as washing machines, kitchen stoves and refrigerators because they help people streamline their domestic duties. The upward trend may also be attributed to economic growth (Ford 2019) as there are now more household appliances manufactured or technological advancements over time as now there is a larger range and variety of household appliances. The downward trend from December 2008 to March 2013 may have been a result of the Global Financial Crisis (GFC) or economic downturn.

The seasonal component of the time series has likely been influenced by the summer Christmas holidays in December in Australia. Household appliances are on sale during this time of the year and an increase in consumer spending during this quarter means that more people are buying them as they have become more affordable. Families spend more time at home during the summer break which means they will be using more household appliances. The annual peaks in December are followed by the annual troughs in March and these low points possibly represent a Christmas "hangover" as people pay off their credit cards after their Christmas spending. There is also some random fluctuation which may be a result of one-off events in particular years. All the above discussed factors and circumstances apply to the relevant forecasting period.

# Questions 5 & 6 (two pages) – WES Method

Q5) To further identify the relevant systematic components of the time series I used (multiplicative) Winters' Exponential Smoothing (WES) in Excel to smooth the time series (remove randomness). This was done for the last 4 years of data (March 2016 to December 2019) and includes relevant forecasts for home appliance expenditure for Tasmania for each quarter beyond the sample data period (one year of quarterly out-of-sample forecasts). The WES model is appropriate for the time series as the time series has seasonal and trend components.

The first step I did was providing a line chart of the last 4 years of data (16 data points) to see what the time series looks like. I adjusted the y-axis so I could clearly see the systematic components of the time series (seasonal and trend).




Moreover, I then generated the initial level by calculating the total average of the previous 4 quarters, the initial trend value by using (y2-y1)/4 and the initial seasonal effects of the first year relative to the initial level. After that I computed the next levels, trends and seasonal components using the equations that represent the systematic components of my WES model which are provided in Question 8. Furthermore, I then calculated the predictions for the existing periods using the previous level, trend and seasonal index and forecasted into the future by using the equation provided in Question 10.

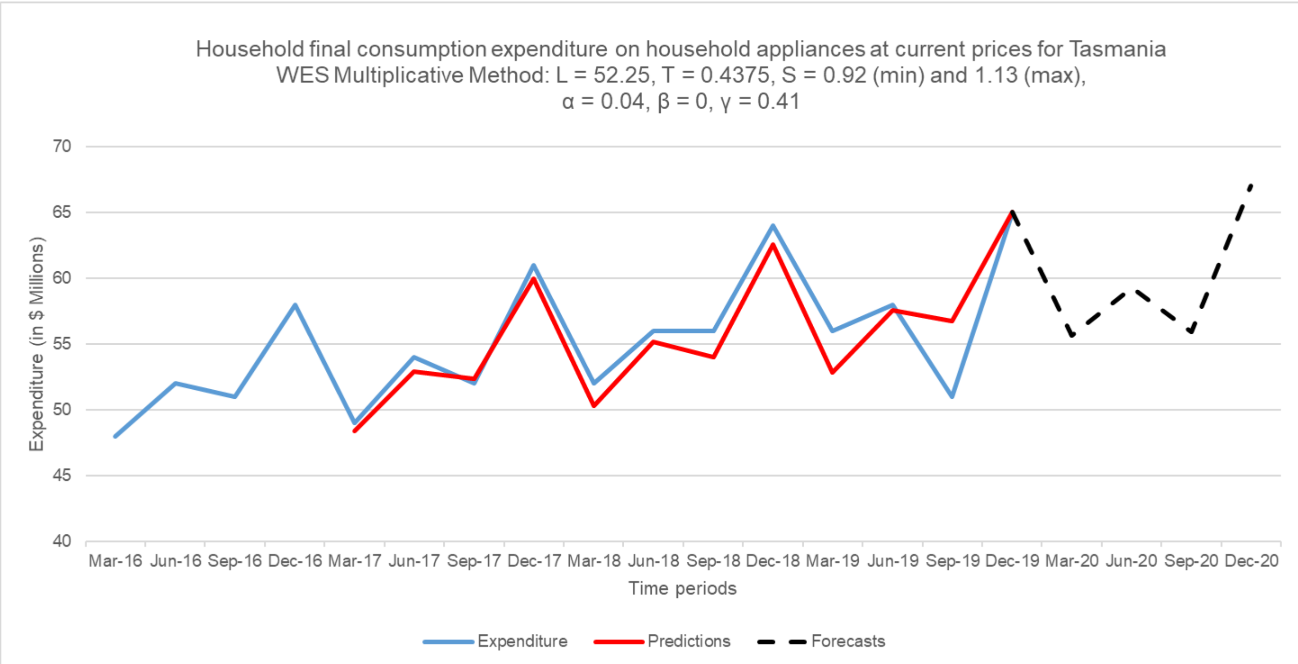
Lastly, I calculated the error criteria for the (multiplicative) WES model and used Excel Solver to find the optimal smoothing parameters [α (level), β (trend) and γ (seasonal)] to minimise the MSE (mean squared error) of the model. Initially, the smoothing parameters were all set to 0.2.

On the next page my Excel output for (multiplicative) Winters' Exponential Smoothing on the time series data is provided.

# Questions 5 & 6 (continued) – WES Method

| Time Index | Date | Expenditure | Level | Trend | Seasonal | Predictions | m | Forecasts | alpha | 0.035737 | Error | ABS_Error | SQ_Error | ABS_%Error | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mar-16 | 48 | | | 0.91866029 | | | | beta | 0 | | | | | | | initial trend calculation | | |
| 2 | Jun-16 | 52 | | | 0.99521531 | | | | gamma | 0.407553 | | | | | | year 1 | year 2 | y2-y1 | (y2-y1)/4 |
| 3 | Sep-16 | 51 | | | 0.97607656 | | | | | | | | | | | 48 | 49 | 1 | 0.25 |
| 4 | Dec-16 | 58 | 52.25 | 0.4375 | 1.11004785 | | | | | | | | | | | 52 | 54 | 2 | 0.50 |
| 5 | Mar-17 | 49 | 52.7108 | 0.4375 | 0.92311935 | 48.4019139 | | | | | 0.5980861 | 0.5980861 | 0.3577070 | 1.2205839 | | 51 | 52 | 1 | 0.25 |
| 6 | Jun-17 | 54 | 53.1880 | 0.4375 | 1.00338741 | 52.8939684 | | | | | 1.1060316 | 1.1060316 | 1.2233059 | 2.0482067 | | 58 | 61 | 3 | 0.75 |
| 7 | Sep-17 | 52 | 53.6129 | 0.4375 | 0.97356544 | 52.3425764 | | | | | -0.3425764 | 0.3425764 | 0.1173586 | 0.6588007 | | | | | |
| 8 | Dec-17 | 61 | 54.0827 | 0.4375 | 1.11732464 | 59.9985744 | | | | | 1.0014256 | 1.0014256 | 1.0028531 | 1.6416812 | | | | initial trend | 0.4375 |
| 9 | Mar-18 | 52 | 54.5849 | 0.4375 | 0.93515250 | 50.3286334 | | | | | 1.6713666 | 1.6713666 | 2.7934665 | 3.2141666 | | | | | |
| 10 | Jun-18 | 56 | 55.0506 | 0.4375 | 1.00903577 | 55.2087676 | | | | | 0.7912324 | 0.7912324 | 0.6260487 | 1.4129149 | | | | | |
| 11 | Sep-18 | 56 | 55.5607 | 0.4375 | 0.98756132 | 54.0212622 | | | | | 1.9787378 | 1.9787378 | 3.9154034 | 3.5334604 | | | | | |
| 12 | Dec-18 | 64 | 56.0440 | 0.4375 | 1.12736485 | 62.5681680 | | | | | 1.4318320 | 1.4318320 | 2.0501428 | 2.2372375 | | | | | |
| 13 | Mar-19 | 56 | 56.6031 | 0.4375 | 0.95723911 | 52.8188117 | | | | | 3.1811883 | 3.1811883 | 10.1199588 | 5.6806933 | | | | | |
| 14 | Jun-19 | 58 | 57.0563 | 0.4375 | 1.01209412 | 57.5559707 | | | | | 0.4440293 | 0.4440293 | 0.1971620 | 0.7655677 | | | | | |
| 15 | Sep-19 | 51 | 57.2847 | 0.4375 | 0.94791825 | 56.7786446 | | | | | -5.7786446 | 5.7786446 | 33.3927334 | 11.3306757 | | | | | |
| 16 | Dec-19 | 65 | 57.7198 | 0.4375 | 1.12686132 | 65.0739555 | | | | | -0.0739555 | 0.0739555 | 0.0054694 | 0.1137777 | | | | | |
| 17 | Mar-20 | | | | | | 1 | 55.6704751 | | | | | | | | | | | |
| 18 | Jun-20 | | | | | | 2 | 59.3034875 | | | | | | | | | | | |
| 19 | Sep-20 | | | | | | 3 | 55.9578275 | | | | MAE | MSE | MAPE | | | | | |
| 20 | Dec-20 | | | | | | 4 | 67.0142562 | | | | 1.5332588444 | 4.6501341370 | 2.8214805375 | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | RMSE | | | | | | |
| | | | | | | | | | | | | | 2.1564169673 | | | | | | |

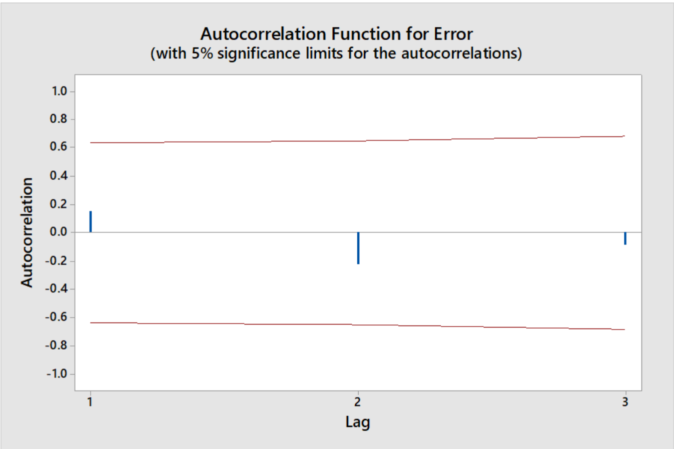
Q6) 5-year time series line chart:

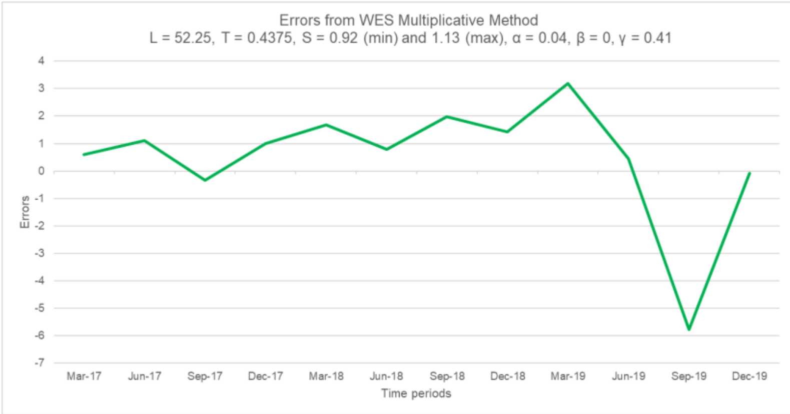



The 5-year time series line chart above includes a 4-year time series line chart comparing the original time series with the generated smoothed values and the forecasts from Question 10. The (multiplicative) WES model is a reasonable model for the data as the predicted and forecasted values fit the actual time series data well and account for the upward trend and seasonal fluctuations (smoothing).

# Questions 7 & 8 (one page) – Tests and Notation

Q7) I conducted an ACF test of the errors/residuals and plotted a line chart of the errors to confirm if the errors of the (multiplicative) WES model are random and check the adequacy (unbiasedness) of the model.



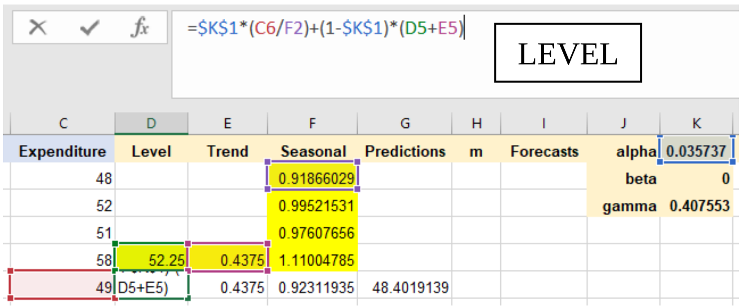

The ACF correlogram confirms that the errors are random as all the sample autocorrelations are statistically insignificant. However, it is not clear from the line chart of the errors if the errors are random. There is not an even spread of the errors above and below zero, there is a run of positive errors (systematic pattern) and one outstanding large error (relative to the errors overall) but the errors are small, and the mean of the errors is close to zero. The model is adequate, but the WES model could be re-evaluated or modified to do a better job at capturing all the systematic components and smoothing the chosen time series. This will be evaluated in Question 9.

Q8) <u>All the equations that represent the systematic components of my (multiplicative) Winters' Exponential Smoothing model</u>:

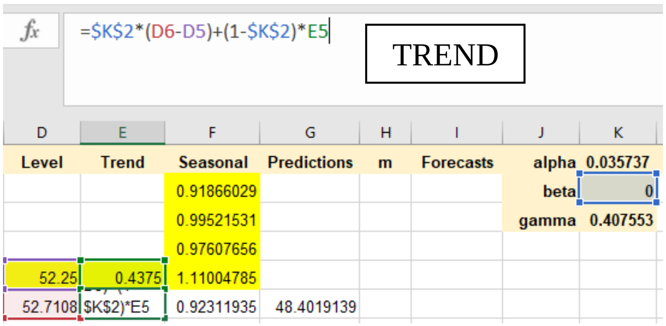
$$L_t = \alpha \boxed{\frac{Y_t}{S_{t-s}}} + (1-\alpha)(L_{t-1} + T_{t-1})$$

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}$$

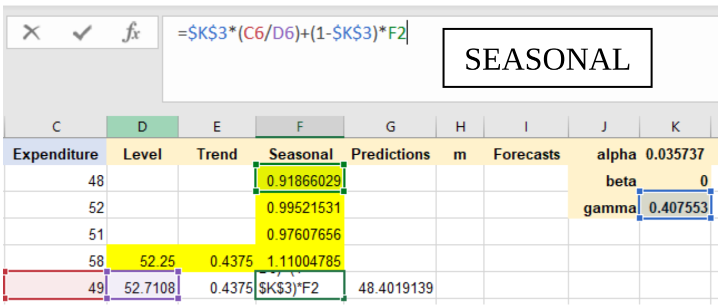
$$\boxed{S_t = \gamma \frac{Y_t}{L_t} + (1-\gamma) S_{t-s}}$$




| C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|
| Expenditure | Level | Trend | Seasonal | Predictions | m | Forecasts | alpha | 0.035737 |
| 48 | | | 0.91866029 | | | | beta | 0 |
| 52 | | | 0.99521531 | | | | gamma | 0.407553 |
| 51 | | | 0.97607656 | | | | | |
| 58 | 52.25 | 0.4375 | 1.11004785 | | | | | |
| 49 | D5+E5) | 0.4375 | 0.92311935 | 48.4019139 | | | | |




| D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|
| Level | Trend | Seasonal | Predictions | m | Forecasts | alpha | 0.035737 |
| | | 0.91866029 | | | | beta | 0 |
| | | 0.99521531 | | | | gamma | 0.407553 |
| | | 0.97607656 | | | | | |
| 52.25 | 0.4375 | 1.11004785 | | | | | |
| 52.7108 | $K$2)*E5 | 0.92311935 | 48.4019139 | | | | |




| C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|
| Expenditure | Level | Trend | Seasonal | Predictions | m | Forecasts | alpha | 0.035737 |
| 48 | | | 0.91866029 | | | | beta | 0 |
| 52 | | | 0.99521531 | | | | gamma | 0.407553 |
| 51 | | | 0.97607656 | | | | | |
| 58 | 52.25 | 0.4375 | 1.11004785 | | | | | |
| 49 | 52.7108 | 0.4375 | $K$3)*F2 | 48.4019139 | | | | |

# Questions 9 & 10 (two pages) – Critique and Forecasts

Q9) My results for the above questions do suggest a re-evaluation or modification of the Winters model. I concluded that the (multiplicative) WES model is a reasonable and adequate model to smooth the time series however it was not clear from the line chart of the errors if the errors are random. Adjustment to the smoothing parameters α, β and γ might make it more conclusive if the errors are random from the line chart of the errors. Additionally, applying a different seasonal model to the time series such as (additive) WES, (additive) Decomposition or (multiplicative) Decomposition may do a better job at minimizing the error criteria and improving the accuracy of the model.

Considering recent events which have included the bushfires over the summer Christmas holidays in Australia and the global coronavirus outbreak, the (multiplicative) WES model is going to be affected by these additional factors and circumstances. These events are also going to impact the quarterly out-of-sample forecasts generated by the model for home appliance expenditure for Tasmania. The ravaging bushfires destroyed people's households and significantly negatively impacted the economy and crippled consumer confidence (Butler 2020).

Furthermore, the worldwide COVID-19 outbreak has forced Australia into lockdown, social distancing and isolation to prevent the spread of the virus. This has facilitated a new way of living where people must undertake their daily tasks and activities at home. Thus, this has led to more household appliances being purchased such as exercise equipment (e.g. exercise bikes) and weights because gyms are closed and people want to continue staying physically and mentally healthy (Livingstone 2020).

When forecasting for the second or third year (of quarterly forecasts) beyond the sample period, all known factors and circumstances must be considered. There may also be one-off events in the future that will impact the accuracy of these forecasts. The WES model does a good job in general of capturing all the systematic components (trend and seasonal) of the chosen time series and these recent one-off events will contribute to the model's random fluctuation. *HomeAppCo* will have to reconsider their business plans to expand and launch stores across Australia right now due to coronavirus restrictions but they can use the generated quarterly out-of-sample forecasts for home appliance expenditure for Tasmania to decide whether they should expand into Australia in the future.

## Questions 9 & 10 (continued) – Critique and Forecasts

Q10) Below is the manual calculations of the relevant forecasts for home appliance expenditure for Tasmania for each quarter beyond the sample data period (one year of quarterly out-of-sample forecasts).

FORECASTS

Equation: $\hat{Y}_t = (L_t + T_t p) \times S_{t+p-s}$

March 2020

$(57.719834547875 + 0.4375 \times 1)$

$\times$

$0.957239108704508$

$= 55.67047509$

June 2020

$(57.719834547875 + 0.4375 \times 2)$

$\times$

$1.012094412026148$

$= 59.30348752$

September 2020

$(57.719834547875 + 0.4375 \times 3)$

$\times$

$0.947918254399092$

$= 55.95782752$

December 2020

$(57.719834547875 + 0.4375 \times 4)$

$\times$

$1.126881319111138$

$= 67.01425821$

# References

Australian Bureau of Statistics, 2019, *Australian National Accounts: National Income, Expenditure and Product, Dec 2019*, 'Table 31. State Final Demand, Detailed Components: Tasmania', time series spreadsheet, cat. no. 5206.0, viewed 1 May 2020, <https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5206.0Dec%202019?OpenDocument>

Butler, B 2020, 'Economic impact of Australia's bushfires set to exceed $4.4bn cost of Black Saturday', *The Guardian*, 8 January, viewed 3 May 2020 <https://www.theguardian.com/australia-news/2020/jan/08/economic-impact-of-australias-bushfires-set-to-exceed-44bn-cost-of-black-saturday>

Ford, S 2019, 'Tasmania's economic growth best in 15 years, ABS finds', *The Advocate*, 15 November, viewed 3 May 2020, <https://www.theadvocate.com.au/story/6494381/tasmanias-economic-growth-best-in-15-years-abs-finds/>

Humphries, A 2018, 'Tasmania's population growth is out of control with no one at the wheel, says planning expert', *ABC News*, 11 October, viewed 3 May 2020, <https://www.abc.net.au/news/2018-10-11/tasmanian-population-growth-labelled-a-runaway-train/10366054>

Livingstone, T 2020, 'Weights and exercise equipment fly off shelves in latest panic buying craze', *9News*, 23 March, viewed 3 May 2020, <https://www.9news.com.au/national/coronavirus-exercise-equipment-flying-off-shelves-as-gyms-close-down/b931c632-aa14-4348-93fa-09cc6586fc2e>