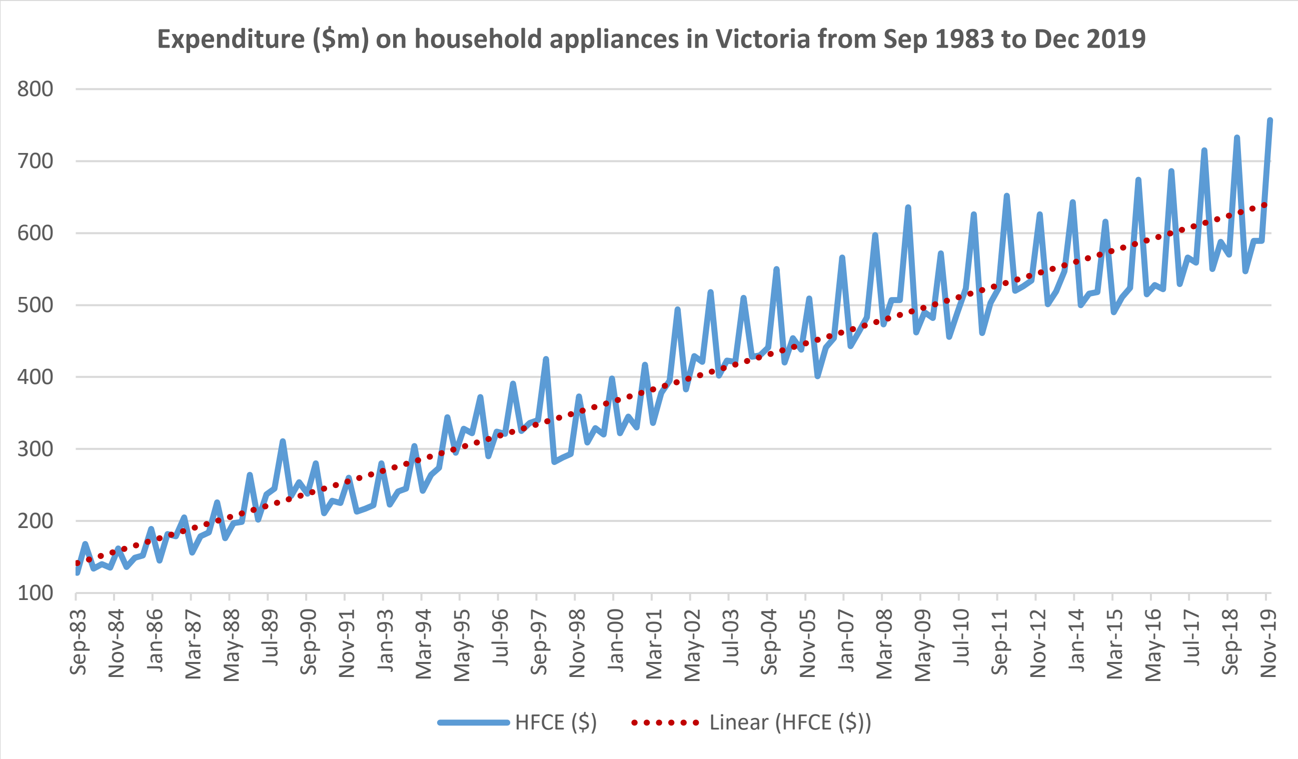
Questions 1 & 2 (1 page) – Plot and Components



<u>Figure 1. Household Final Consumption Expenditure on Household Appliances</u>

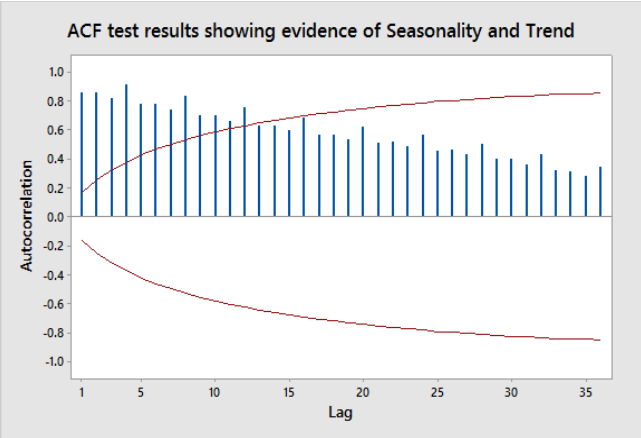
1) The Household Final Consumption Expenditure (HFCE) data was obtained through the Australia Bureau of Statistics website. The data is based on the results of sample surveys between 7,000 and 10,000 household residence in private dwellings. Observations excluded were those where the reference person for the household is less than 20 years of age and where consumption expenditure was negative (Australian Housing and Urban Research Institute, 2017).

   HFCE data at current price measures the net expenditure by households and non-profit institutions serving households. This item excludes expenditures by unincorporated business and expenditures on assets by non-profit institutions (ABS, 2004).

2) It is clear from the time series there are trend, seasonal and random components. The trend component is evident from the upward path of the time series over the 36 years of quarterly data with 146 data points. The underlying positive trend appears to be linear. There is also evidence of seasonality. The time series seems to peak in December (covering the months for October and November) of each year with the low point of each year being March. This pattern is relatively consistent over the 36 years observed, but it appears to have some random fluctuation between each of the quarterly patterns around the systematic components.

   The main factor which has caused the pattern is likely to be an increase in prices (trend) of household appliances such as air conditioner, ceiling fan, washing machine, and dishwasher. The seasonality is likely to be a combination of weather (December period is summer, so more consumers are likely to spend on air conditioners in preparation to combat the heat) and Christmas time with household appliances as presents. The non-systematic random fluctuations can be caused by factors such as unusual weather patterns (heatwaves, storms) or other broad environmental factors such as social, political, or economic.

Questions 3 & 4 (1 page) – Corellogram and Factors



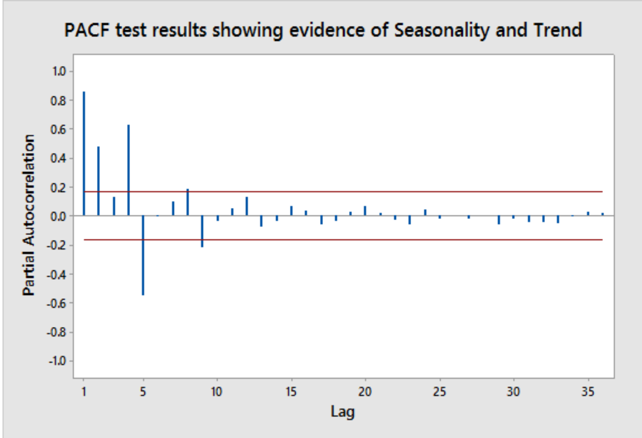


Figure 2 & 3. ACF and PACF Test Results Showing Evidence of Seasonality and Trend

3) The autocorrelation function (ACF) and partial autocorrelation function (PACF) of the HFCE data confirms trend and seasonal components of the time series. The trend component is reflected by the relatively slow decline of the correlations from lag 1 onwards. The seasonality is shown by the correlations that are at multiples of the seasonal period. In this case, we have quarterly data and the seasonal cycle repeats every 4 months. Thus, we expect the correlation between observations 4 months apart to be high. There is a clear spike outside the significance limits at lag number 4 (there is one at 8 and 12 too), indicating and confirming the presence of quarterly seasonality

4) The upward trend could be attributed to economic and population growth (as population expands it is likely that spending on household appliance will also increase) or possible increased market penetration (more house appliances introduced in different parts of Melbourne as national income and purchasing power increases – household essentials are likely to be a good/service on which spending disproportionately increases with increased income). The HFCE data are also likely to be impacted by increasing prices as measurements are in current dollars and not adjusted for inflation.

   Another reason for appliances becoming more commonplace in Australian homes is the growth in consumer demand for healthy foods. A report by the NPD Group shows that millennials are now the largest healthy eating consumer group in Australia, accounting for 32% (NPD, 2020). Working adults are thus investing their money on appliances needed to prepare healthy meals for their children (or even themselves). Cooking at home allows health-conscious consumers to choose how their food is cooked, and the ingredients that go in it. According to Australia's industrial research agency, CSIRO, growing interest in a healthy and sustainable lifestyle could be worth about AUD$25 billion and constitute 10% of the value of Australia's food and agribusiness sector by the end of the next decade (Wynn, 2019).

   Lack of functional appliances – including ovens, refrigerators, and stoves – impacts the ability to prepare home-cooked meals, resulting in families making unhealthy food choices (eating out). With this information, it is feasible for *HomeAppCo* to launch stores across Victoria, Australia.

   Further research on the above explanations are necessary and would need to be investigated.

Questions 5 & 6 (two pages) – WES Method

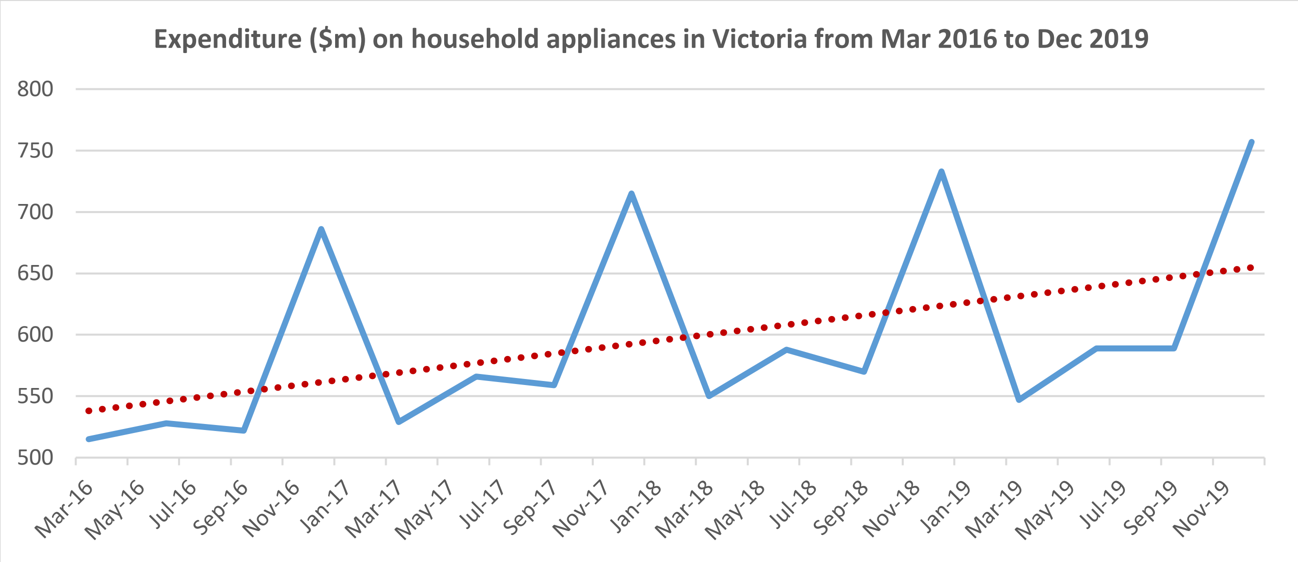


Figure 4. HFCE ($) on Household Appliances in Victoria from Mar 2016 to Dec 2019

5) I have changed the Y-axis Minimum to 500, which increases the scale of the line chart and gives you a clearer picture of the random fluctuation of the data. Based on the chosen time series of just the last 4 years of data, it clearly shows evidence of trend, seasonal and random components. The data is smoothed (to remove randomness) using the Winters' Exponential Smoothing (WES) Multiplicative method.

2015 quarter figures are used to determine the initial values for Level, Trend, and Seasonal components in order to plot the 5-year time series from 2016 to 2019 (predictions) to 2020 (forecasts).

The generating process includes:

- Give an initial Level (L_4) by taking the average of the first 4 quarterly periods (Note: Calculations are done in Question 8 of this report)
- Give an initial Trend (T_4) by calculating the average of: (Y2-Y1)/4
- Calculate the first 4 Seasonal values: Y_1/L_4 ... Y_4/L_4
- Give initial values of alpha = 0.2, beta = 0.2, gamma= 0.2
- Apply the formulas and compute the next Levels, Trends, and Seasonal components
- SOLVER is then used to minimize an error criterion – Mean Squared Error (MSE)

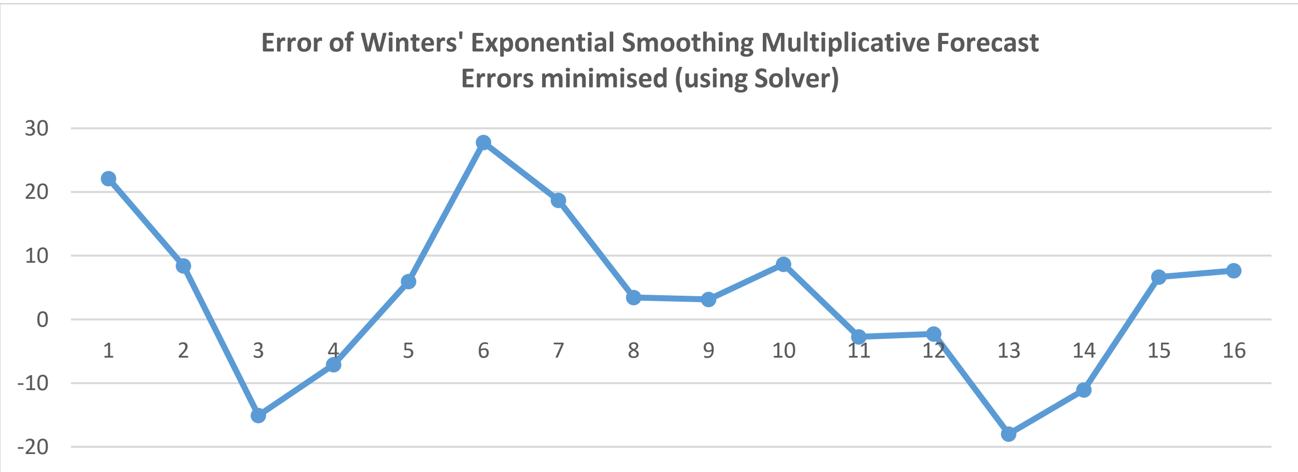
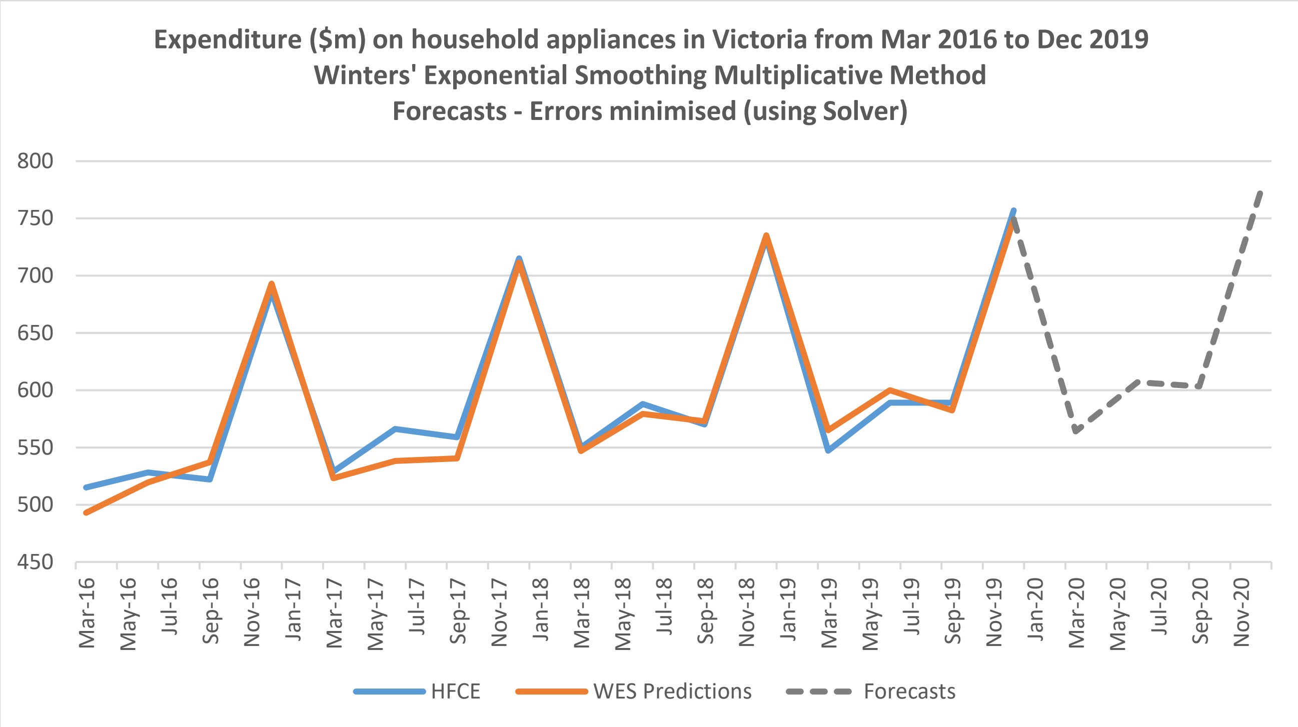


Figure 5. Errors of Winters' Exponential Smoothing

Questions 5 & 6 (continued) – WES Method

The WES (alpha = 0.0993) forecast errors look random. There is an even spread of errors above and below zero as shown in Figure 5. There are no runs of positive or negative errors, no outstanding large errors (relative to the errors overall) and no other discernible patterns.



<u>Figure 6. Comparison of Original Time Series with Generated Smoothed Values (5-year Time Series Line Chart)</u>

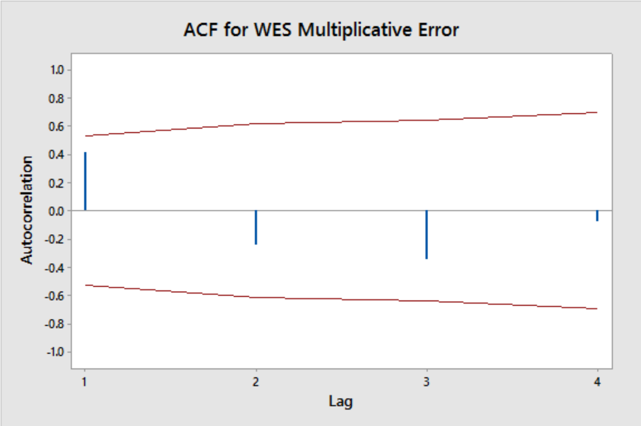
6) Considering the plot and observed model fit of WES in Figure 6, the WES seems to both follow and smooth the time series. The forecasts reasonably extrapolate these components into the future (one year of quarterly out-of-sample data). However, the result does not mean that the WES Multiplicative is the best forecast method (which will be further discussed in Question 9 of this report).

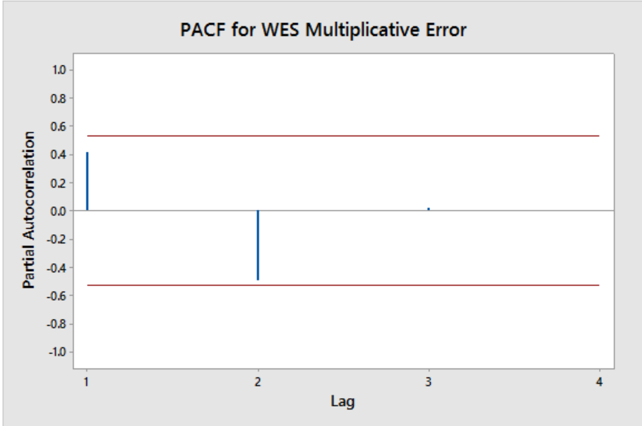
A more accurate forecast can be judged using the error criteria (MAE, MSE, RMSE, MAPE). On that basis, adjustments to the initial Level, Trend and Seasonal smoothing values – alpha = 0.2, beta = 0.2, and gamma = 0.2 – had been undertaken to improve the model with forecast errors appearing random:

Forecasting Method	MAE	MSE	RMSE	MAPE
WES Multiplicative (a=0.2, b=0.2, g=0.2)	13.106	232.613	15.252	2.249
WES Multiplicative - Errors Minimised using Solver (a=0.0993, b=0.1017, g=0.8199)	10.547	165.763	12.875	1.863

Excel's SOLVER solution has minimised the errors as shown in the table above, with the smoothing values resulting to an optimum value of alpha = 0.0993, beta = 0.1017, and gamma = 0.8199 and overall *lower* error criteria – from an MSE value of **<u>232.613</u>** to **<u>165.763</u>**.

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





Figures 7 & 8. ACF and PACF for WES Multiplicative Error

7) The ACF and PACF for the WES Multiplicative error is conclusive of a consistent result for showing that the errors are random. Errors are statistically insignificant (none of the correlations are significant) and has a symmetric distribution with a mean of zero. Furthermore, the graphs appear to be consistent with no manifest patterns over time.

8) The four equations that represent the systematic components of WES Multiplicative model:

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

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

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

$$F_{t+m} = (L_t + mT_t) \times S_{t+m-s}$$

Where L = Level, T = Trend, S = Seasonality, Y = Actual, t = a time index, m = future period #1,2,3), F_{t+m} = Winter's forecast for m periods into the future, and smoothing constants for Level: α (alpha), Trend: β (beta), Seasonality: γ (gamma)

Example – Assuming the final SOLVER solution of α, β, γ = 0.0993, 0.1017, 0.8199 and initial Level, Trend, Seasonal = 549.750, 3.250, 0.891:

$L_{Mar\text{-}16}$ = 0.0993*(515/0.891) + (1 – 0.0993)*(549.750 + 3.250) = 555.462

$T_{Mar\text{-}16}$ = 0.1017*(555.462 – 549.750) + (1 – 0.1017)*3.250 = 3.500

$S_{Mar\text{-}16}$ = 0.8199*(515/555.462) + (1 – 0.8199)*0.891 = 0.9207

$F_{Mar\text{-}16}$ = (549.750 + 3.250)*0.891 = 492.897

$F_{Jun\text{-}20}$ = (615.678 + 1*3.8703)*0.9103 = 563.997

$F_{Sep\text{-}20}$ = (615.678 + 2*3.8703)*0.9736 = 606.961

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

Forecasting Method	MAE	MSE	RMSE	MAPE
WES Multiplicative (a=0.2, b=0.2, g=0.2)	13.106	232.613	15.252	2.249
WES Multiplicative - Errors Minimised using Solver (a=0.0993, b=0.1017, g=0.8199)	10.547	165.763	12.875	1.863
WES Additive (a=0.2, b=0.2, g=0.2)	10.833	188.249	13.720	1.934
WES Additive - Errors Minimised using Solver (a=0.1208, b=0.0981, g=0.8134)	10.622	168.823	12.993	1.860
Decomposition Multiplicative	6.413	57.481	7.582	1.147
Decomposition Additive	7.006	67.144	8.194	1.233

9) Yes, there needs to be a re-evaluation of the Winters Model. After calculating the methods that are suitable for forecasting the HFCE ($) time-series data (refer to Appendix 1 to Appendix 3), the summary is given in the table above. The method with the lowest error criteria (in this case for all error criteria) is the Decomposition Multiplicative method, with the MSE value of **57.481** (row highlighted in yellow). This would be the best forecasting method to use; thus, our forecasts for the next year of quarterly forecasts are:

Quarter	Forecasts
Mar-20	576.301
Jun-20	616.393
Sep-20	602.969
Dec-20	780.118

It is important to determine the type of seasonality as it could be either Additive or Multiplicative. Given that both trend and seasonal components are present, and the seasonal fluctuation appears relative and dependent on the linear time series (but constant %), the most appropriate method is the Decomposition Multiplicative forecasting method (outperforming the initial WES Multiplicative model).

Factors to consider when using the Decomposition Multiplicative forecasting method for the second or third period (of quarterly data) is as follows (refer to Appendix 2 & 3 for graphs):

- Step 1: Remove the season and random components by using Centered Moving Average (MA) approach via 4MA. Start from period #2 for 4MA and period #3 for Centered MA.
- Step 2: De-seasonalise the data by calculating the seasonal relative and seasonal index. Use the seasonal index to then calculate the seasonally adjusted values. Plot the actual and seasonally adjusted values (Note: the sum of seasonal index is equal to 4).
- Step 3: Project a linear trend using the seasonally adjusted data.
- Step 4: Re-compose and forecast by using the projected trend and seasonal index. Plot the actual, decomposition predictions and forecasts in one graph.

Questions 9 & 10 (continued) – Critique and Forecasts

10) For this report, the one year of quarterly out-of-sample forecasts for the HFCE in Victoria will be calculated using the WES Multiplicative forecasting method. This is to ensure consistency in Question 6. Working is done and attached below:

Home Appliance Expenditure for Victoria, Australia.

Note: one year of 2020 quarterly out-of-sample forecasts are based on the Level and Trend for Dec-19.

$L_{Dec\text{-}19} = 615.678$

$T_{Dec\text{-}19} = 3.870$

The seasonal components are based on figures in 2019.

$S_{Mar\text{-}19} = 0.910$

$S_{Jun\text{-}19} = 0.974$

$S_{Sep\text{-}19} = 0.962$

$S_{Dec\text{-}19} = 1.228$

Assuming final solver solution:

$\alpha = 0.09927$

$\beta = 0.10167$

$\lambda = 0.81993$

Time Period

1 Forecast Mar-20 $= (615.678 + 1 \times 3.870) \times 0.910$
$= 563.997$ //

2 Forecast Jun-20 $= (615.678 + 2 \times 3.870) \times 0.974$
$= 606.961$ //

3 Forecast Sep-20 $= (615.678 + 3 \times 3.870) \times 0.962$
$= 603.351$ //

4 Forecast Dec-20 $= (615.678 + 4 \times 3.870) \times 1.228$
$= 774.759$ //

Quarter	Forecasts
Mar-20	563.997
Jun-20	606.961
Sep-20	603.351
Dec-20	774.759

References

Australian Bureau of Statistics (December, 2019). 5206.0 - Australian National Accounts: National Income, Expenditure and Product, Table 27. State Final Demand, Detailed Components: Victoria, time series spreadsheet. Retrieved April 30, 2020, from https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5206.0Dec%202019?OpenDocument

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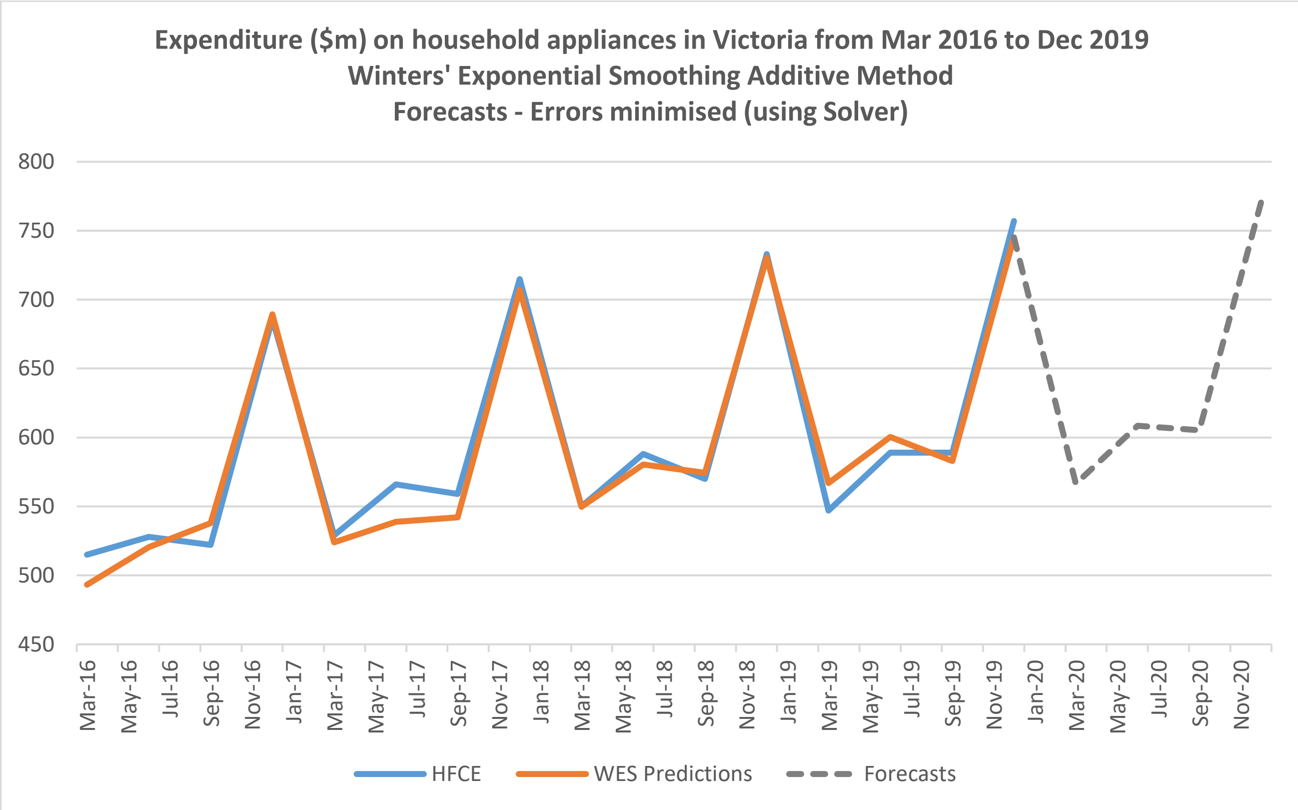
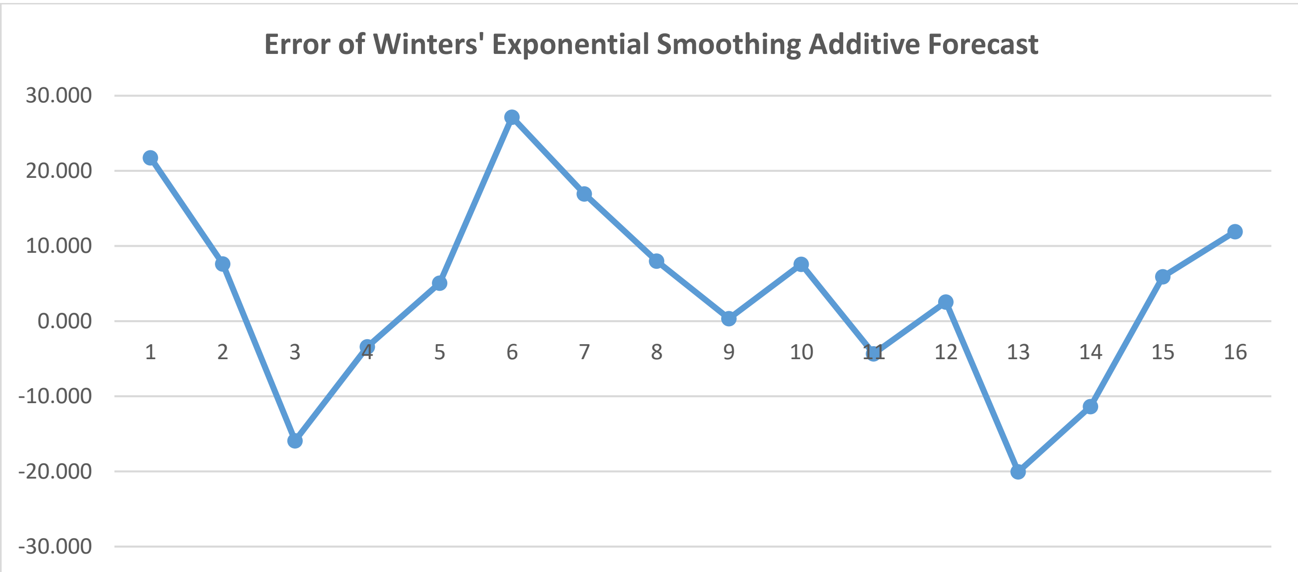
NPD Group (April, 2018). Healthy Millennials Driving Change in Australian Food Culture. Retrieved April 30, 2020, from https://www.thenpdgroup.com.au/wps/portal/npd/au/news/press-releases/healthy-millennials-driving-change-in-australian-food-culture/

Wynn, K. (January, 2020). Health and sustainability market could be worth $25 billion to Australian producers by 2030. Retrieved April 30, 2020, from https://theconversation.com/health-and-sustainability-market-could-be-worth-25-billion-to-australian-producers-by-2030-122856

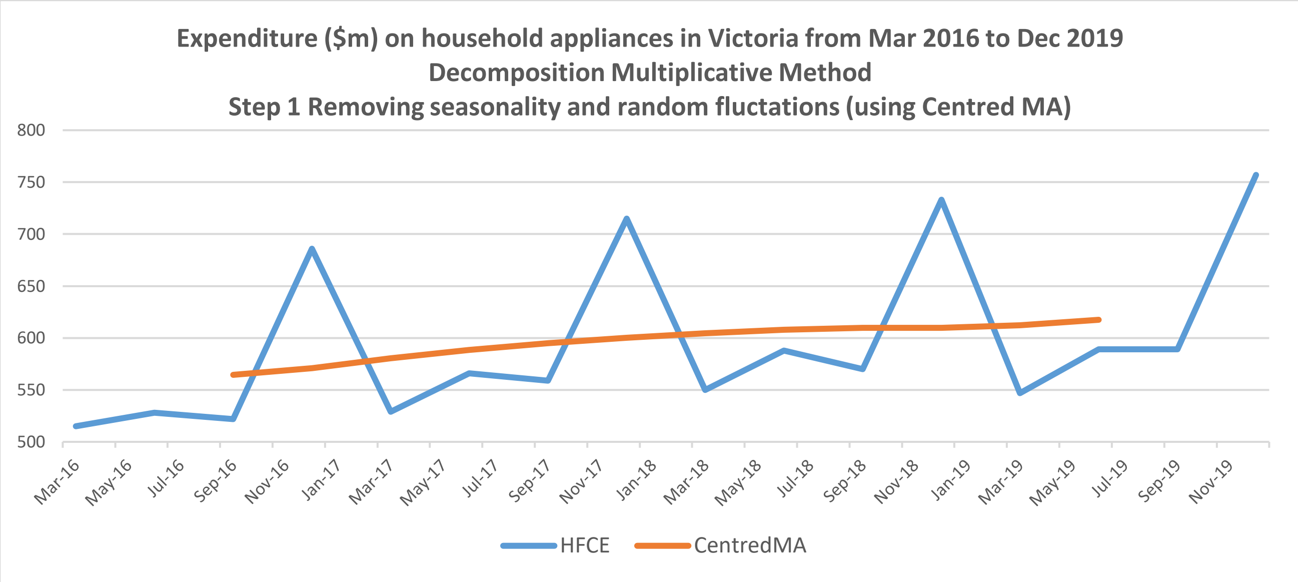
Appendices

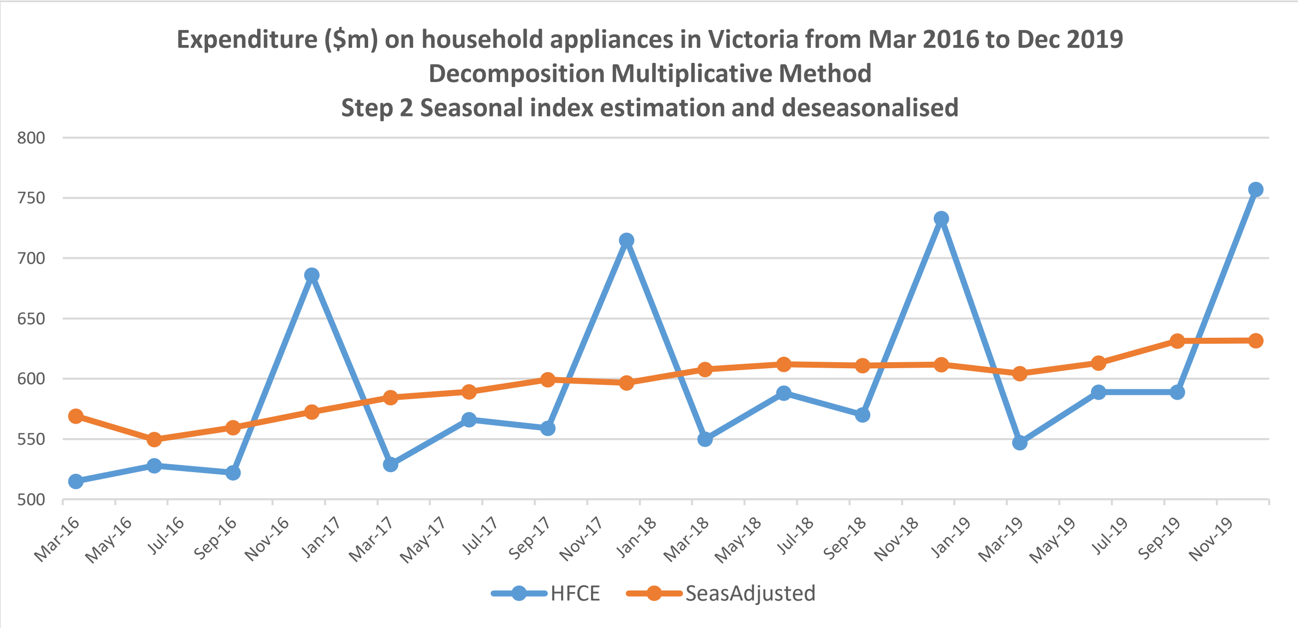
Appendix 1. Winters' Exponential Smoothing Additive Method

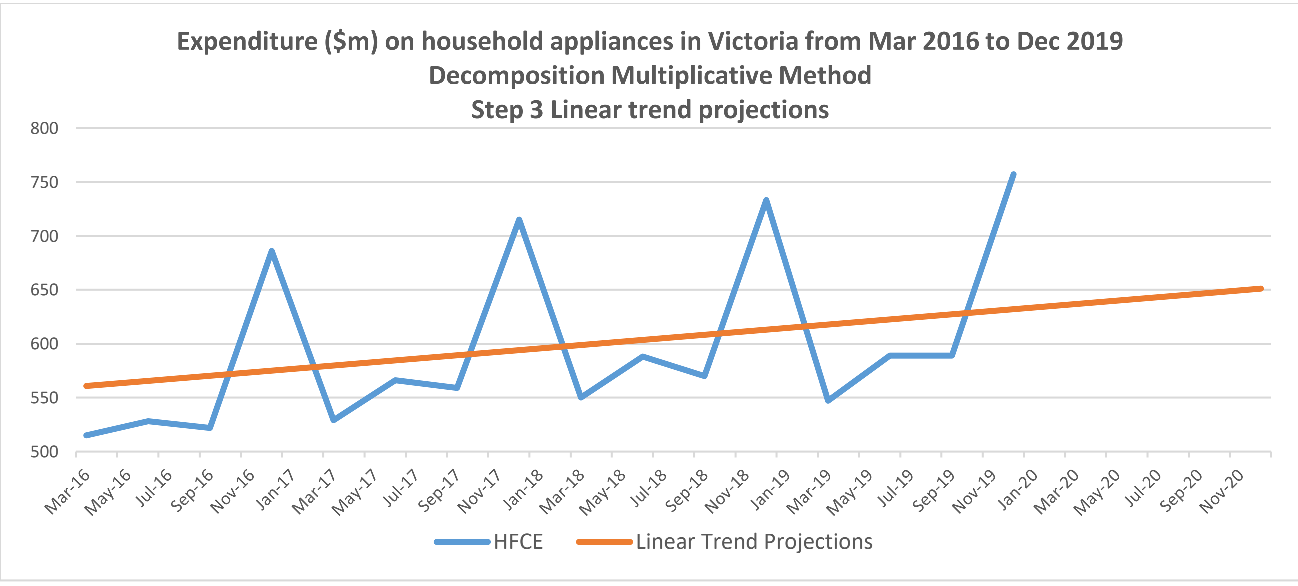


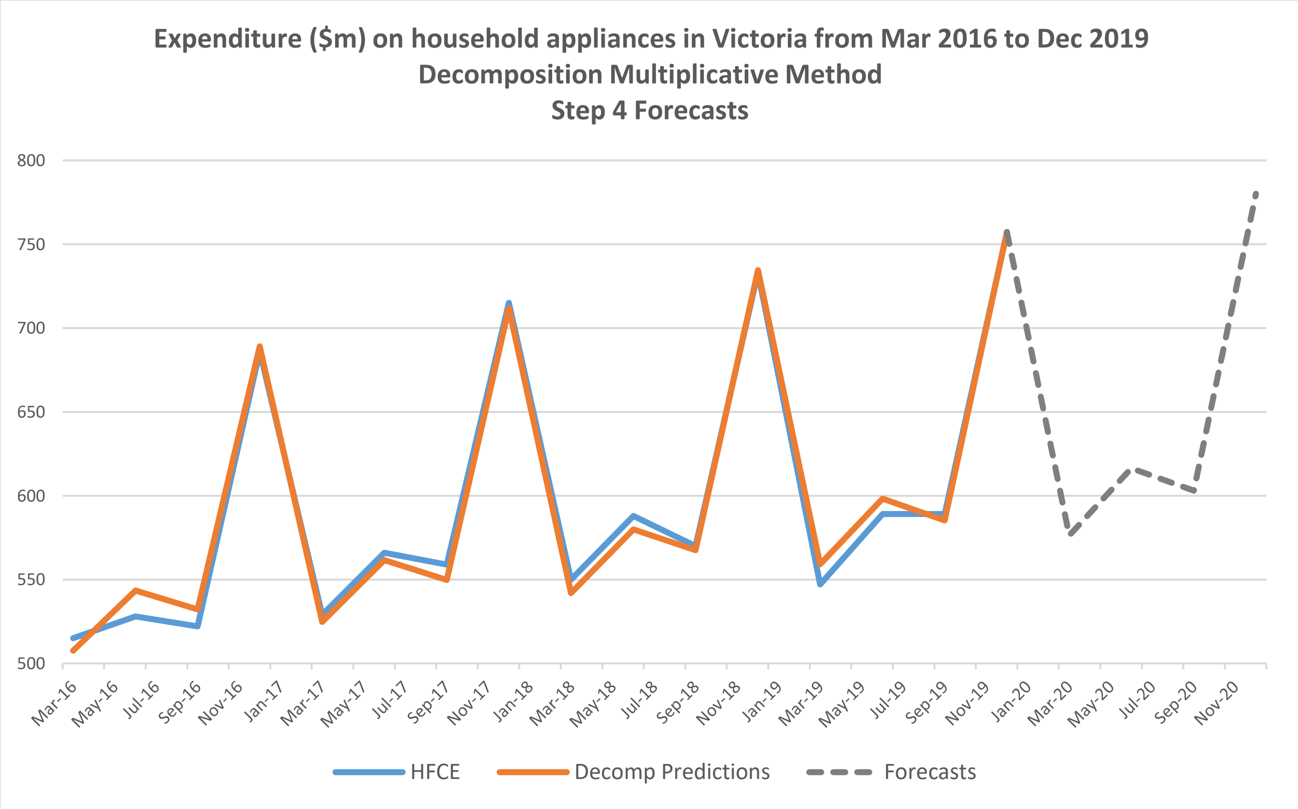


Appendix 2. Decomposition Multiplicative Method








Expenditure ($m) on household appliances in Victoria from Mar 2016 to Dec 2019
Decomposition Multiplicative Method
Step 4 Forecasts
800
750
700
650
600
550
500
Mar-16
May-16
Jul-16
Sep-16
Nov-16
Jan-17
Mar-17
May-17
Jul-17
Sep-17
Nov-17
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Mar-18
May-18
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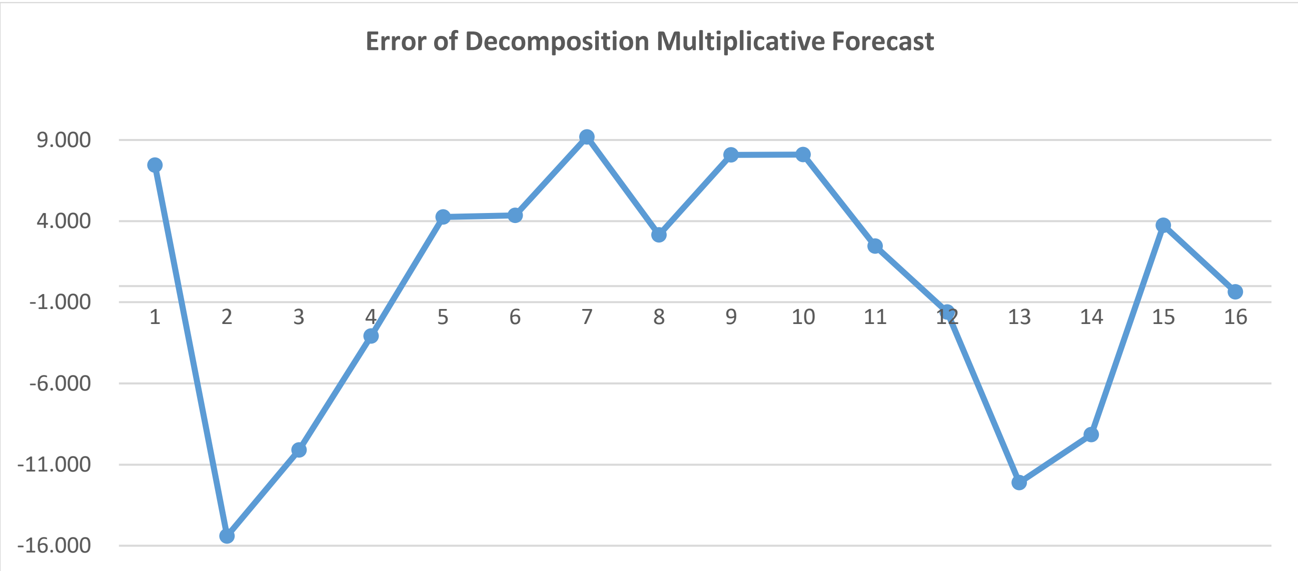
HFCE
Decomp Predictions
Forecasts


Error of Decomposition Multiplicative Forecast
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4.000
-1.000
-6.000
-11.000
-16.000
1
2
3
4
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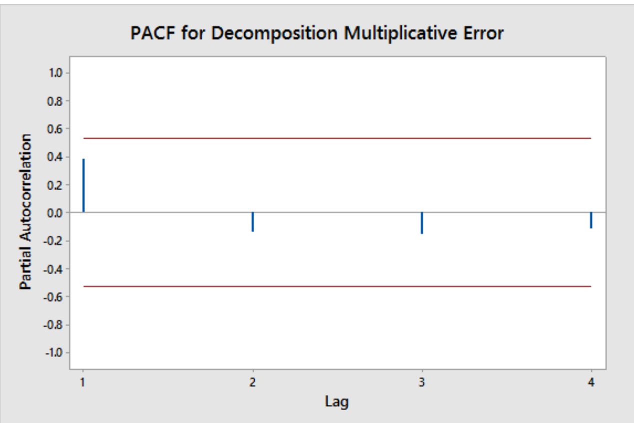
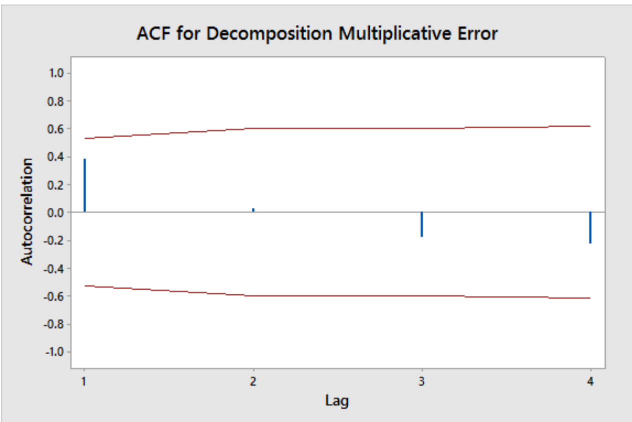
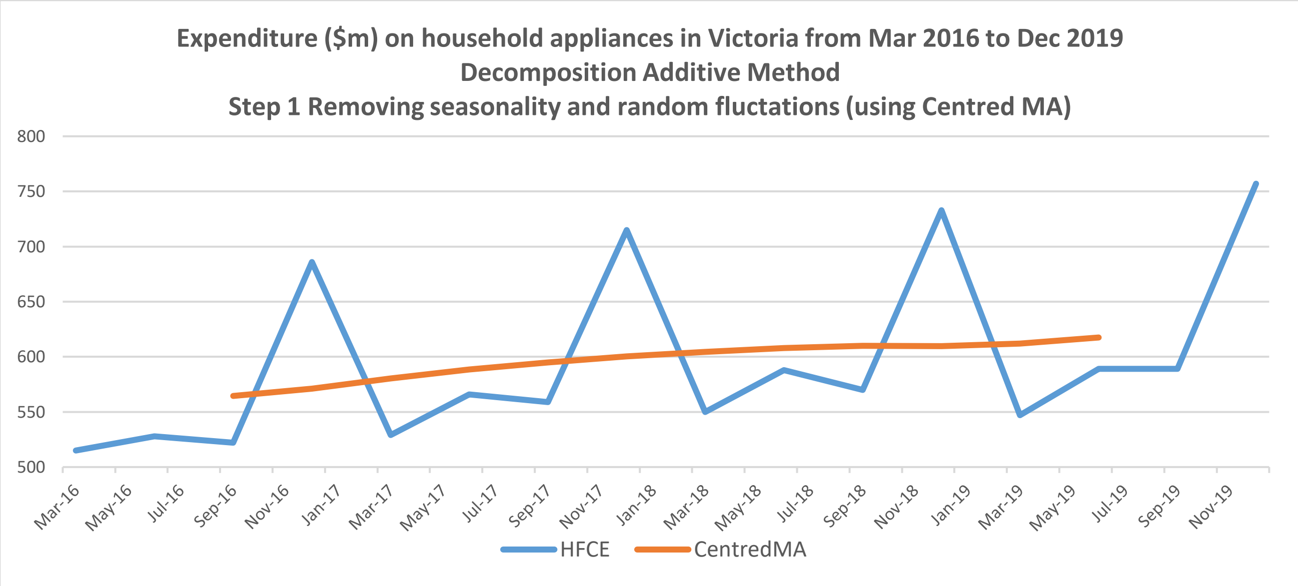
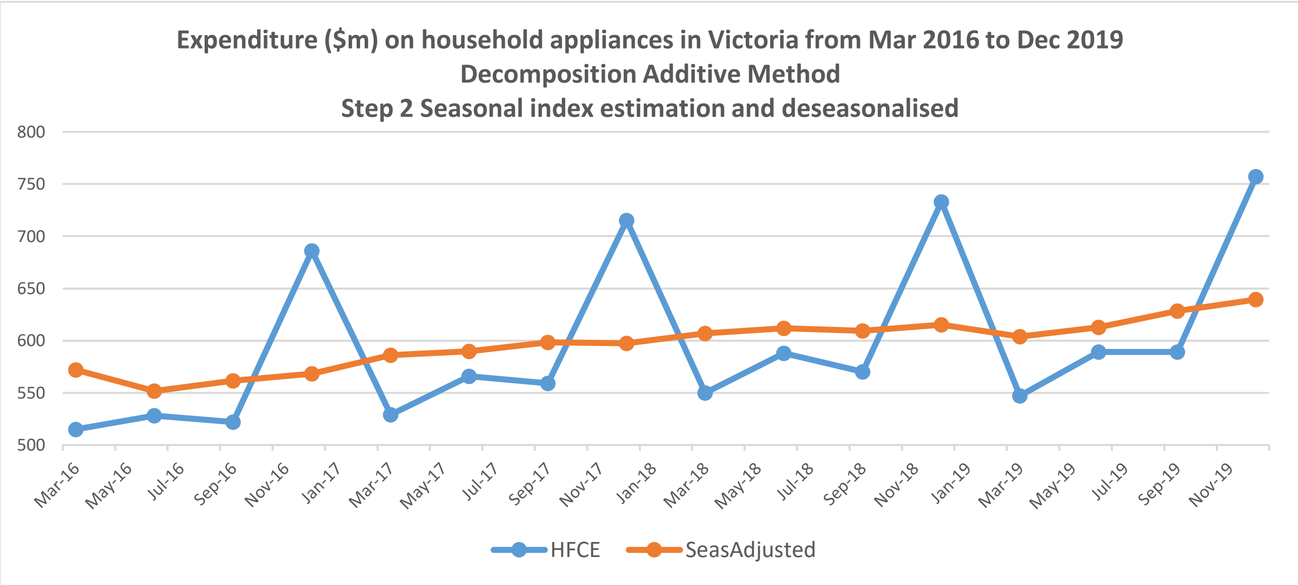
14
15
16

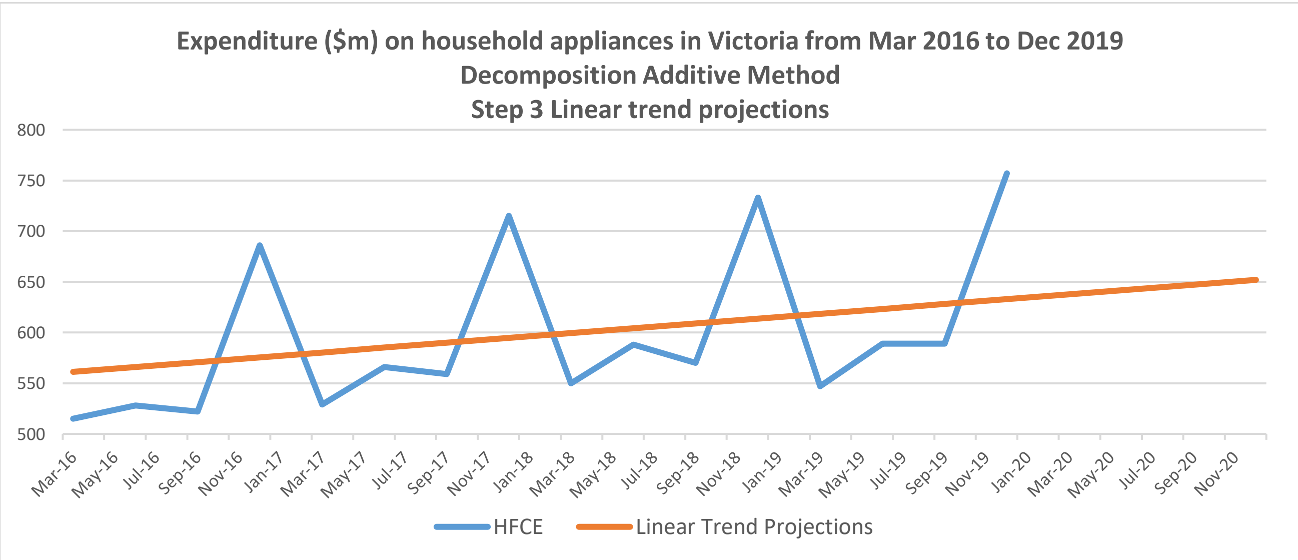

PACF for Decomposition Multiplicative Error
Partial Autocorrelation
Lag

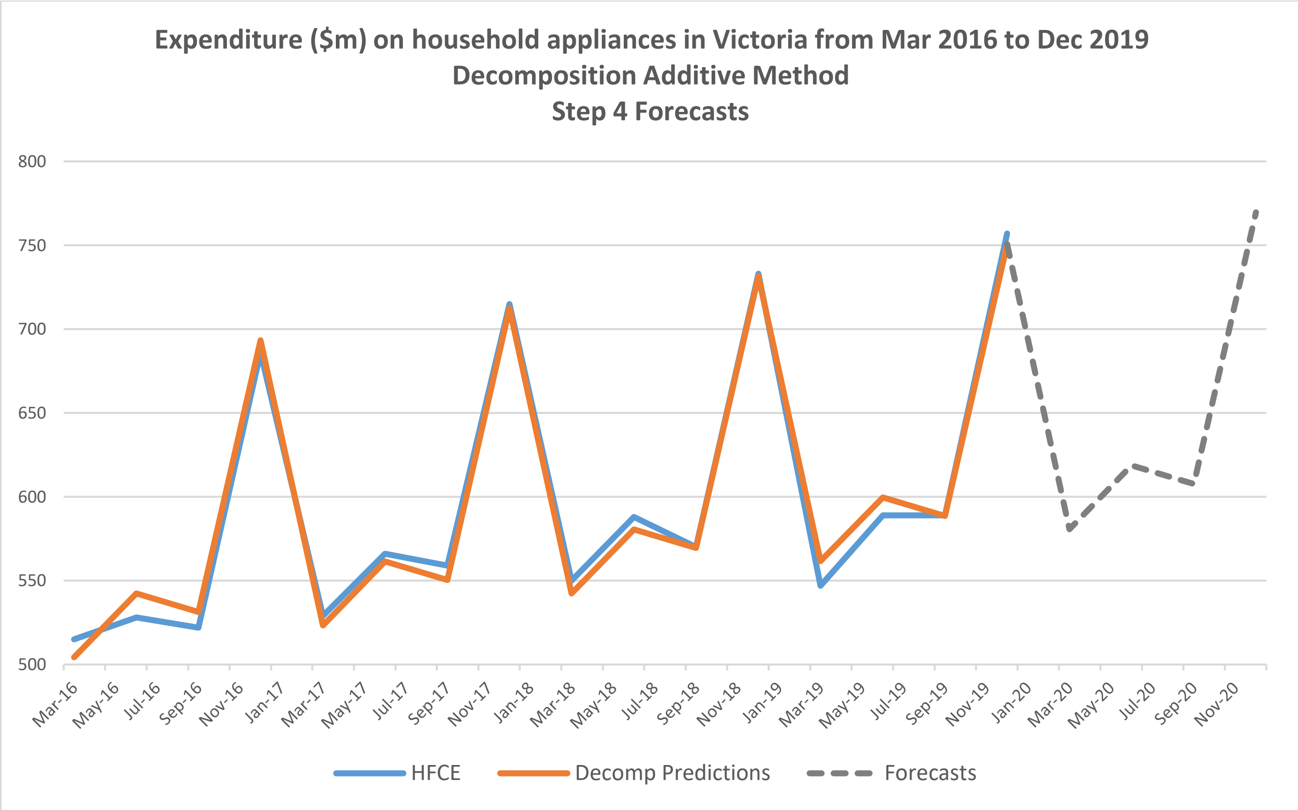

ACF for Decomposition Multiplicative Error
Autocorrelation
Lag

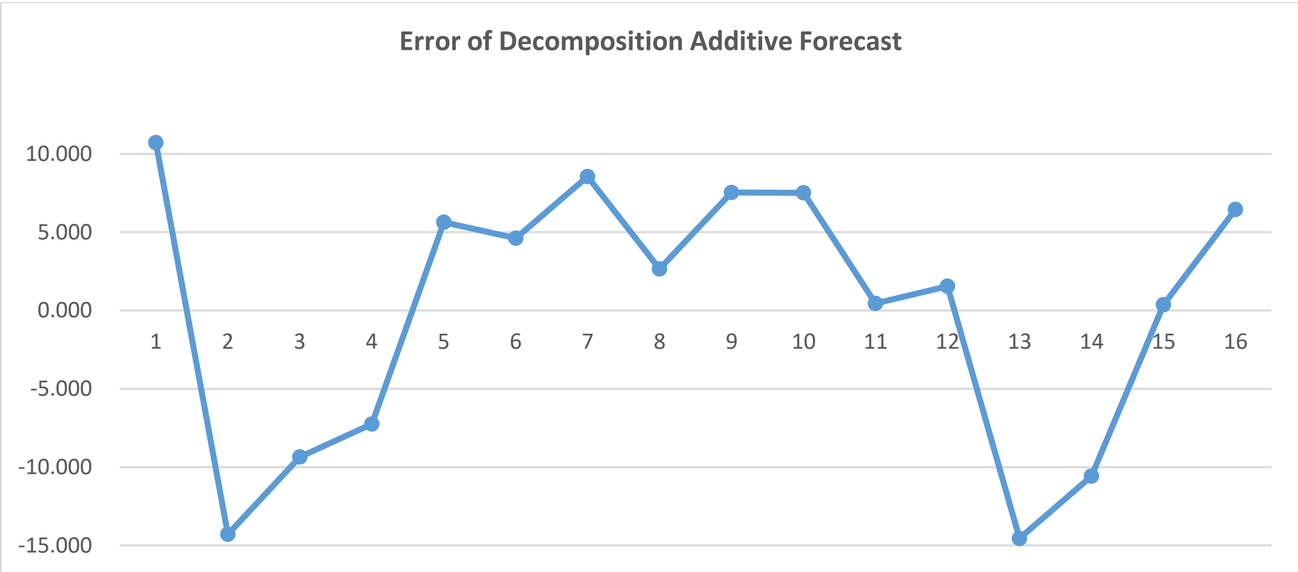
Appendix 3. Decomposition Additive Method








Expenditure ($m) on household appliances in Victoria from Mar 2016 to Dec 2019
Decomposition Additive Method
Step 4 Forecasts
800
750
700
650
600
550
500
Mar-16 May-16 Jul-16 Sep-16 Nov-16 Jan-17 Mar-17 May-17 Jul-17 Sep-17 Nov-17 Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19 Jul-19 Sep-19 Nov-19 Jan-20 Mar-20 May-20 Jul-20 Sep-20 Nov-20
HFCE
Decomp Predictions
Forecasts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5.000
0.000
-5.000
-10.000
-15.000
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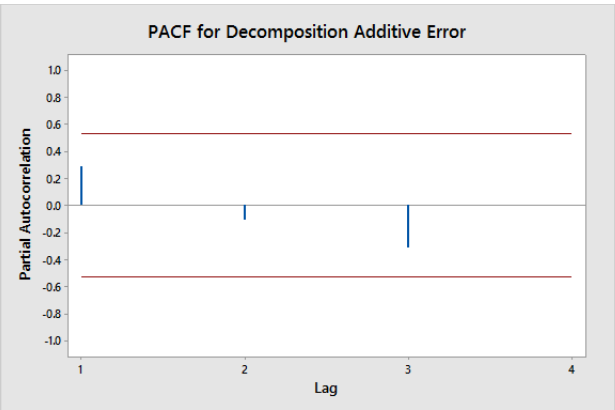
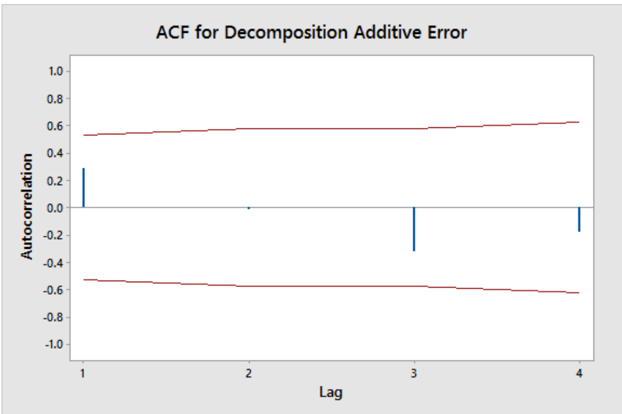

PACF for Decomposition Additive Error
Partial Autocorrelation
Lag


ACF for Decomposition Additive Error
Autocorrelation
Lag