1) Introduction

Nowcasting Quarterly GDP by using monthly indicators is a method of using monthly information as the quarter unfolds in order to have a better 1 step ahead prediction on Quarterly GDP. In this paper, we will test the effectiveness of using different monthly indicators such as Retail Trade Sales, TSX Index, International Reserves and Canadian Dollar Effective Exchange Rate Index (CERI) together with monthly GDP (at basic prices) in order to improve the prediction of the components of Quarterly GDP. We will use a historical dataset from year 1997 up to 2019 and explore techniques in fitting a time series model on Quarterly Components of GDP with monthly external regressors. We will also explore ways into effectively fitting a time series model using the AIC criterion since our goal is to get a better forecast.

To evaluate the performance of our model, we will perform Time Series Cross Validation on the last 20 Quarters to avoid overfitting. Comparing the results will enable us to get a representative score of using different monthly indicators in nowcasting the four different Components of Quarterly GDP.

2.1) Data

Using the expenditure approach, we can break down Quarterly GDP Into 4 parts namely: Consumption, Investments, Government Expenditure and Net Exports.

Consumption is the largest part of the Quarterly GDP, it includes Household final consumption expenditure and non-profit institutions serving households' final consumption expenditure. We will explore the relationship between Quarterly Consumption and monthly Retail Trade Sales (at start of quarter) to figure out whether Retail Trade Sales is a good external regressor for Consumption.

The next component that we are going to model is the Investments. Investments, include business gross fixed capital formation, non-profit institutions serving households' gross fixed capital formation and business investment in inventories. We will explore the relationship between Quarterly Investments and TSX Index at the start of Quarter to determine whether TSX Index is a good external regressor for Investments.

Government Expenditures measures the total amount of government money spent in goods and services. It includes general government final consumption expenditure, general government gross fixed capital formation and government investment in inventories subtracted by the business investment in inventories. We will Explore the relationship between Quarterly Government Expenditures and Monthly Canadian International Reserves to check whether International Reserves is a good external regressor for Government Expenditures.

Net Exports is the difference between the total exports and total imports. We will explore the relationship between Quarterly Net exports and Monthly Canadian Effective Exchange Rate Index (CERI) and determine whether CERI is a good external regressor of Quarterly Net Exports. (Note: Canadian Effective Exchange Rate Index (CERI) is a measurement on Canadian Dollar exchange rate against the currencies of Canada's major trading partners. However, since It was replaced by a new metric (CEER) on January 2018. For January 2018 to August 2019, we have imputed CEER metric into our CERI dataset).

We now explore the different relationships between the components of Quarterly GDP and Several Monthly Indicators:

Retail trade sales in Canada is an important indicator for consumer purchasing. This indicator is a part of many economic models, and it is used on many other nowcasting models. From the graph (Fig 2.1.1) we observe a linear increasing relationship between Quarterly Consumptions and retail trade. It provides a measurement of economic health. When consumers are buying more products, companies produce more products. As a result we add retail trade sales as an external regressor for our Quarterly Consumptions with the Monthly GDP.

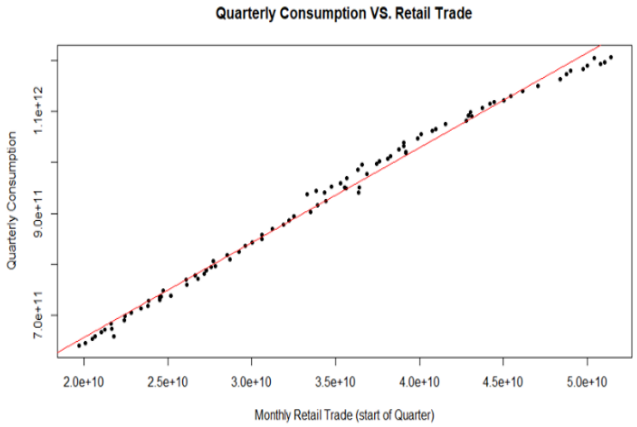


Fig (2.1.1). Scatter Plot of Monthly Retail (Start of Quarter) vs Quarterly Consumptions

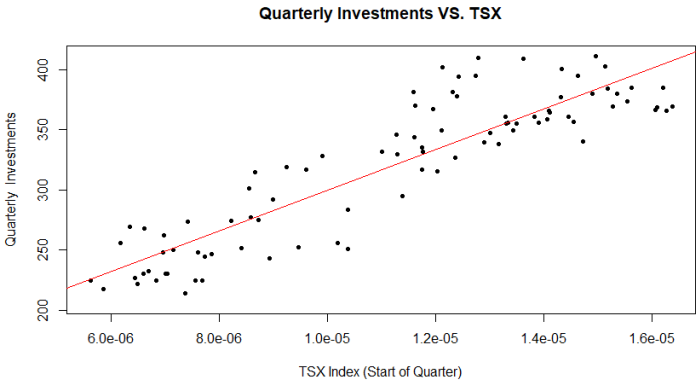


Fig (2.1.2). Scatter Plot of Start of Month TSX Index vs Quarterly Investments

One important indicator for Investment in Canada is S&P/TSX composite index. TSX index is the benchmark for Toronto Stock Exchange. This data is a good linear predictor for the investment part of GDP. From the graph of Quarterly Investments and TSX index (Fig 2.1.2), we observe a linear increasing relationship between these two variables. This behavior is expected as when the stock index increase, the market enters a bull market. Companies are willing to expand their investment and hire more people. We will use Monthly TSX Index as it is a good additive predictor for Quarterly Investments together with monthly GDP.

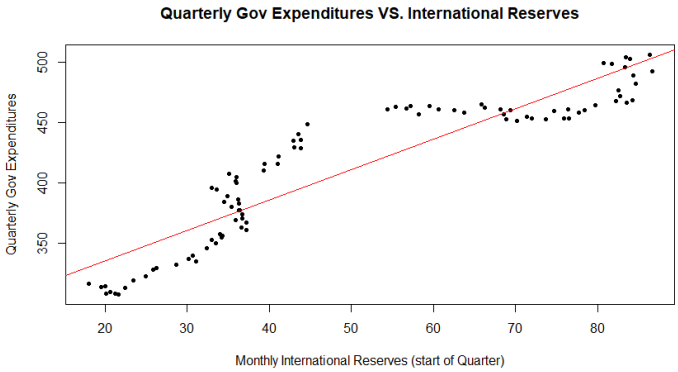


Fig (2.1.3). Scatter Plot of Monthly International Reserves (Start of Quarter) vs. Quarterly Gov Expenditures

International reserves is any kind of reserve funds which central banks can pass among themselves. Reserves can either be gold or a specific currency such as the Dollar or Euro. For Canada however, the US dollar is the main international reserve. By plotting the scatterplot of Quarterly Government Expenditures and Canadian International Reserves (Fig 2.1.3), we observe a linear increasing relationship among these two variables. We will add international reserves as an external regressor for government expenditures as it showcases a good linear relationship.

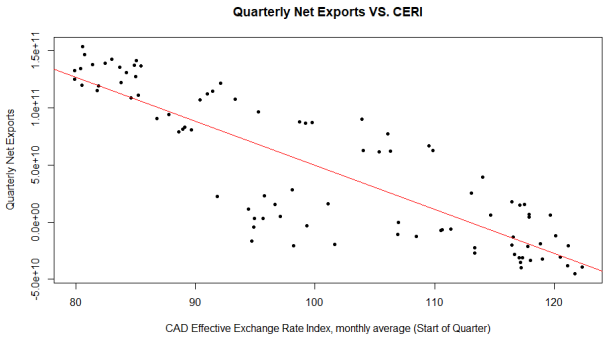


Fig (2.1.4). Scatter Plot of CERI (Start of Quarter) vs. Quarterly Net Exports

Canadian-Dollar Effective Exchange Rate index (CERI) – (CEER from January 2018 onwards) has a clear negative relationship with Quarterly Net Exports (Fig 2.1.4). This is expected as when Canadian dollar exchange rate increases with respect to other currencies, exports of Canadian goods and services decreases. At the same time Canadians can buy foreign products at a cheaper price, and this increase import amount. Overall these decreases net exports. We will include this as an external regressor in predicting quarterly net exports.

(Data Summary)

Table 2.1	REGRESSORS
Consumption	Monthly GDP, Monthly Retail Trade Sales
Investments	Monthly GDP, Start of Month TSX Index
Gov Expenditures	Monthly GDP, Monthly International Reserves
Net Exports	Monthly GDP, Average Monthly CERI/CEER

(See Table 2.1 for summary of our choices for Monthly Regressors for Respective Quarter Component)

2.2) Methods

Since our data is seasonally adjusted, a general ARIMA model in modeling the 4 parts of Quarterly GDP will suffice. As the goal of our model is to improve prediction, we will select the model with the lowest AIC score.

In order to scale our variables, we first apply a logarithmic transformation for both Monthly regressors and Quarterly time series for the Consumption, Investments and Government Expenditures Models. We then take the inverse to get the actual prediction and perform Cross Validation to our model in order to avoid overfitting. For the Net Exports Model, we opt for standardizing instead of the logarithmic transform as it is not strictly positive.

2.3) Discussions/Analysis

Total GDP Model

- Fitting an ARIMA(1,1,1) model on the Log of Total Quarterly GDP with Log Monthly GDP External Regressor, we get an AIC of -854.78
- From the plots in Appendix B.1 (Model Diagnostics) we can see that the Normality Assumption is not violated and our ARIMA(1,1,1) model captures the information from our data (residuals are white noise).

Consumption Model

- Performing a 2nd month nowcast using Log of GDP and Retail Trade Sales together with Fitting an ARIMA(0,1,0) model on the Log of Total Consumptions, we get an AIC of -733.91
- For this model, the Normality Assumption is likely to be violated as the QQ Plot demonstrates some deviation from a straight line however, our ARIMA(0,1,0) model still captures most of the useful information from our data. (residuals are white noise). (See Appendix B.2 for Model Diagnostics of Consumption Model)

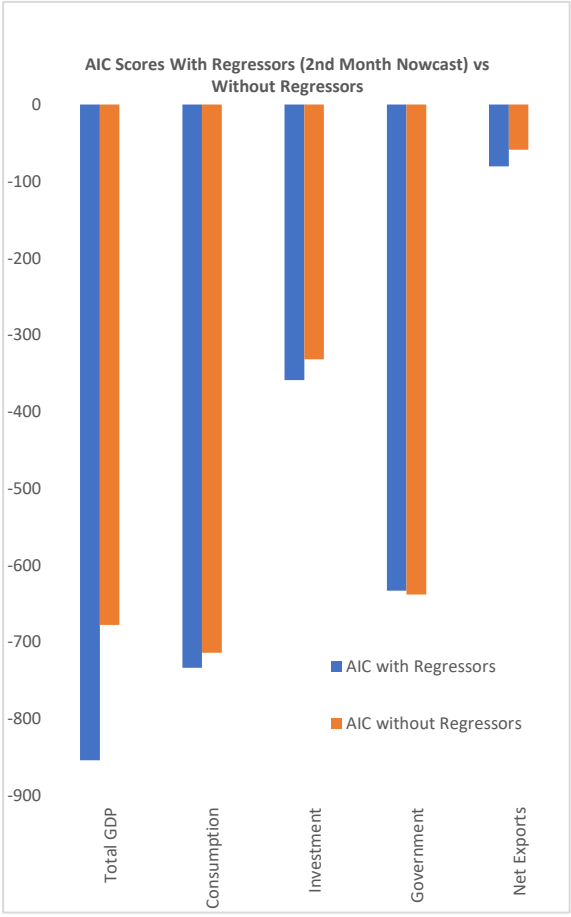


Figure 2.3.1 AIC Scores with 2nd Month Nowcast Regressors and AIC Scores without Regressors

Investment Model

- Performing a 2nd month nowcast using Log of Monthly GDP and TSX Index together with Fitting an ARIMA(0,1,0) model on the Log of Total Investments, we get an AIC of -359.14
- Both Normality assumption and residual ACF as white noise are not rejected. (See Appendix B.3 for Model Diagnostics of Investment Model)

Government Expenditures Model

- Performing a 2nd month nowcast using Log of Monthly GDP and International Reserves as external regressors, together with Fitting an ARIMA(2,1,0) model on Quarterly Government Expenditures, we get an AIC of -633.66, Surprisingly this is larger than if we do not use any regressors where we get an AIC of -638.78
- Both Normality assumption and residual ACF as white noise are not rejected. (See Appendix B.4 for Model Diagnostics of Government Expenditures Model)

Net Exports Model

- Performing a 2nd month nowcast using Standardized Values of Monthly GDP and average CERI together with Fitting an ARIMA(0,1,0) model on the Standardized Net exports, we get an AIC of -80.735
- Both Normality assumption and residual ACF as white noise are not rejected. (See Appendix B.5 for Model Diagnostics of Net Exports Model)
- From the ACF/PACF plots of the differenced series there seems to be no significant Auto Correlations (series is white noise). A Time Series model might not be the best model for this specific case

General Comments

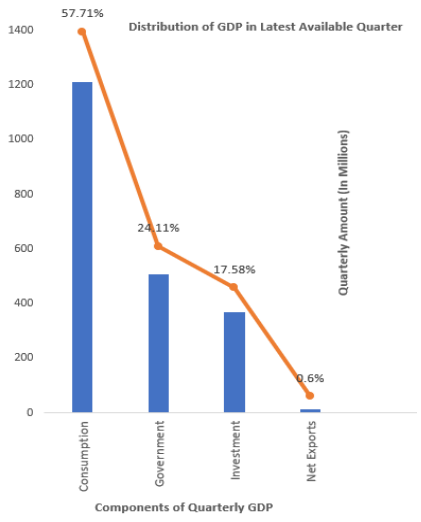


Figure 2.3.2 Contribution of Components of (Latest Available Quarter) GDP to Actual GDP

- All the models we used are Integrated, (i.e First Order Differencing makes the Quarterly Component Stationary) (See Appendix A.4 for ACF/PACF Plots)

- From Figure 2.3.1, we can see that the AIC scores of our Time Series Models except for Government Expenditures are all lower when we use External Regressors (2nd Month Nowcast) than if we do not use them

- From Figure 2.3.2, we can see that the Consumption and Government Expenditure Component of GDP makes up a large part of Total Quarterly GDP. Improving the accuracy of these 2 components would make the largest impact in forecasting Total GDP

2.4) Results

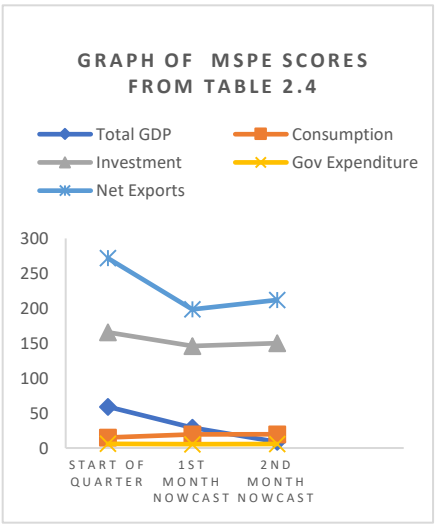
We perform Time Series Cross Validation on the last 20 Quarters in order to Validate the accuracy of our model. That is, we fit our model on the first 71 Quarters and first 71 regressors and perform a 1 step ahead prediction. Afterwards, we compare this 1 step ahead prediction to the true value and fit our model to first 71 Quarters and proceed as before. Taking the average squared error and absolute error of these 20 predictions would give us the MSPE and MAPE cross validation scores as below:

Table 2.4

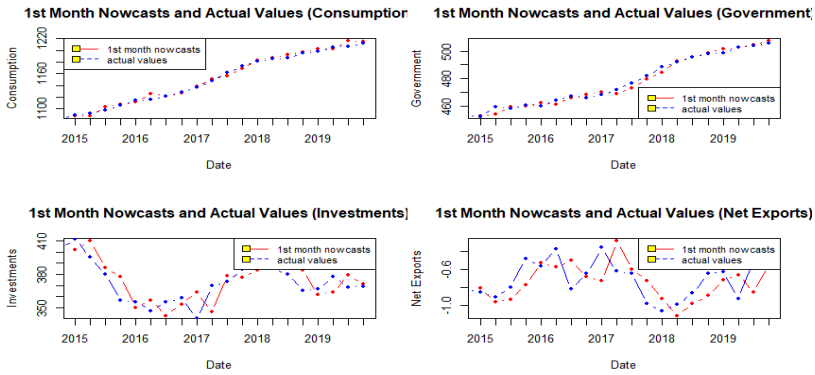
MSPE / MAPE Cross Validation Scores

	Start of Quarter MSPE	1st Month Nowcast MSPE	2nd Month Nowcast MSPE	Start of Quarter MAPE	1st Month Nowcast MAPE	2nd Month Nowcast MAPE
Total GDP Model Arima(1,1,1)	59.071	29.124	8.777	0.00319	0.00231	0.00113
Consumption Model Arima(0,1,0)	15.034	19.344	19.685	0.00254	0.00312	0.00311
Investments Model Arima(0,1,0)	165.57	146.029	150.139	0.02819	0.02729	0.02729
Gov Exp Model Arima (2,1,0)	5.557	4.966	5.2927	0.00415	0.00394	0.00418
Standardized Net Exports Model Arima(0,1,0)	0.0607	0.04349	0.05401	0.31624	0.2857	0.296

- Note: Predictions Compared in the Net Exports Model are Standardized, Also there might be a more efficient way of modelling Net Exports as we can see from Appendix A.5 the ACF/PACF Plots do not showcase any significant auto correlations.



- For the Total GDP Model, the MAPE and MSE decreases as we get more information as the quarter unfolds.
- For the other models however, more information does not imply a more accurate model and this could be a case of overfitting.
- As we can see from the plot below (Figure 2.4), The Consumption and Government Model Nowcasts are more accurate and less volatile than the 2 other models. Consumption and Government Exp are the largest part of GDP and has the largest impact in Forecasting GDP.



- The models with the least amount of significant autocorrelations (Investment and Net Exports) also are the models that have the highest MAPE scores. (See Appendix A.4 for ACF/PACF)

Figure 2.4 Plot of Nowcasts and Actual Values for Components of GDP

3) Conclusions and Limitations

Nowcasting GDP can be decomposed into smaller components for better prediction. Retail Trade Sales, TSX Index, International Reserves and CERI are all good linear predictors to Quarterly Consumption, Investments, Government Expenditures and Net Exports respectively. When splitting the GDP into its four components, we get a more intuitive model that captures more information of the series. Consumption and Government Expenditure makes the majority of total GDP and it can be easily modeled using an ARIMA model however high errors in the other Investment and Net Exports Model could add noise in forecasting the Total Quarterly GDP.

Even though we split the components of Quarterly GDP into its 4 components and used good Linear Monthly External Regressors, there are still various limitations for our model. This Includes the risk of overfitting due to a small dataset and correlated exogenous variables. The monthly predictors we used are highly correlated and our dataset only contains 91 Quarters which is a relatively small dataset and this could lead to overfitting which can be seen in the increase of MSPE/MAPE as we include more information in the model. Also, Quarterly GDP contains all economic activity in a country and a few sets of predictors can only explain a small amount of information in GDP nowcasting. For future studies, this could be addressed through dimensionality reduction techniques, getting a larger historical dataset and using more monthly exogenous variables to nowcast Quarterly GDP.

APPENDIX A.

Explanatory Time Series Analysis

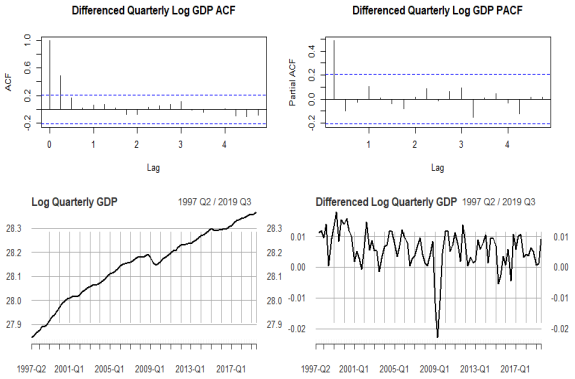


Fig A.1 (Total GDP)

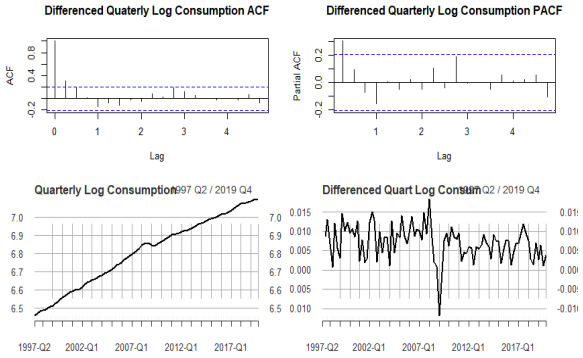


Fig A.2 (Consumption)

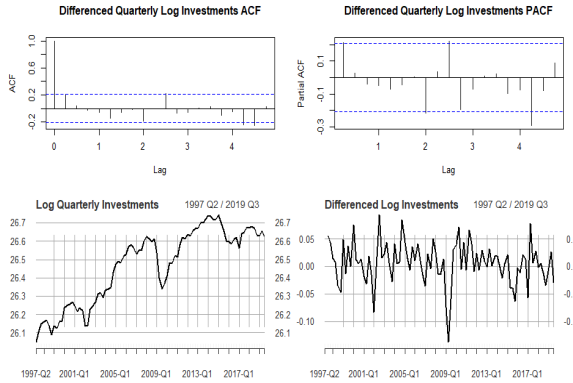


Fig A.3 (Investment)

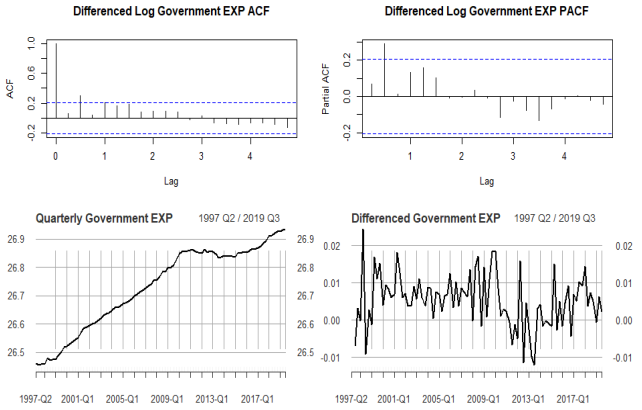


Fig A.4 (Gov Expenditures)

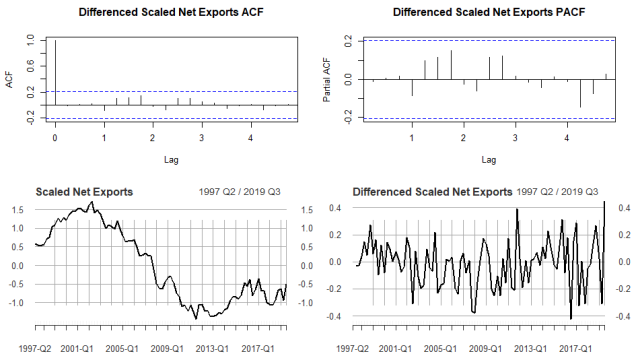


Fig A.5 (Net Exports)

APPENDIX B.

(Model Diagnostics)

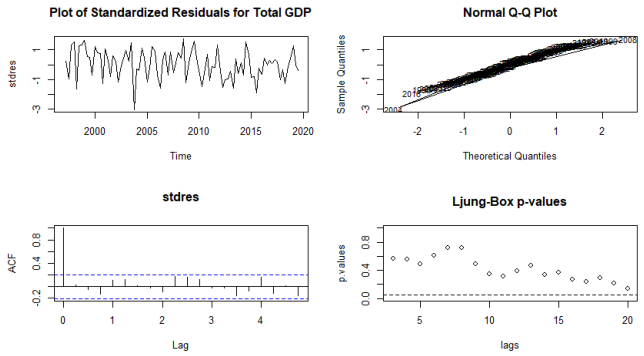


Fig B.1 (Total GDP)

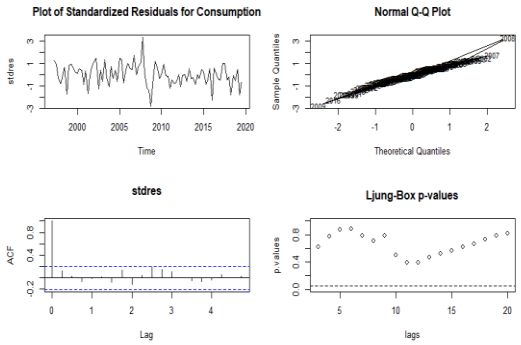


Fig B.2 (Consumption)

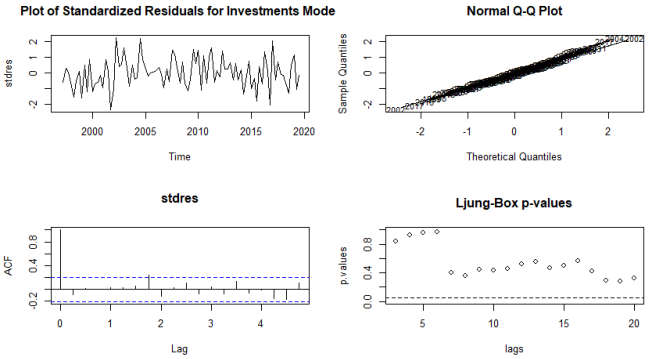


Fig B.3 (Investment)

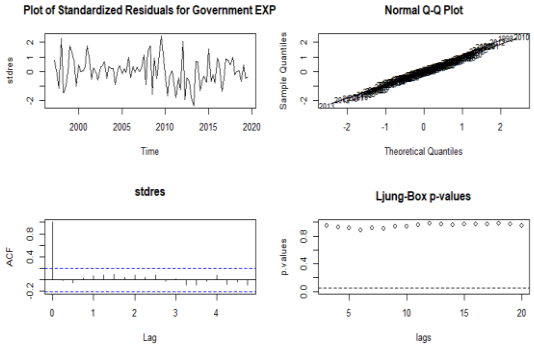


Fig B.4 (Gov Expenditures)

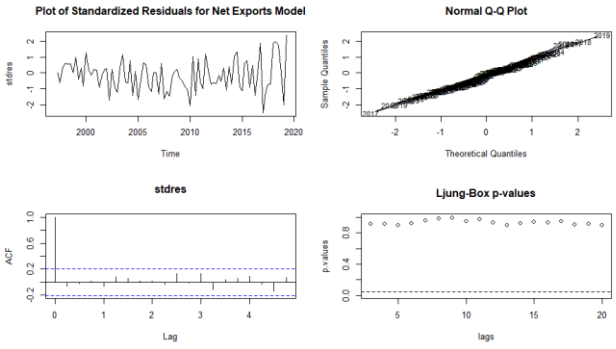


Fig B.4 (Net Exports)