Imports ARIMA

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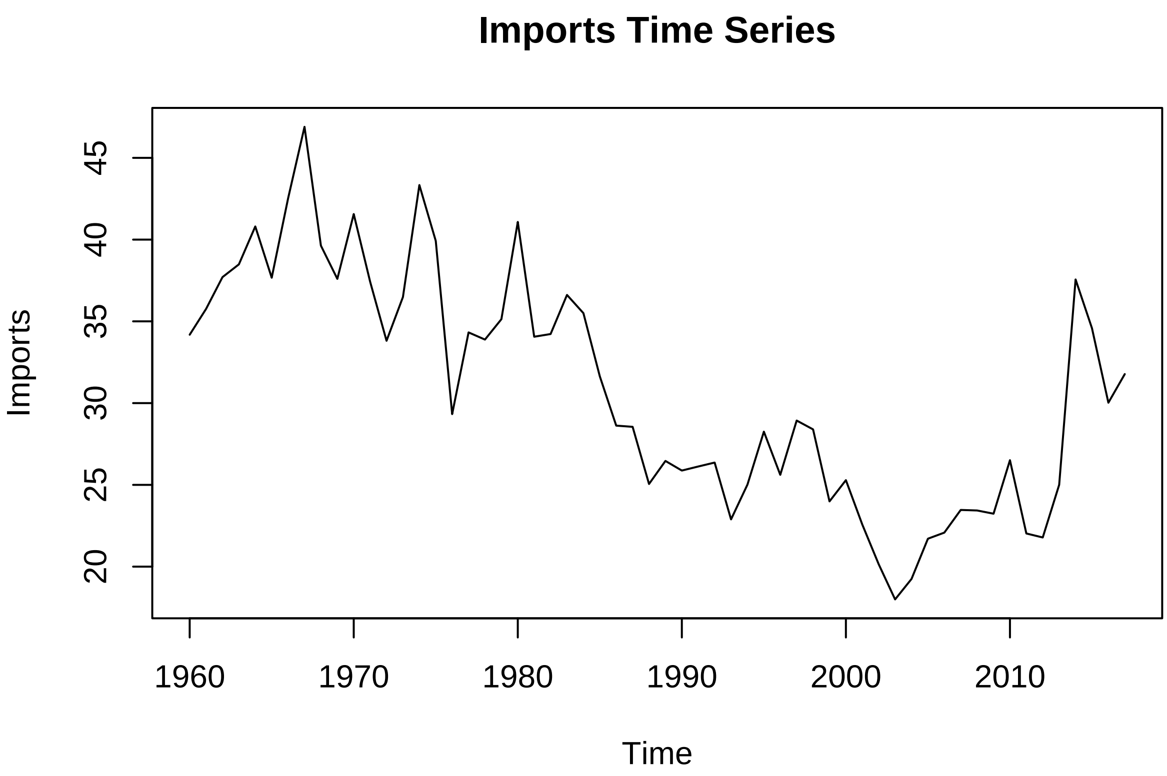
Col Removal

Keep Year, Imports, and GDP columns

```
finalPro_data <- finalPro_data[, c("Year", "Imports")]
```

Plot Time Series

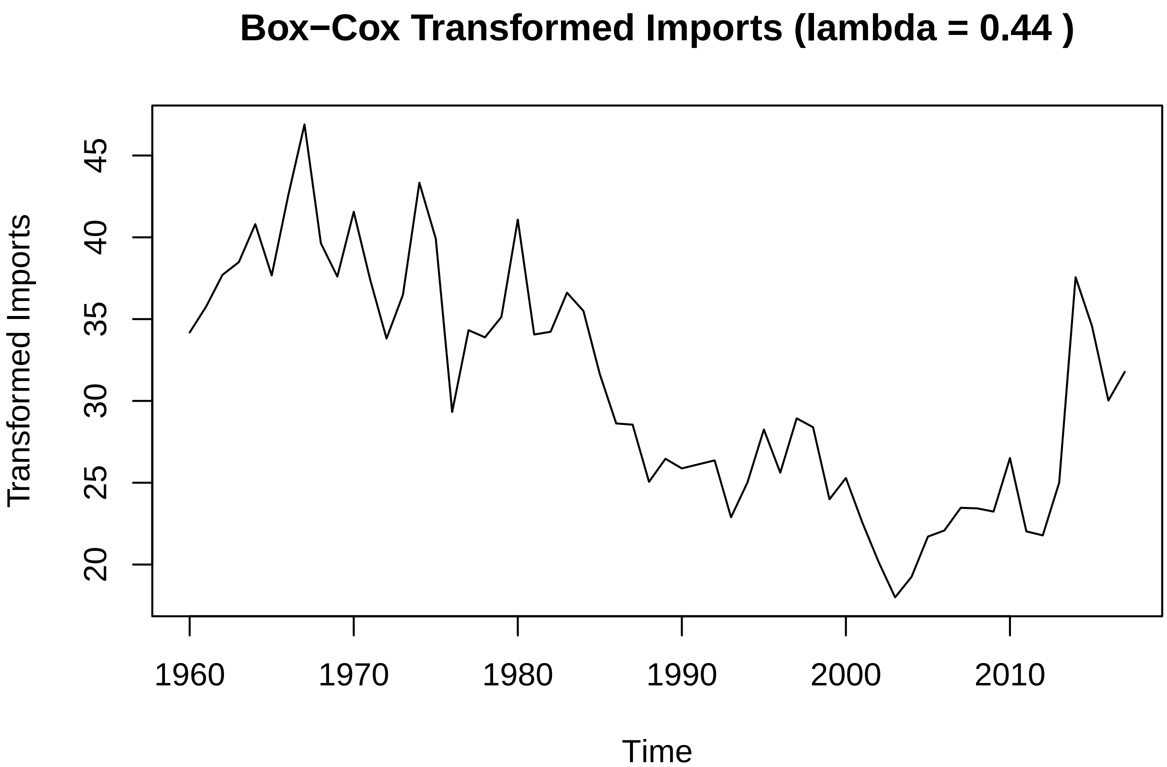
```
# Plot Imports
imports_ts <- ts(finalPro_data$Imports, start = 1960, frequency = 1)

ts.plot(imports_ts, main="Imports Time Series", ylab="Imports")
```



Summary: - Imports time series has upward trend, this shows this is non-stationary - It has peaks around every 10 year: 1980, 1990, 2010

Transform

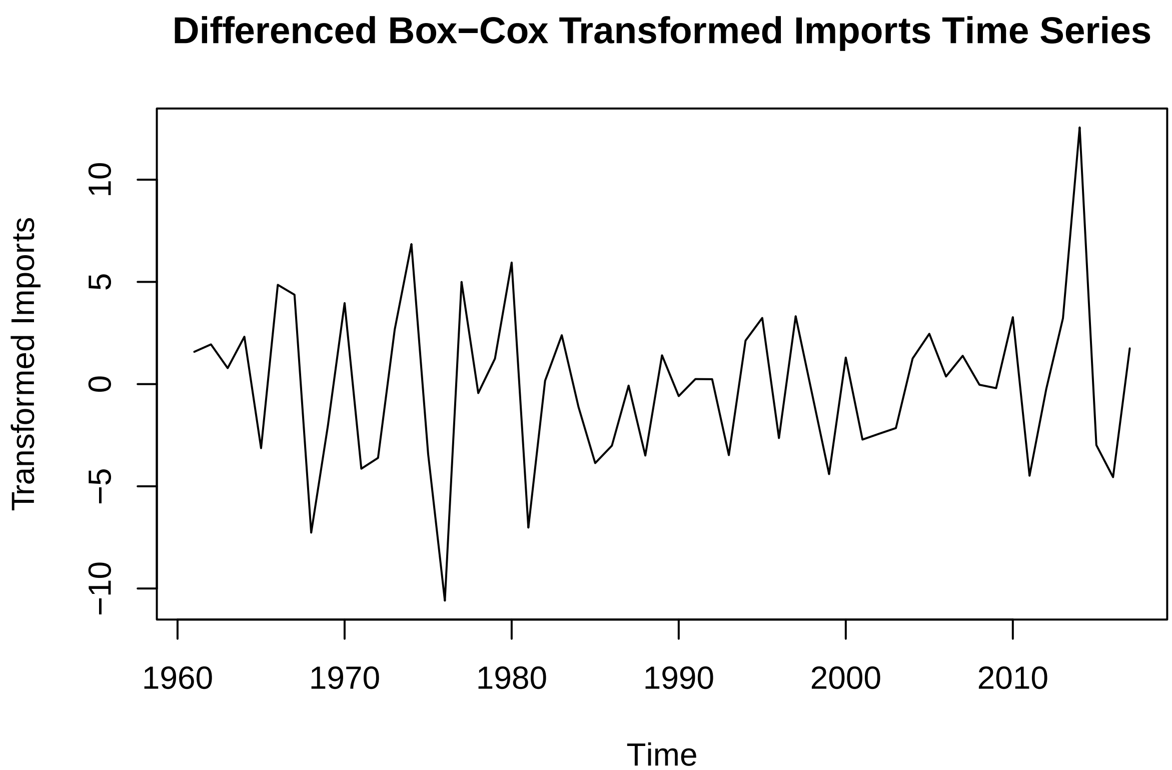
```
# Box-Cox transform Imports
lambda <- BoxCox.lambda(imports_ts)
boxcox_imports_ts <- imports_ts # BoxCox(imports_ts, lambda)
ts.plot(boxcox_imports_ts, main = paste("Box-Cox Transformed Imports (lambda =", round(lambda, 3), ")")
```



We tried log, but residuals not normal.

Differencing Imports

```
diff_imports_bc <- diff(boxcox_imports_ts, differences=1)

# Plot differenced Box-Cox Imports
ts.plot(diff_imports_bc, main="Differenced Box-Cox Transformed Imports Time Series", ylab="Transformed 
```



Root test for stationarity check

```r
# Load tseries for ADF test
library(tseries)

# Augmented Dickey-Fuller Test
adf_result <- adf.test(diff_imports_bc)
```

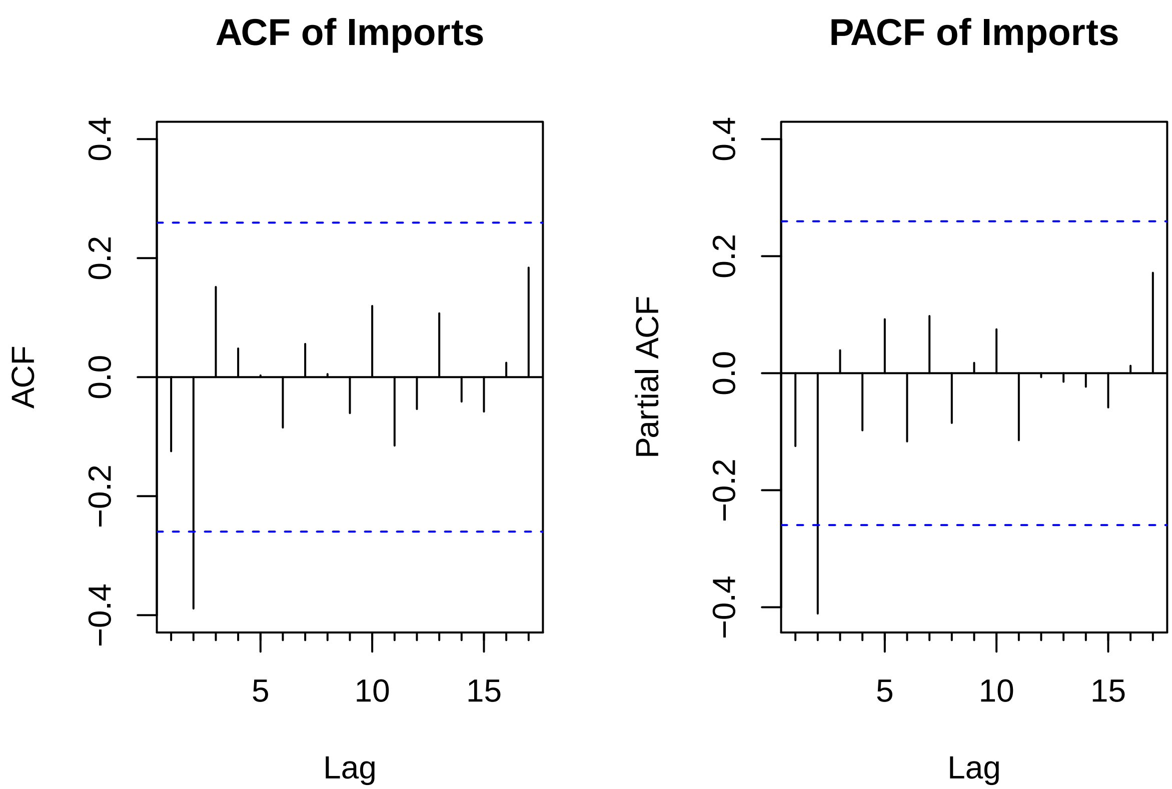
```
## Warning in adf.test(diff_imports_bc): p-value smaller than printed p-value
```

```r
cat("ADF test p-value:", round(adf_result$p.value, 4),
    ifelse(adf_result$p.value < 0.05, "(PASS - Stationary)", "(FAIL - Non-stationary)"), "\n")
```

```
## ADF test p-value: 0.01 (PASS - Stationary)
```

ACF / PACF plots

```r
# ACF and PACF of the transformed and differenced series
par(mfrow = c(1, 2))
Acf(diff_imports_bc, main = "ACF of Imports")
Pacf(diff_imports_bc, main = "PACF of Imports")
```



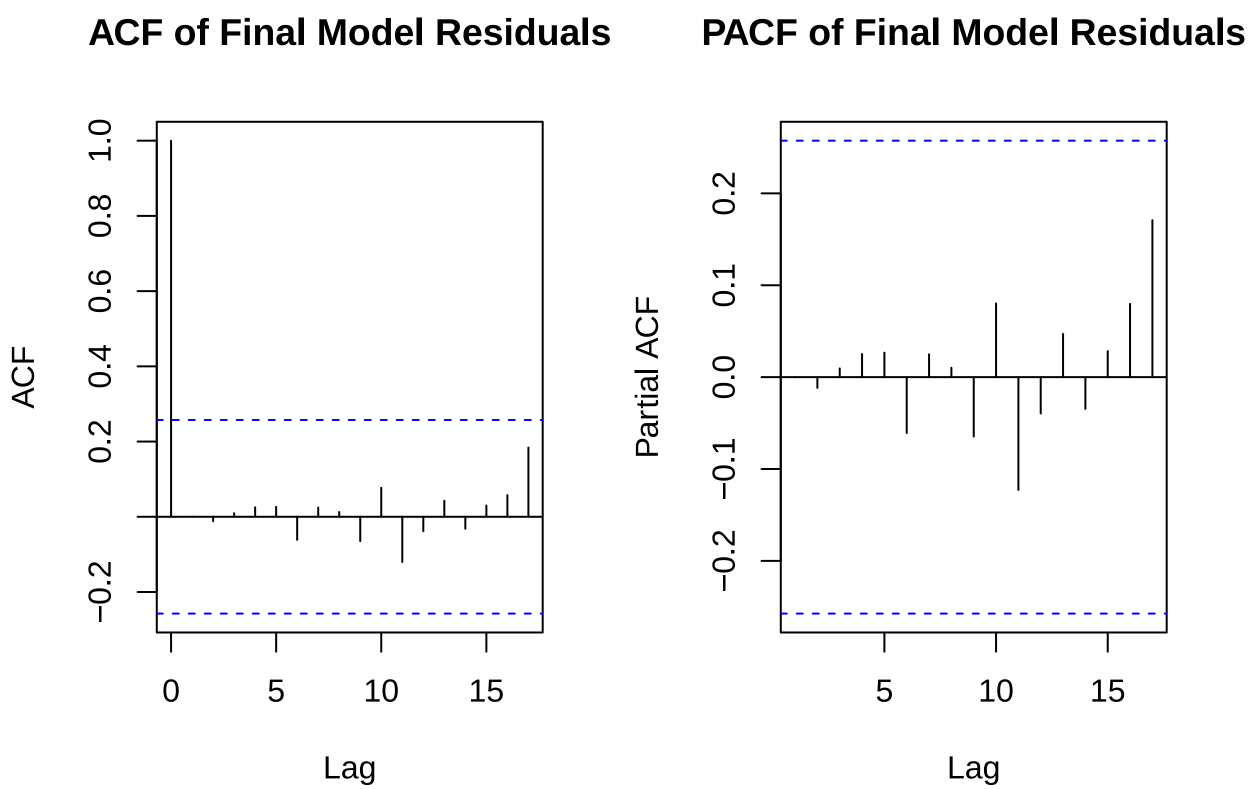

```r
par(mfrow = c(1, 1))
```

Modeling

```r
# Central African Republic Imports ARIMA Model

# Diagnostics on chosen model
final_model <- Arima(boxcox_imports_ts, order = c(2, 1, 2), method = "ML")
print(final_model)
```

```
## Series: boxcox_imports_ts
## ARIMA(2,1,2)
##
## Coefficients:
##           ar1      ar2     ma1      ma2
##       -0.4076  -0.1258  0.2827  -0.3737
## s.e.   0.2738   0.2779  0.2598   0.2725
##
## sigma^2 = 12.32:  log likelihood = -150.65
## AIC=311.3   AICc=312.48   BIC=321.51
```

```r
residuals_final <- residuals(final_model)

# Residual ACF and PACF for final model
par(mfrow = c(1, 2))  # Side-by-side layout
acf(residuals_final, main = "ACF of Final Model Residuals")
pacf(residuals_final, main = "PACF of Final Model Residuals")
```




```
par(mfrow = c(1, 1))  # Reset layout

# Diagnostic Tests (Simplified)
cat("\nDiagnostic Tests (Simplified):\n")
```

```
##
## Diagnostic Tests (Simplified):
```

```
# 1. Portmanteau (Ljung-Box) Test for Autocorrelation
ljung <- Box.test(residuals_final, lag = 10, type = "Ljung-Box")
cat("Ljung-Box test p-value:", round(ljung$p.value, 4),
    ifelse(ljung$p.value > 0.05, "(PASS - residuals   white noise)", "(FAIL)"), "\n")
```

```
## Ljung-Box test p-value: 0.9997 (PASS - residuals   white noise)
```

```
# 2. Shapiro-Wilk Test for Normality
# this does not violate model assumptions, but it violates confidence interval assumptions
shapiro <- shapiro.test(residuals_final)
cat("Shapiro-Wilk test p-value:", round(shapiro$p.value, 4),
    ifelse(shapiro$p.value > 0.05, "(PASS - approx. normal residuals)", "(FAIL)"), "\n")
```

```
## Shapiro-Wilk test p-value: 0.0022 (FAIL)
```

```
# STEP 3: Model Comparison
# Expanded grid search from ARIMA(0,1,0) to ARIMA(4,1,4)
models <- list()
for (p in 0:4) {
  for (q in 0:4) {
    name <- paste0("ARIMA(", p, ",1,", q, ")")
    models[[name]] <- c(p, 1, q)
  }
```

```r
}
results <- data.frame(Model=character(), AIC=numeric(), BIC=numeric(),
                      Ljung_Box_p=numeric(), stringsAsFactors=FALSE)

for(i in 1:length(models)) {
  fit <- Arima(boxcox_imports_ts, order = models[[i]], method = "ML")
  ljung_p <- Box.test(residuals(fit), lag = 10, type = "Ljung-Box")$p.value
  results <- rbind(results, data.frame(
    Model = names(models)[i],
    AIC = fit$aic,
    BIC = BIC(fit),
    Ljung_Box_p = ljung_p
  ))
}
print(results)
```

```
##           Model      AIC      BIC Ljung_Box_p
## 1  ARIMA(0,1,0) 316.3143 318.3573   0.1755999
## 2  ARIMA(0,1,1) 315.3522 319.4383   0.6210100
## 3  ARIMA(0,1,2) 309.3683 315.4975   0.9363533
## 4  ARIMA(0,1,3) 309.2473 317.4195   0.9997589
## 5  ARIMA(0,1,4) 311.2467 321.4620   0.9997698
## 6  ARIMA(1,1,0) 317.4368 321.5229   0.2515772
## 7  ARIMA(1,1,1) 314.9475 321.0767   0.7413242
## 8  ARIMA(1,1,2) 309.4892 317.6614   0.9995161
## 9  ARIMA(1,1,3) 311.2468 321.4620   0.9997687
## 10 ARIMA(1,1,4) 313.2469 325.5052   0.9997686
## 11 ARIMA(2,1,0) 308.9097 315.0388   0.9779056
## 12 ARIMA(2,1,1) 310.8015 318.9737   0.9749142
## 13 ARIMA(2,1,2) 311.2997 321.5149   0.9996982
## 14 ARIMA(2,1,3) 313.2449 325.5032   0.9997572
## 15 ARIMA(2,1,4) 315.2144 329.5157   0.9996537
## 16 ARIMA(3,1,0) 310.8494 319.0216   0.9762303
## 17 ARIMA(3,1,1) 311.6273 321.8425   0.9988347
## 18 ARIMA(3,1,2) 313.2359 325.4942   0.9997612
## 19 ARIMA(3,1,3) 315.2106 329.5120   0.9997852
## 20 ARIMA(3,1,4) 315.1932 331.5376   0.9977253
## 21 ARIMA(4,1,0) 312.4420 322.6573   0.9857691
## 22 ARIMA(4,1,1) 313.0303 325.2886   0.9998808
## 23 ARIMA(4,1,2) 311.8824 326.1837   0.9999999
## 24 ARIMA(4,1,3) 313.7943 330.1387   1.0000000
## 25 ARIMA(4,1,4) 317.1901 335.5776   0.9976952
```

```r
# If we inspect the BIC too, the one with min AIC is likely to also have the min BIC
cat("\nBest model by AIC:", results$Model[which.min(results$AIC)], "\n")
```

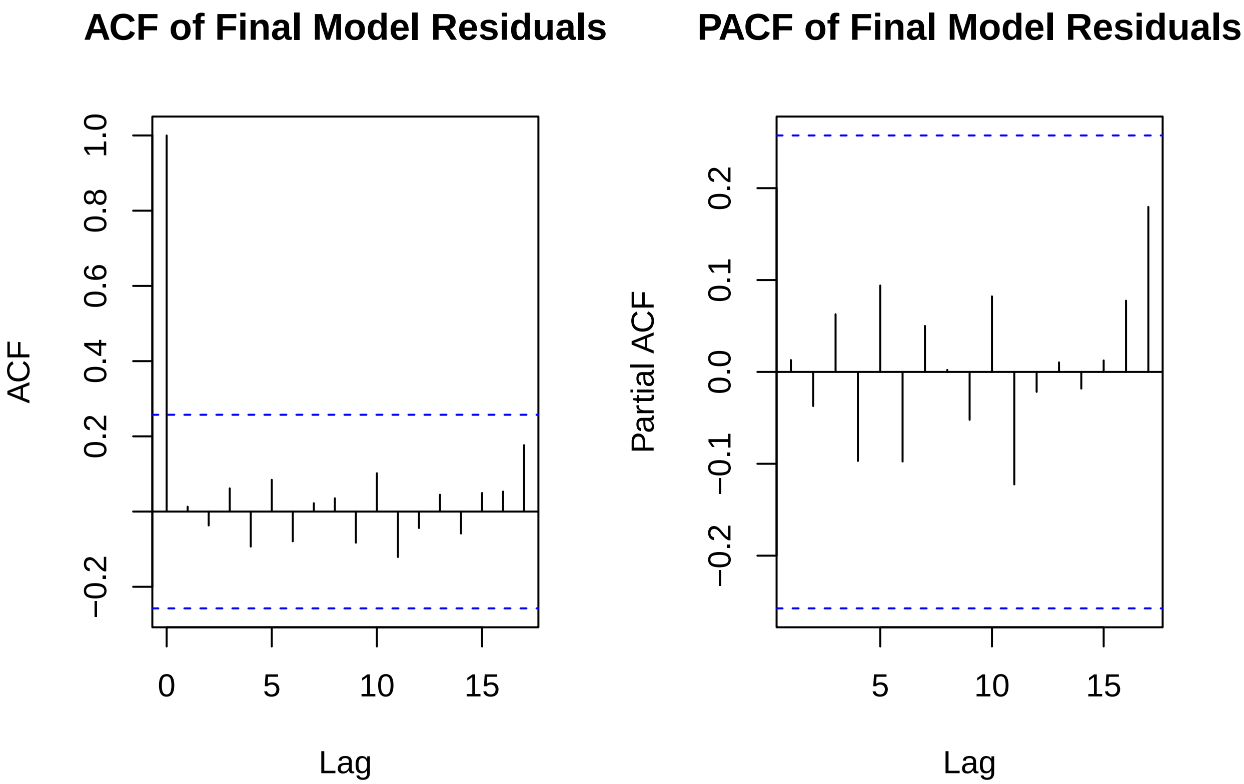
```
##
## Best model by AIC: ARIMA(2,1,0)
```

```r
# STEP 4: Final Model and Diagnostics
final_model <- Arima(boxcox_imports_ts, order = c(2, 1, 0), method = "ML")
print(final_model)
```

```
## Series: boxcox_imports_ts
## ARIMA(2,1,0)
```

```
##
## Coefficients:
##           ar1      ar2
##       -0.1727  -0.4101
## s.e.   0.1203   0.1197
##
## sigma^2 = 12.25:  log likelihood = -151.45
## AIC=308.91   AICc=309.36   BIC=315.04
```

```r
residuals_final <- residuals(final_model)

# Residual ACF and PACF for final model
par(mfrow = c(1, 2))  # Side-by-side layout
acf(residuals_final, main = "ACF of Final Model Residuals")
pacf(residuals_final, main = "PACF of Final Model Residuals")
```




```r
par(mfrow = c(1, 1))  # Reset layout

cat("\nDiagnostic Tests:\n")
```

```
##
## Diagnostic Tests:
```

```r
# 1. Ljung-Box test
ljung <- Box.test(residuals_final, lag = 10, type = "Ljung-Box")
cat("Ljung-Box test p-value:", round(ljung$p.value, 4),
    ifelse(ljung$p.value > 0.05, "(PASS)", "(FAIL)"), "\n")
```

```
## Ljung-Box test p-value: 0.9779 (PASS)
```

```r
# 2. Normality test
# this does not violate model assumptions, but it violates confidence interval assumptions
shapiro <- shapiro.test(residuals_final)
cat("Shapiro-Wilk test p-value:", round(shapiro$p.value, 4),
    ifelse(shapiro$p.value > 0.05, "(PASS)", "(FAIL)"), "\n")
```

```
## Shapiro-Wilk test p-value: 0.0253 (FAIL)
```

```r
# 3. ARCH test
arch <- Box.test(residuals_final^2, lag = 5, type = "Ljung-Box")
cat("ARCH test p-value:", round(arch$p.value, 4),
    ifelse(arch$p.value > 0.05, "(PASS)", "(FAIL)"), "\n")
```

```
## ARCH test p-value: 0.9631 (PASS)
```

```r
cat("\nSlight non-normality detected but acceptable for ARIMA modeling\n")
```

```
##
## Slight non-normality detected but acceptable for ARIMA modeling
```

```r
cat("Q-Q plot shows approximate normality with minor tail deviations\n\n")
```

```
## Q-Q plot shows approximate normality with minor tail deviations
```

```r
# STEP 5: Forecast with Inverse Transformation
forecast_result <- forecast(final_model, h = 3)
# Inverse Box-Cox transformation
forecast_original <- (lambda * forecast_result$mean + 1)^(1/lambda)
lower_original <- (lambda * forecast_result$lower + 1)^(1/lambda)
upper_original <- (lambda * forecast_result$upper + 1)^(1/lambda)
cat("1-step ahead forecast (original Imports scale):", round(forecast_original[1], 2), "Imports\n")
```

```
## 1-step ahead forecast (original Imports scale): 522.05 Imports
```

```r
cat("95% prediction interval: [", round(lower_original[1,2], 2), ",",
    round(upper_original[1,2], 2), "] Imports\n\n")
```

```
## 95% prediction interval: [ 320.9 , 779.33 ] Imports
```

```r
cat("FINAL MODEL: ARIMA(2, 1, 0) for Box-Cox transformed Imports\n")
```

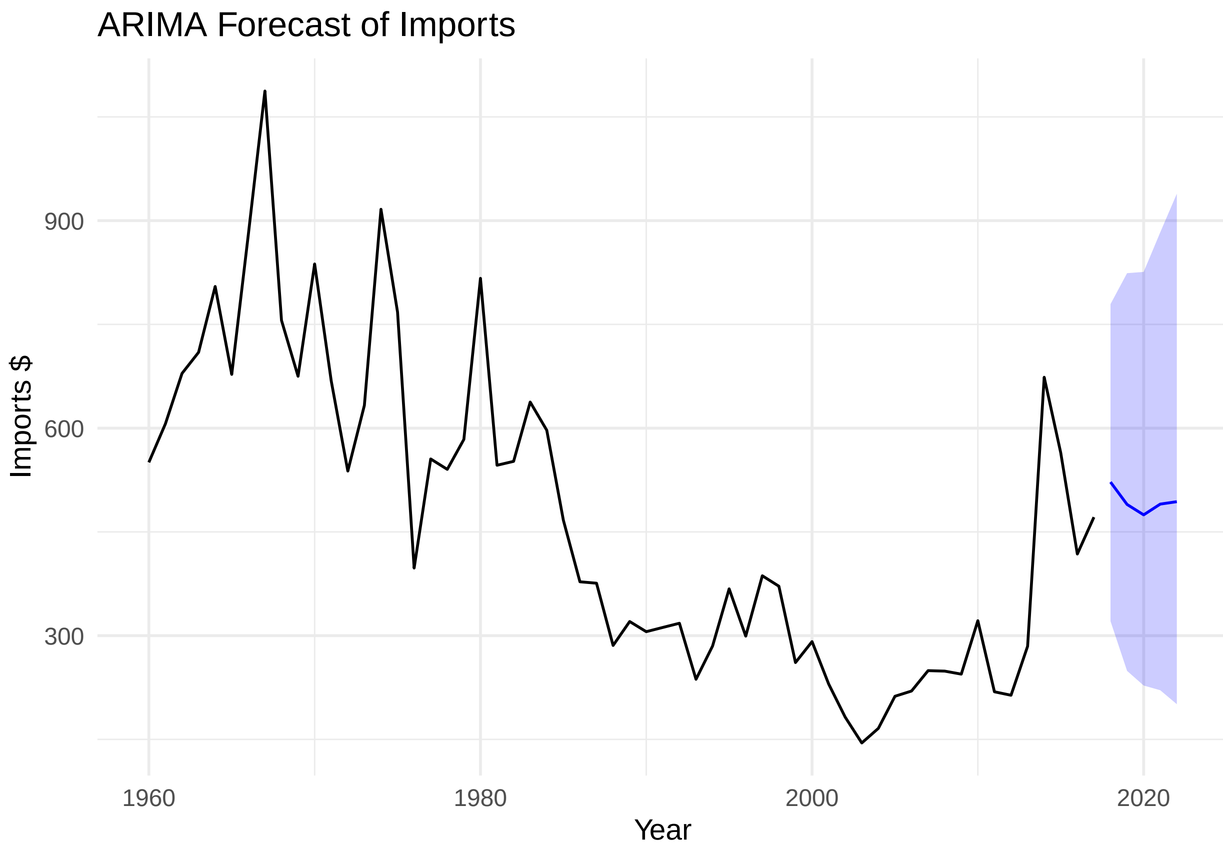
```
## FINAL MODEL: ARIMA(2, 1, 0) for Box-Cox transformed Imports
```

Forecast next 5 periods using the best model and inverse Box-Cox transform

```r
forecast_horizon <- 5
imports_forecast <- forecast(final_model, h = forecast_horizon)

# Inverse Box-Cox function
inv_boxcox <- function(x, lambda) {
  if (lambda == 0) exp(x) else (lambda * x + 1)^(1 / lambda)
}

# Use stored lambda from earlier
inv_forecast <- inv_boxcox(imports_forecast$mean, lambda)
inv_lower <- inv_boxcox(imports_forecast$lower[, 2], lambda)
inv_upper <- inv_boxcox(imports_forecast$upper[, 2], lambda)
```

```r
# Combine historical and forecast data
historical_years <- time(boxcox_imports_ts)
historical_values <- inv_boxcox(boxcox_imports_ts, lambda)
df_history <- data.frame(
  Year = historical_years,
  Imports = historical_values
)

forecast_years <- time(imports_forecast$mean)
df_forecast <- data.frame(
  Year = forecast_years,
  Forecast = inv_forecast,
  Lower = inv_lower,
  Upper = inv_upper
)

# Plot forecast with historical data
ggplot() +
  geom_line(data = df_history, aes(x = Year, y = Imports), color = "black") +
  geom_line(data = df_forecast, aes(x = Year, y = Forecast), color = "blue") +
  geom_ribbon(data = df_forecast, aes(x = Year, ymin = Lower, ymax = Upper), alpha = 0.2, fill = "blue")
  ggtitle("ARIMA Forecast of Imports") +
  xlab("Year") + ylab("Imports $") +
  theme_minimal()
```

```
## Don't know how to automatically pick scale for object of
## type <ts>. Defaulting to continuous.
## Don't know how to automatically pick scale for object of
## type <ts>. Defaulting to continuous.
```


ARIMA Forecast of Imports
900
600
300
Imports $
1960
1980
2000
2020
Year