Research Question:

Is airline passenger data a predictor of economic health, and can it be used to forecast GDP?

The data:

The data that will be used to answer this question comes from the following sources:

1) The Bureau of Transportation Statistics:

This dataset is collected by the Bureau of Transportation Statistics, which is part of the Department of Transportation. It tracks airline passenger data from the end of 2002 to the present, at a monthly frequency. This airline passenger data is from all airports, and all U.S. and foreign carriers.

Variables:

- DOMESTIC: The number of domestic airline passengers in the United States each quarter.
- INTERNATIONAL: The number of international airline passengers in the United States each quarter.

Initial Data Manipulation:

- The airline passenger data was originally monthly data. This data was aggregated into quarterly data to better coincide with the GDP data.
- Removed the “TOTAL” variable due to it being redundant.

2) FRED:

This dataset is collected by the Federal Reserve. This data is collected quarterly and is in billions of dollars.

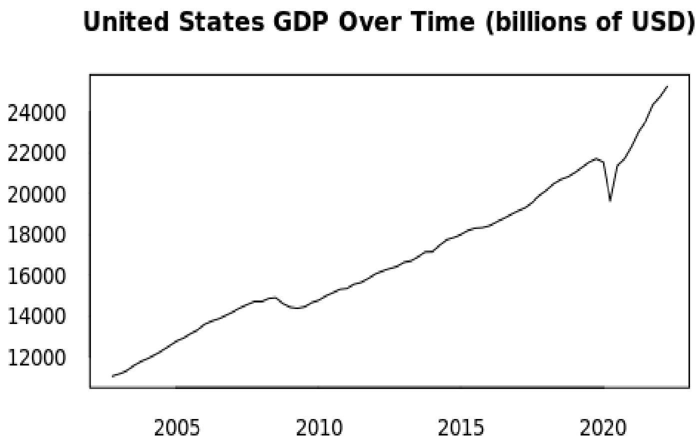
Variables:

- GDP: The market value of the goods and services produced by labor and property located in the United States.

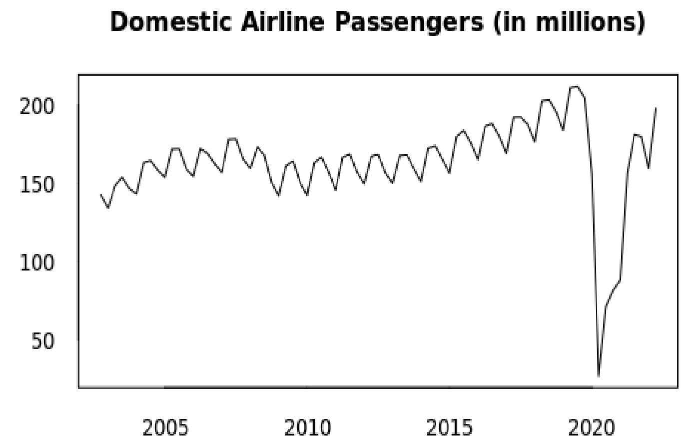
Initial Data Manipulation:

- The main data file only contains GDP values starting from Q4 2002 to maintain the same number of observations as the other variables.
    - When utilized as a variable in isolation, all observations will be utilized (the raw data from the Federal Reserve will be used).

Plots of the Variables:



Source: FRED (2022)



Source: Bureau of Transportation Statistics (2022)

Source: Bureau of Transportation Statistics (2022)

Initial Observations of the Data:

GDP:

- This variable appears to be random. It does not seem to follow any seasonal pattern.
- The variable does, however, appear to have a clear upward trend as time passes.
- There are two notable jumps in the data.
    - One seems to be around the time of the “Great Recession,” extending from the end of 2007 until 2009.
    - The second jump would be when COVID-19 occurred. This jump contains two parts, the first being a severe downward shock, immediately followed

by the second part, a severe upward shock and steep increase, unlike past windows of time accounted for in the data.

Domestic:

- The variable appears to have a seasonal component.
- The data seems to have a slight upward trend (ignoring obvious shocks).
- Notable jumps in the variable at the time of the “Great Recession” and COVID.

International:

- The variable appears to have a seasonal component.
- The data seems to have an upward trend (ignoring obvious shocks).
- Notable jumps in the variable at the time of the “Great Recession” and COVID.

Unit Root Testing:

Testing for unit roots is a necessary part of forecasting and utilizing time trends to analyze data. Simple, for this paper's application, this test allows for the ability to test a variable's stationarity and will provide the required knowledge of whether or not a variable must be deseasonalized/detrended before it can properly be used to forecast.

In-Depth Process/Results from the Unit Root Testing:

Approach Used:

- The Dickey-Fuller Test will be used to test for unit root behavior.
- The test involves estimating at least three models for each variable:
  1: A Pure Random Walk Model
  2: A Random Walk with Drift Model
  3: A Random Walk Drift and Trend Model
- If each model passes the unit root test (indicating it has unit root behavior), then it will be interpreted as being stationary, and the variable will not need to be detrended and deseasonalized before its continued usage.
- If a single one of the models fails the unit root test (showing that it is non-stationary), then that variable must be detrended and deseasonalized before it can be in models to forecast.

Unit Root Test Applied:

GDP Unit Root Test Results:

	Critical Value	Estimated Coefficient	Standard Error	Results
Pure Random Walk	-1.95	1.011017	0.002204	5 > -1.95 pass
Random Walk with Drift	-2.98	1.01528	0.01112	1.37 > -2.98 pass
Random Walk with Drift and Trend	-3.45	0.96362	0.06161	-0.59 > -3.45 pass

Domestic Unit Root Test Results:

	Critical Value	Estimated Coefficient	Standard Error	Results
Random Walk with Drift	-2.98	.0835	.0835	-3.65 < -2.98 fail

International Unit Root Test Results:

	Critical Value	Estimated Coefficient	Standard Error	Results
Pure Random Walk	-1.95	.99536	.01533	-.45 > -1.95 pass
Random Walk with Drift	-2.98	.8281	.06344	-2.71 > -2.98 pass
Random Walk with Drift and Trend	-3.45	.8205	.06554	-2.74 > -3.45 pass

- The initial plot of the international variable indicated that there is seasonality in this variable. This would cause the variable to be non-stationary and thus should not show unit root behavior like it did in this test.
- With only about 20 years of data, there is a high probability that the shock due to COVID is making the variable appear to be stationary.

- Accounting for this, the unit root test is performed again on the international variable from Q4 of 2002 up until Q1 of 2020.

	Critical Value	Estimated Coefficient	Standard Error	Results
Random Walk with Drift and Trend	**-3.45**	**.2907**	**.1301**	**-5.45 < -3.45 fail**

- The variable now fails to exhibit unit root behavior as expected.

Results Summary:

Unit Root Test	**GDP**	**DOMESTIC**	**INTERNATIONAL**
RESULT	Exhibits unit root behavior.	Does not exhibit unit root behavior.	Does not exhibit unit root behavior.

GDP: Passed all three tests being observed with unit root behavior.
Domestic: The first model did not present evidence of unit root behavior.
International: Initially, the variable did exhibit unit root behavior but, after accounting for COVID, the variable was found to not exhibit unit root behavior.

Interpretation:

GDP: Exhibits unit root behavior. It can be concluded that GDP is stationary. It does not require that seasonality or trend be accounted for before being used.
Domestic: Does not exhibit unit root behavior (this data has a seasonal component.) It will need to have this seasonal component accounted for before it can be used.
International: Does not exhibit unit root behavior (this data has a seasonal component.) It will need to have this seasonal component accounted for before it can be used.

Deseasonalizing and Detrending the Data:

- The main takeaway from the unit root testing is that the domestic and international variables must be deseasonalized and detrended before they can be used to forecast.
- The secondary takeaway was that the GDP variable is already stationary and has no need to be deseasonalized or detrended.

Domestic and International:

For this paper's analysis, the domestic variable will be deseasonalized and detrended.

The main reason for this is that forecasting requires that the variables being used be stationary, which in their raw form they are not. Deseasonalizing/detrending the domestic variable will make it stationary and usable as a variable to forecast.

Secondary reasons include that excluding cyclical shocks (for example due to COVID and the “Great Recession”) both variables show clear signs of seasonality in their irrespective time series plots. Each variable has “good quarters” and “bad quarters.” A constant up and down cycle within each year separate from the variables suggests a somewhat consistent trend upwards.

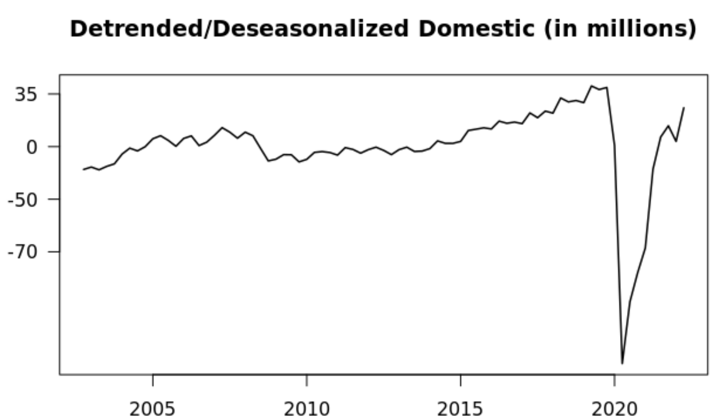
GDP:

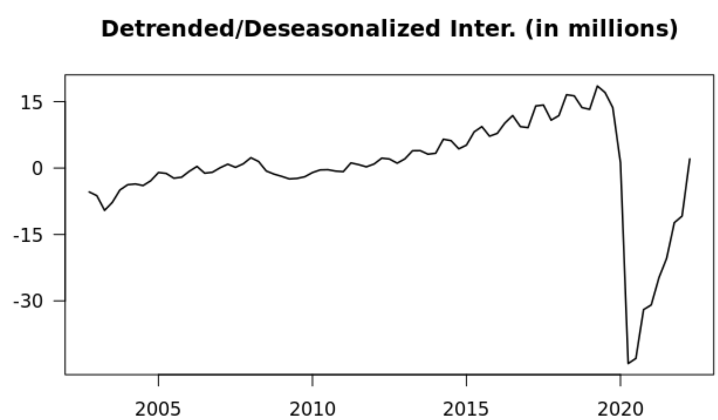
This variable is already stationary and, for this paper, will not be detrended or deseasonalized. This is clear from the unit root test and has been shown by others in the past to be true in most cases.

Deseasonalizing Process:

- The process used here is quite simple for both the domestic and international variables.
- Seasonal dummy variables are pulled out of either variable respectively and then used and regressed on the original time series data.
- This new time series is combined with a trended version of the original series.
- The combined time series is regressed on the original variable again.
- The final detrended and deseasonalized variable is the residuals of the final time series object.

Plots of the Deseasonalized/Detrended Variables:





Univariate Forecasts:

For the univariate forecasts, GDP is the main variable of interest. To forecast GDP, an auto-regressive moving averages (ARMA) model will be used.

Model Selection and Notable Changes:

One of the major differences that will be made will be the GDP data used. The data file that accompanies this paper contains GDP data from Q4 2002 up until Q2 2022. For the ARMA forecast, the entire FRED dataset (Q1 1947 through Q3 2022).

Lags:

The main issue in model selection for an ARMA model is how many lags to forecast with.

The standard practice seems to vary somewhat depending on various factors, but for this paper's ARMA selection, the number of lags that will be tested will be 1-5. The reason for this is 1-5 is the frequency plus 1, with a frequency of 4, as it is quarterly data.

The Akaike Information Criterion (AIC) will be used to find the best possible number of lags for the GDP ARMA model. In the test, the lag amount that returns the lowest AIC will be utilized to conduct the 13-step ARMA forecast on GDP.

Results of AIC Lag Test:

The first test returned 5 lag values for both sides of the ARMA model (as they provide the lowest AIC). For this forecast of GDP 5, AR and MA lags will be used.

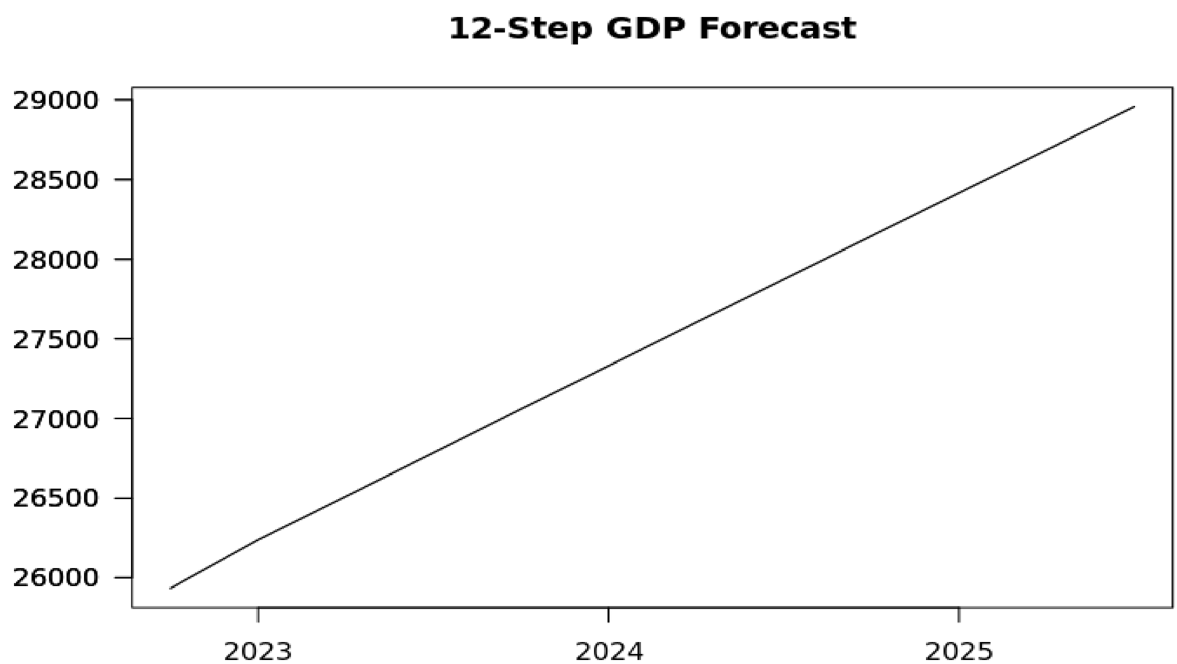
A side note: one of the tests for this model returns that the AR lags should be 0 and the MA lags should be 5, but the forecasts from this model are highly unrealistic. This test's suggestions will be ignored for these reasons.

12-Step GDP Forecast (in billions):

Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023	Q1 2024
25934.37	26238.58	26511.09	26784.04	27059.73	27330.29

Q2 2024	Q3 2024	Q4 2024	Q1 2025	Q2 2025	Q3 2025
27602.91	**27874.28**	**28145.21**	**28416.05**	**28686.28**	**28956.24**

Plot of 12-step GDP Forecast:



Multivariate Forecasts:
To perform a multivariate forecast on each variable, a VAR(p) model will be used.

Explain Model and selection

- For GDP, only one lag will be used.
- For Domestic and International 5 lags will be used.
- Each VAR model will have its lags as well as the lags of the other two variables.

12-Step Forecasts:

GDP (in billions):

Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023	Q1 2024
25471.19	**25707.56**	**25952.64**	**26212.69**	**26485.42**	**26770.26**

Q2 2024	Q3 2024	Q4 2024	Q1 2025	Q2 2025	Q3 2025
27066.47	**27373.25**	**27689.83**	**28015.59**	**28349.59**	**28691.58**

DOMESTIC (in millions):

Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023	Q1 2024
76	**139**	**200**	**254**	**289**	**317**
Q2 2024	**Q3 2024**	**Q4 2024**	**Q1 2025**	**Q2 2025**	**Q3 2025**
337	**340**	**316**	**256**	**152**	**3**

INTERNATIONAL (in millions):

Q4 2022	Q1 2023	Q2 2023	Q3 2023	Q4 2023	Q1 2024
30	**64**	**97**	**131**	**165**	**197**
Q2 2024	**Q3 2024**	**Q4 2024**	**Q1 2025**	**Q2 2025**	**Q3 2025**
222	**239**	**243**	**226**	**183**	**113**

Scenario Analysis on GDP:

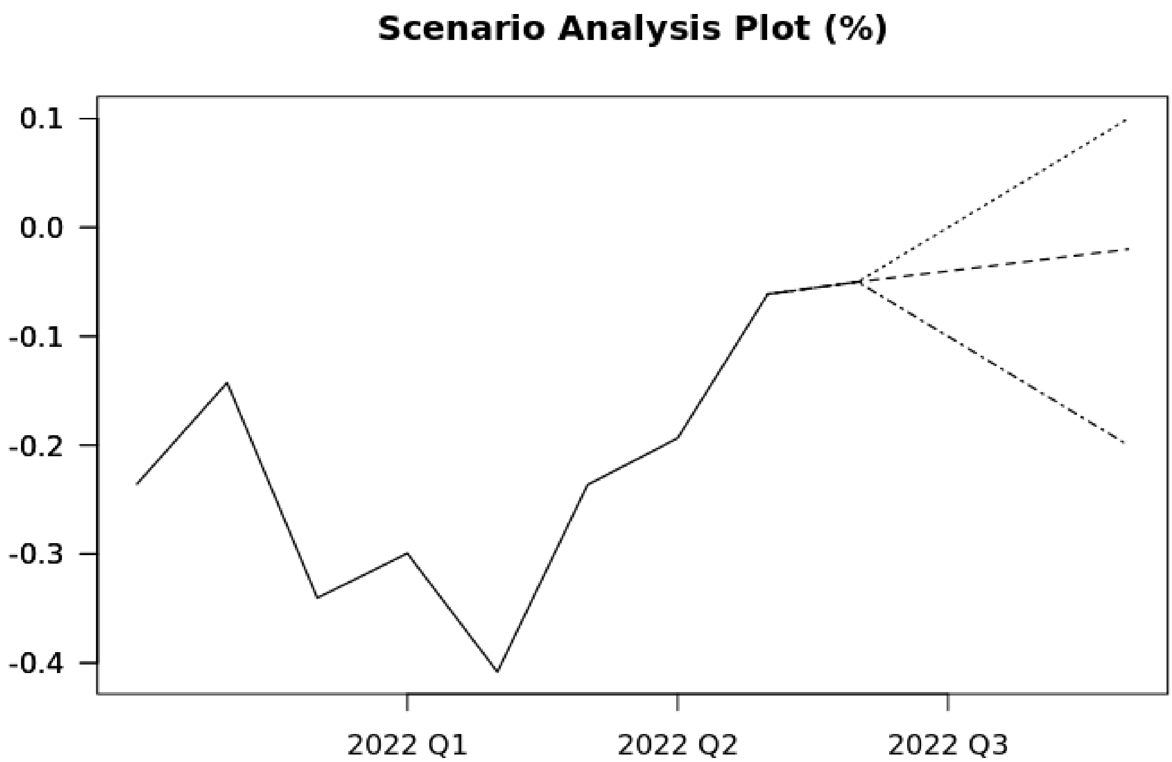
- This scenario analysis will see how GDP is expected to grow based on what might happen to domestic arrivals.
- Three different scenarios were chosen to test the effects of domestic arrivals on GDP growth.
- These three different scenarios will be used to forecast GDP in 3-steps to fully notice any valuable data.
- The domestic variable being used is the detrended/deseasonalized version and thus represents its cyclical component and is viable to be used in a VAR forecast
-

  The Scenarios:
- The first scenario chosen was testing when domestic arrivals had a 0% increase.
- The second scenario considers an 8% increase in domestic arrivals.
  - This number was chosen as it was a recurring percentage change from Q2-Q3 (which would be the first step in this instance).
- The third scenario tests the opposite of the second, with an 8% decrease.

Results:

Scenario Analysis	Step-1 Q3 2022	Step-2 Q4 2022	Step-3 Q1 2023
0% Increase	25537.53	25831.49	26130.45
8% Increase	25537.53	25820.28	26107.84
8% Decrease	25537.53	25842.71	26153.07

Scenario Analysis Plot:



Conclusion:

The main point of this paper was to analyze and see if the number of airline passengers in the United States was a good predictor of the United States' GDP.

The conclusion from the analysis conducted above must be inconclusive.

The data in its current form is only from the end of 2002 and is heavily affected by the drop in numbers from the COVID-19 pandemic. Having such a small dataset paired with such a dramatic shock makes it quite difficult to be used against a much cleaner and more lengthy dataset (GDP).