The Research and Forecasts on Real GDP Growth and the Unemployment Rate in the United States

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Abstract. Empirically, the real GDP growth rates and the unemployment rates are typically negatively correlated. From the post-COVID-19 era, countries around the world have not fully recovered from the pandemic. In this case, forecasts of GDP growth and unemployment rate are a vital reference for governments to recover economies in the future. This study collected the real GDP and unemployment rate data of the United States from 1948 to 2023, studied their relationship through linear and nonlinear regression, and predicted their future trends, respectively, with the ARIMA model. By comparing linear regression and nonlinear regression (locally estimated scatterplot smoothing) between the GDP growth rate and change in the unemployment rate, this study found that nonlinear regression can more accurately express the relationship between these two factors. The forecasts of GDP growth rates and unemployment rates provided by the ARIMA model show a relatively optimistic future with healthy GDP growth and low unemployment. However, wide ranges of confidence intervals also pointed to the danger of low GDP growth and widespread unemployment. The relationship between GDP and unemployment and their projections in this study serve as valuable references for future economic planning and incentive policies in the U.S. government. It may also be applicable to other countries that have similar economic conditions.

Keywords: GDP growth, Unemployment rate, Forecast, ARIMA model.

1. Introduction

1.1. Research Background and Significance

The two primary and frequently discussed variables in economics are GDP and jobs. In 1962, the economist Arthur Okun proposed the prestigious Okun's Law on GDP growth and unemployment rates. This law predicts that for every 2% decline in GDP, unemployment rises by 1% [1]. This theory has been around for more than 60 years. Thus, this law worked for the world economy of the 1960s, but may be outdated for the world economic environment of the 21st century. In the post-financial crisis of 2008 and the post-COVID-19 era, the relationship between GDP growth and unemployment may be different from what it was 60 years ago. In this case, it is necessary to re-examine the connection between the rate of growth in GDP and the unemployment rates through new forecasting models and theories. The relationship between these two variables and the forecast may provide a reference for countries around the world when formulating economic policies.

1.2. Literature Review

A number of studies have recognized that Okun's law is relatively outdated in the 21st century, as well as the small number of variables it considers and its geographical and temporal limitations. As a result, many studies have adopted new models and methodologies and added more variables to achieve a more accurate representation of the relationship between GDP and unemployment. The research by Francesco Bartolucci et al. added new variables based on the findings of Okun's Law, such as the estimation of the first difference relationship, the feasible lag effect of GDP dynamics on unemployment changes, etc., and adopted a new linear mixed-effects model for forecasting [2]. Stanislaw Gedek et al. used the stationarity test to find that the GDP and unemployment rate levels are not stationary and used the SUR method to estimate the theoretical model parameters [3].

Francesca Di Iorio and Umberto Triacca used a vector autoregressive model (VAR) to jointly model the growth rates of both GDP and unemployment [4].

In addition, recent studies have focused more on the country level to obtain expressions of GDP and unemployment that apply to specific countries rather than generalizing all countries as a whole. Ladislav Mura et al. focused their research on GDP and unemployment in Visegrad four countries of the Central European region [5]. Teboho Jeremiah Mosikari concentrated his studies on how unemployment affects South Africa's GDP [6].

1.3. Research Contents and Framework

This study first showcases the facts of the rate of growth in GDP and the rate of unemployment in the United States. Based on these data, this study generates a scatterplot and uses linear regression and nonlinear regression (locally estimated scatterplot smoothing) to explore the association between the GDP expansion rate and the rate of unemployment. The comparison of these two regressions shows that nonlinear regression is more suitable to reflect the relationship between these two variables. The ARIMA model is applied to forecast U.S. GDP growth and unemployment to the year 2030.

2. Method

For this study, the Federal Reserve Economic Data's (FRED, https://fred.stlouisfed.org/) quarterly real GDP data for the United States were chosen from the first quarter of 1948 to the second quarter of 2023 [7]. The rates of growth for quarterly real GDP are obtained by dividing the difference between the GDP in the current quarter and the GDP in the previous quarter by the previous quarter's GDP. The formula is as follows:

$$Quartly\ real\ GDP\ growth\ rate\ (\%) = \frac{Real\ GDP\ in\ current\ quarter - Real\ GDP\ in\ previous\ quarter}{Real\ GDP\ in\ previous\ quarter} \times 100 \quad (1)$$

In order to explore the relation between the real GDP growth rates and the unemployment rates in the United States of America, this study also selected data on the U.S. unemployment rate from FRED for the same time span. However, since unemployment rate data of the U.S. were collected on a monthly basis, this data has to be modified and converted to quarterly data to match the time scale of the GDP data. Therefore, the average of the U.S. unemployment rate from January to March is the U.S. unemployment rate for the first quarter. Similarly, the average U.S. unemployment rate from April to June is the U.S. unemployment rate for the second quarter. The rest can be done in the same manner.

The relationship between the rates of U.S. real GDP growth and the quarterly change in the rates of unemployment was presented in the form of scatterplots, a type of graph plotting the two variables against each other. Quarterly change in the unemployment rate was calculated by first differencing. Linear and nonlinear regression models were used to speculate on their relationship. Using these statistical regression models, this study examined the goodness of fit of linear and nonlinear regressions to discern which regression their relationship is more consistent with. The coefficient of determination R^2 and root mean square deviation (RMSE) were applied for linear regression to determine its goodness of fit. For nonlinear regression, only the RMSE was used to determine its goodness of fit because R^2 is a good indicator only for linear regression model.

This paper also forecasted the U.S. real GDP growth rate and the rate of unemployment. Therefore, the ARIMA model was used for forecasting. The advantage of ARIMA models is that they can account for a variety of trends, such as linear or non-linear trends, constant or changing variability, and non-seasonal and seasonal changes [8]. Due to the broad applicability of the ARIMA model, the ARIMA model can provide more accurate forecasts for time series of high variability, such as real GDP and the unemployment rate.

3. Results

3.1. Facts about GDP and Unemployment Rate in the United States

The GDP growth rate has fluctuated around one percent. In terms of the overall amplitude of fluctuation, the amplitude from 1948 to 1985 is larger than the amplitude from 1986 to 2023.

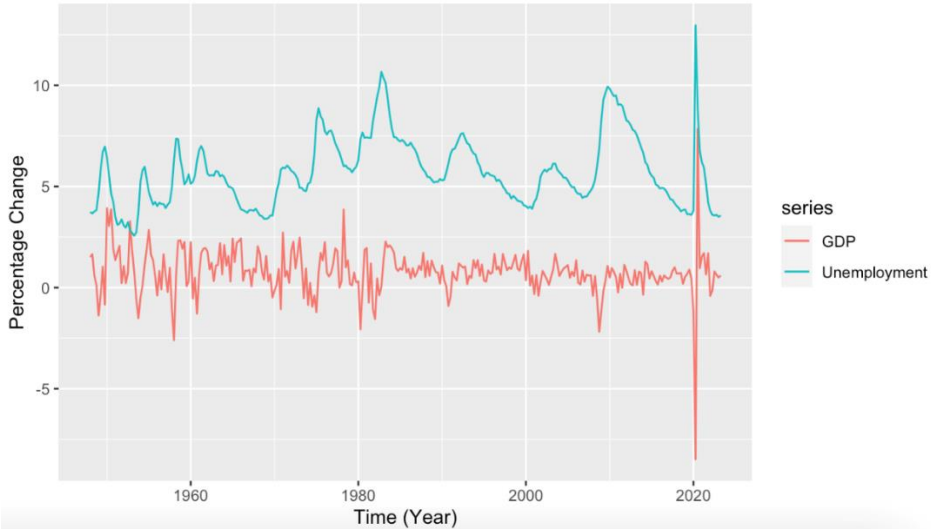


Fig. 1 GDP Growth Rate and Unemployment Rate

One very noticeable anomaly in Figure 1 is the extreme decline in GDP growth in 2020 to -8.5% and then the extreme rise to 7.5%. This considerable drop and rise correspond to the extremely rapid transmission of COVID-19 in the United States. The absence of understanding of the virus in the early stages of the worldwide COVID-19 pandemic outbreak forced the U.S. government to order a massive shutdown of stores, resulting in a sharp drop in GDP growth. However, with the advent of the vaccine, the spread of COVID-19 was contained. In this case, stores began to open, and the economy was relieved of the shock it had received under COVID-19. Unemployment rate hovers around 6 percent. Similar to the rate of real GDP growth, the sharp rise and fall in unemployment occurred in 2020 during the outbreak of COVID-19.

3.2. Linear Regression Between GDP Growth Rate and Change in the Rate of Unemployment

The linear regression model between the quarterly GDP growth rate and the quarterly changes in the unemployment rates shows a negative correlation.

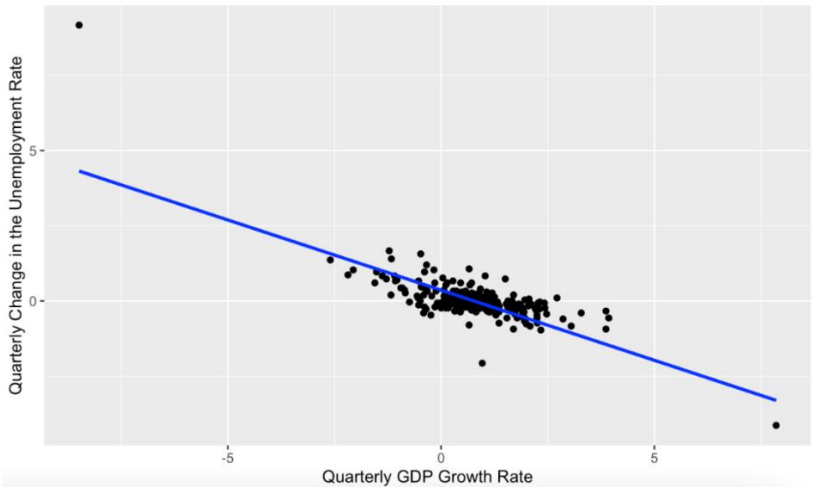


Fig. 2 Linear Regression for Quarterly GDP Growth Rate and Quarterly Change in the Rate of Unemployment

As shown in Figure 2, the unemployment rate falls by one percent for every two percent higher in GDP growth. The empirical relationship between unemployment and national production losses observed by Okun's law is that for every 1% increase in unemployment, GDP typically falls by 2% [1]. The linear regression model depicted in Figure 2 aligns with the predictions of Okun's law. The R^2 (R-squared) value for this linear regression is 0.575. In general, when the value of R^2 is greater than 0.8, the fit of the model is accurate enough to predict the relationship between two variables. However, 0.575 is smaller than 0.8. The Root Mean Square Error (RMSE) for this linear regression model is 0.459, which is a relatively high value. This high RMSE value suggests that the model's predictions are not fitting the data well. It indicates a lack of precision and accuracy in using linear regression to represent the connection between the GDP growth rate and the unemployment rate. Thus, it might be advisable to explore other modeling techniques or consider additional variables to achieve a more accurate understanding of this relationship.

3.3. Nonlinear Regression Between GDP Growth Rate and Change in the Unemployment Rate

This study employs a nonlinear regression to evaluate the correlation between the rate of GDP expansion and the change in the rate of unemployment since linear regression is unreliable.

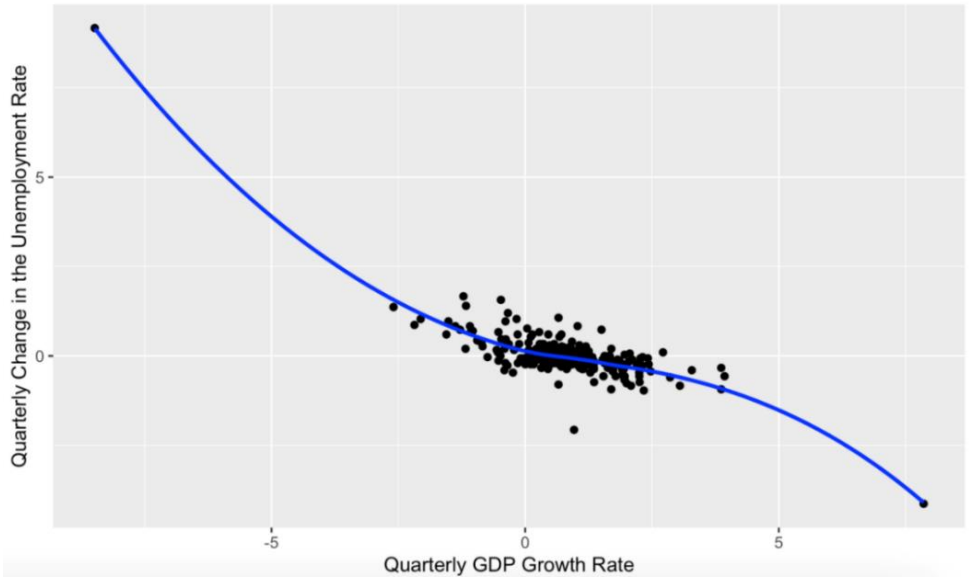


Fig. 3 Locally Estimated Scatterplot Smoothing for Quarterly GDP Growth Rate and Quarterly Change in the Unemployment Rate

Locally estimated scatterplot smoothing in Figure 3 considers the outliers. Compared to linear regression in Figure 2, this nonparametric smoothing method in Figure 3 is utilized to identify patterns or trends within a dataset without making assumptions regarding its underlying distribution or structure. The RMSE value for locally estimated scatterplot smoothing is 0.306, much lower than 0.459 of RMSE for the linear regression model. Therefore, this model can provide a more accurate representation of the association between real GDP growth and unemployment rates. This model also shows that their relationship is not simply linear. On the contrary, their relationship requires more complex models to be a more accurate expression.

3.4. Forecasts for Unemployment Rate by ARIMA Model

The unemployment rate is forecasted using the ARIMA (0,1,0) model.

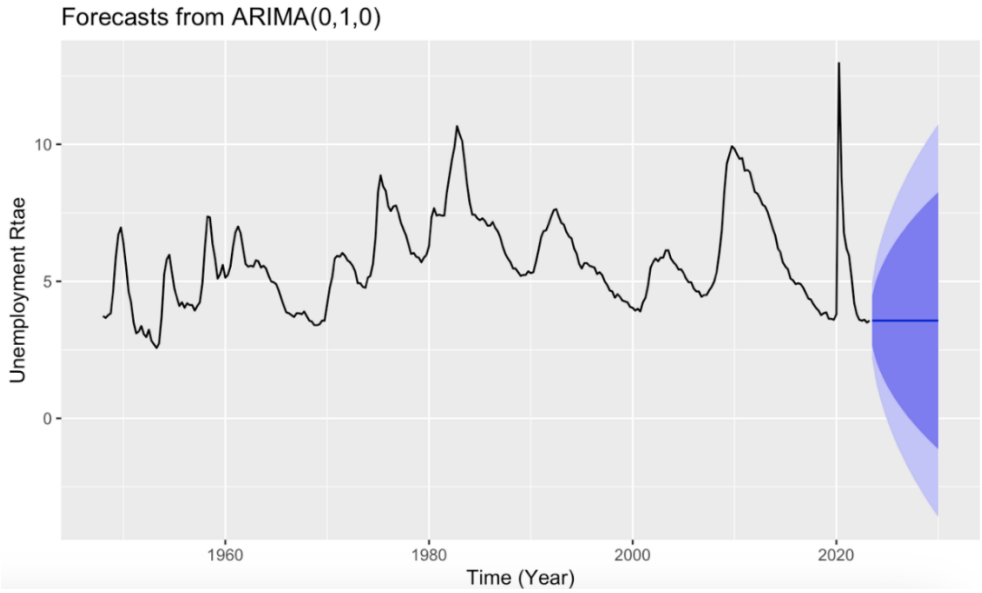


Fig. 4 Forecasts for Unemployment Rate

The point forecasts in Figure 4 show that the unemployment rate in the United States will be approximately 3.5% until 2030. This is an optimistic view that the economic conditions that have led to low unemployment will continue. However, the wide range of 80% and 95% confidence intervals reflects uncertainty about the future unemployment rate. It may reflect a complex relationship of factors in an enormous economy, including fiscal and monetary policy, technological change, global economic conditions, and other unpredictable factors.

3.5. Forecasts for Quarterly GDP Growth Rate by ARIMA Model

The GDP growth rate on a quarterly basis is forecasted using the ARIMA (0,1,2) model.

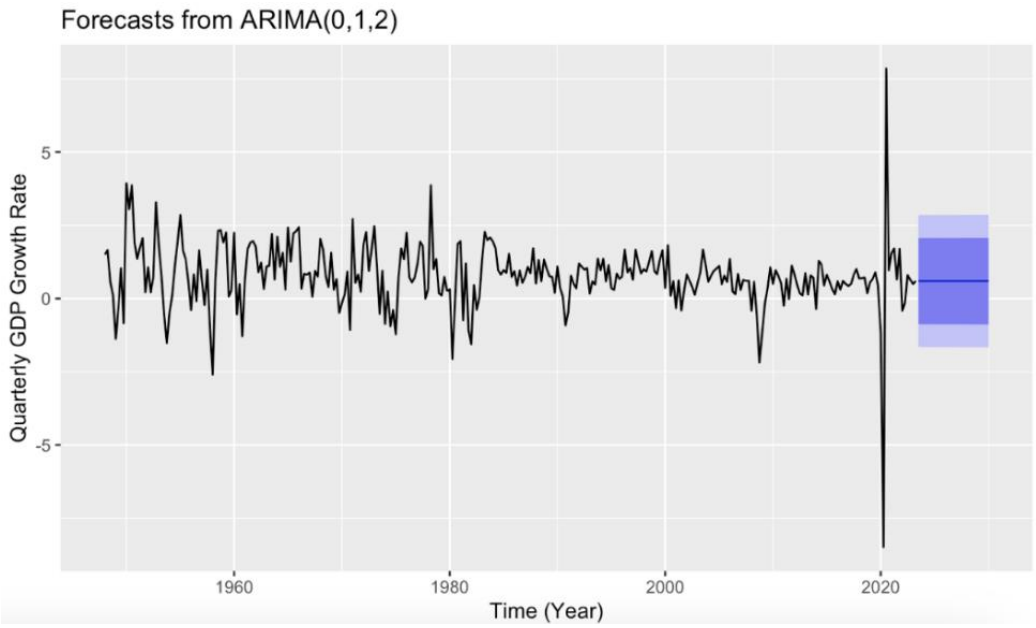


Fig. 5 Forecasts for GDP Growth Rate on a Quarterly Basis

The point forecasts in Figure 5 show that the real GDP growth rate in the United States will be approximately 0.6% until 2030. The range of confidence intervals do not widen over time. This is an unusual feature and may indicate that the model has found a remarkable underlying pattern in the

historical data. According to 95% confidence interval, GDP growth rate will be between 2.8% and -1.6%. There is a high probability that future GDP growth will fluctuate around 0.6% and will hardly be higher than 2.8%.

4. Discussion

The forecast for the unemployment rate in Figure 4 shows a stability of around 3.5%, indicating that the future job problems in the United States will be relative optimistic and the low unemployment economic conditions will continue. Meanwhile, Figure 5 also showcases a relatively optimistic result for the future GDP growth rate in the United States, indicating that the U.S. GDP will continue to grow. To maintain GDP growth and low unemployment rate, the U.S. government can invest in infrastructure and promote career training. Nevertheless, the wide range of 80% and 95% confidence intervals is also a warning of the possibility of extremely high unemployment and low GDP growth in the future. To further refine these forecasts, it is valuable to include other variables to consider or capture the dynamic association between unemployment, GDP, and other economic indicators. Factors such as the rate of inflation, interest rates or investment can have a huge impact on the unemployment rate and its trend [9]. The link between the rate of inflation and the rate of unemployment is demonstrated by the Phillips curve: As the rate of inflation rises, the rate of unemployment falls. This study only models the historical data of the unemployment rate and predicts the future trend, and does not take into account the impact of inflation or interest rate and other factors on the unemployment rate [10]. Therefore, including these factors into the study is a useful supplementary method to improve the prediction model and give more accurate prediction in the future research. This would allow policymakers and economists to prepare for a variety of potential future states, rather than relying solely on estimated points and intervals given by historical data. Additionally, forecasts of real GDP growth rate also fail to take into account other control variables. Investment, net exports, consumption and so on all have an impact on GDP. Therefore, in future studies, the model for predicting GDP growth rate should also become multi-variable.

5. Conclusion

Studies of GDP growth rates and unemployment rates produced the famous Okun's Law over 60 years ago. However, the world economic system has changed dramatically in the last 60 years. Hence, the study of GDP growth rate and unemployment rate needs to be updated with new theories and forecasting models. To study their relationship, this study uses linear regression and nonlinear methods to forecast the scatterplot of the GDP growth rate and unemployment rate in the United States. The ARIMA model is also used to forecast unemployment and GDP growth rates. The final finding is that nonlinear regression can more accurately express the relationship between them. In addition, the probability that GDP growth and unemployment rates will remain at healthy levels until 2030 is high, but the probability that catastrophically high unemployment and low GDP growth will occur also exists in the United States. This study is of great reference significance for the U.S. government and the Federal Reserve in formulating fiscal policy and monetary policy. It is also useful for policymakers in other countries with similar economic systems to the United States. This study has limitations in predicting future GDP growth and unemployment in the United States. The ARIMA model is not necessarily the best model for predicting these two variables. At the same time, the rate of GDP growth and unemployment are affected by factors such as the rate of inflation and the years of education of citizens. Therefore, the shortcoming of this study is that these control variables are not taken into account in the prediction of the model.

Future research on forecasting GDP growth and unemployment rates should add other control variables to the forecasting model. In this case, this study suggests using the vector autoregressive (VAR) model for prediction.

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