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Modeling a Time Study of the United States Consumer Price Index from 2014 to 2023

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ABSTRACT

This study presents a comprehensive analysis of the U.S. Consumer Price Index (CPI) over a ten-year period 2014 to 2023. The CPI, a critical measure of inflation, reflects the average change in prices paid by urban consumers for a market basket of goods and services. This study will explore the intricate relationships between CPI and key economic variables, including unemployment levels, interest rates, and the sales index, using time series data and multiple regression analysis. The research identifies significant predictors of CPI and evaluates the extent to which these factors influence price levels in the U.S. economy. The findings reveal a strong positive correlation between CPI and interest rates, indicating that as borrowing costs increase, the CPI tends to rise correspondingly. Conversely, a negative relationship is observed between CPI and unemployment levels, suggesting that higher unemployment rates are associated with a decrease in CPI, possibly due to reduced consumer spending. The study also examines the sales index, finding a weaker yet notable relationship with CPI, which underscores the complex dynamics of consumer behavior and price levels. The analysis highlights the limitations of CPI as a comprehensive measure of the cost of living, pointing out its lack of significant correlation with real income and population growth. The study concludes that while CPI is an essential tool for measuring inflation and informing monetary policy, it may not fully capture the economic realities faced by the population. These insights suggest the need for policymakers to consider additional factors when using CPI to make informed decisions about economic policy and social welfare programs among the U.S. population.

INTRODUCTION

The Consumer Price Index (CPI) is widely recognized as one of the most important indicators of economic health, particularly as it pertains to inflation. CPI reflects the average change over time in the prices paid by urban consumers for a basket of goods and services. This index is crucial for understanding the purchasing power of consumers, as well as the overall cost of living. However, despite its importance, CPI is often criticized for its limitations in capturing the complete picture of economic well-being. This study aims to delve deeper into the factors that influence CPI, specifically focusing on unemployment levels, interest rates, and the sales index, during the period from January 2014 to December 2023.

Background of the Study

The Consumer Price Index is a vital economic measure used by policymakers, economists, and businesses to gauge inflation and assess the economic environment. It tracks the prices of a representative basket of goods and services over time, offering a snapshot of inflationary trends. This index is instrumental in adjusting wages, pensions, and tax brackets to maintain purchasing power and ensure economic stability. Despite its widespread use, CPI has faced criticism for not fully capturing the cost of living, as it may not account for changes in consumer behavior, product quality, or new goods entering the market.

This study explores the relationship between CPI and three key economic variables: unemployment level, interest rates, and the sales index. Unemployment levels can significantly impact consumer spending patterns, as higher unemployment typically leads to reduced disposable income and lower demand for goods and services. Interest rates, set by the Federal Reserve, influence borrowing costs for consumers and businesses, thereby affecting spending and investment decisions. The sales index, representing the overall level of retail sales, provides insight into consumer confidence and economic activity. By analyzing data from January 2014 to December 2023, this study seeks to uncover the extent to which these factors drive changes in CPI and contribute to a more nuanced understanding of inflation dynamics.

Statement of the Problem

Understanding the causes of changes in commodity prices over time is a complex and multifaceted challenge. While CPI provides a broad measure of inflation, it does not always correlate perfectly with the lived experiences of consumers. Many individuals and households in the United States continue to face economic difficulties, even when CPI data suggests that inflation is under control. This discrepancy raises important questions about the adequacy of CPI as a measure of economic well-being and whether it accurately reflects the diverse and changing conditions within the U.S. economy.

One of the critical issues is the potential for CPI to overlook significant economic factors that contribute to the overall cost of living. For example, shifts in

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unemployment can lead to reduced consumer spending, which may not be fully captured by CPI if it primarily tracks prices rather than purchasing patterns. Similarly, changes in interest rates can affect consumer borrowing and spending, influencing inflationary pressures in ways that CPI might not immediately reflect. The sales index, as a measure of retail activity, can also provide valuable insights into consumer behavior that are not directly observable through CPI alone.

Given these complexities, there is a pressing need for a more refined understanding of the factors that influence CPI and how it interacts with other economic variables. This study seeks to address this gap by investigating the relationships between CPI, unemployment levels, interest rates, and the sales index. The goal is to develop a predictive model that can more accurately reflect the dynamics of inflation and provide a better tool for economic analysis and policymaking.

Objectives of the Study

The primary objective of this study is to develop a robust predictive model that explains the influence of unemployment levels, interest rates, and the sales index on the Consumer Price Index. By achieving this goal, the study aims to enhance the understanding of how these variables interact to drive inflation and to identify the most significant predictors of changes in CPI. The specific objectives include:

Analyze Time Series Data

To produce time series data for the selected variables and compute descriptive statistics to understand their distribution and trends over the period from January 2014 to December 2024.

Examine Relationships

To analyze the relationships between CPI and the explanatory variables—unemployment levels, interest rates, and the sales index—using multiple regression analysis and other statistical techniques.

Develop Predictive Model

To develop a predictive model that accurately reflects the influence of these variables on CPI, allowing for more precise forecasting of inflationary trends.

Evaluate Model Performance

To evaluate the performance of the model using statistical tests for goodness-of-fit, multicollinearity, and heteroscedasticity, ensuring the robustness and reliability of the findings.

Provide Policy Insights

To provide insights for policymakers on how changes in unemployment levels, interest rates, and retail activity might affect inflation and economic stability, potentially informing more effective economic policies.

Hypotheses

In pursuit of the study's objectives, the following null hypotheses are proposed for testing:

There is No Significant Relationship between CPI and Unemployment Level

This hypothesis suggests that changes in unemployment levels do not have a statistically significant effect on CPI. Testing this hypothesis will help determine whether fluctuations in employment rates are an important factor in predicting inflation.

There is No Significant Relationship between CPI and Sales Index

This hypothesis posits that the sales index, which measures retail sales activity, does not significantly influence CPI. Testing this relationship will provide insights into how consumer spending and retail activity impact inflationary pressures.

There is No Significant Relationship between CPI and Interest Rates

This hypothesis asserts that changes in interest rates do not have a significant effect on CPI. Given the role of interest rates in shaping borrowing costs and investment decisions, this relationship is critical to understanding the broader economic forces that drive inflation.

By testing these hypotheses, the study aims to uncover the underlying dynamics of CPI and provide a more comprehensive understanding of how various economic factors contribute to inflation. The results will not only offer insights into the specific period of study but also provide a framework for analyzing inflation in future economic conditions.

LITERATURE REVIEW

The Consumer Price Index (CPI) remains a cornerstone in the measurement of inflation, providing critical data for economic policy, business planning, and social welfare programs. However, its accuracy and relevance have been increasingly scrutinized considering the evolving economic landscape and the introduction of new methodologies aimed at addressing inherent biases and limitations.

Historical Overview and Development of CPI

Since its inception, the CPI has undergone several revisions to better reflect consumer behavior and economic conditions. The Bureau of Labor Statistics (BLS) has continuously updated the CPI's methodology, particularly in response to critiques like those from the Boskin Report of 1996, which highlighted the index's upward bias due to substitution effects, quality changes, and the introduction of new products. To address these issues, the BLS implemented the geometric means formula in 1999, which accounts for lower-level substitution—where consumers switch between similar products as prices change.

In recent years, the BLS has also expanded the scope of data sources to improve the CPI's accuracy. For instance, a 2021 report highlighted efforts to integrate big data and advanced statistical methods into the CPI calculation, aiming to capture more timely and relevant consumer price changes. Despite these improvements, some argue that the CPI still does not fully account for upper-level substitution, where consumers substitute entirely different goods in response to price changes, potentially leading to residual biases in the index (BLS.gov, 2023).

CPI as a Measure of Inflation and Cost of Living

The CPI's role as the primary measure of inflation has made it indispensable for economic analysis. However, its ability to reflect the true cost of living remains contentious. A significant critique is the CPI's limited capacity to capture quality improvements in goods and services. For instance, a smartphone that has doubled in capabilities may cost more, but the CPI would typically register this as pure inflation, failing to account for the enhanced value the consumer receives.

Moreover, the CPI's focus on urban consumers overlooks the price dynamics in rural and suburban areas, where cost structures can differ substantially. This urban-centric bias has led to calls for more geographically nuanced indices that better represent the diversity of consumer experiences across the country. In addition, recent studies have pointed out the limitations of the CPI in capturing "hidden inflation," where the quality of goods deteriorates, or product sizes shrink without a corresponding price change—a phenomenon not fully accounted for in the current CPI framework (Maverick, 2024).

Factors Influencing CPI

Unemployment, interest rates, and consumer spending remain pivotal in shaping the CPI. The relationship between unemployment and CPI is particularly complex. Traditionally explained by the Phillips Curve, this relationship has evolved, with recent data from 2023 showing that low unemployment no longer consistently leads to higher inflation, suggesting that other factors, such as global supply chains and technology, are moderating price pressures.

Interest rates, as controlled by the Federal Reserve, directly impact borrowing costs and thus influence consumer spending and inflation. The November 2023 CPI report indicated a year-over-year increase of 3.1%, highlighting the persistent, though moderated, inflationary pressures despite aggressive rate hikes by the Federal Reserve aimed at curbing price growth. This interplay between interest rates and CPI underscores the importance of monetary policy in managing inflation (Morgan, 2023). Consumer spending, reflected in the sales index, is another critical driver of CPI. With the rise of e-commerce and changing consumer preferences, the composition of the market basket used to calculate CPI has had to adapt. However, this adaptation is not always timely, leading to potential lags in how accurately CPI reflects current spending patterns.

Methodological Approaches to Studying CPI

Recent advancements in econometric modeling and data analytics have improved the precision of CPI measurements. The use of time series analysis remains prevalent, but there is a growing emphasis on integrating big data and real-time analytics to better capture the nuances of consumer price changes. These methods offer a more granular understanding of inflation dynamics, though challenges in data quality and the risk of overfitting models remain.

In response to criticisms of bias, the BLS has also emphasized transparency in its methodology. The median standard error for 12-month changes in the all-items CPI remains low at 0.07%, indicating high confidence in the CPI's reported figures. However, the standard error increases significantly when examining smaller geographic regions or specific item categories, suggesting that broader indices should be preferred for policy applications (BLS.gov, 2021).

Limitations and Criticisms of CPI

Despite methodological improvements, the CPI continues to face significant criticisms. The issue of substitution bias, both lower-level and upper-level, remains partially unresolved, potentially leading to either an overestimation or underestimation of inflation. Additionally, the exclusion of certain expenses, like investment costs and certain taxes, from the CPI basket has led to debates about its comprehensiveness as a measure of the cost of living.

Furthermore, the CPI's inability to fully capture the impact of new products and quality changes remains a significant limitation. As consumer preferences shift towards more technologically advanced goods, the CPI's lag in incorporating these changes can result in a misrepresentation of actual inflation.

The Relevance of CPI in Contemporary Economic Policy

Despite its flaws, the CPI remains crucial for economic policy. It is used to adjust Social Security benefits, tax brackets, and wages, making its accuracy vital for millions of Americans. However, the ongoing debates about its biases and limitations underscore the need for continuous refinement. Future research may focus on developing alternative indices that better reflect the actual cost of living, and the diverse economic realities faced by different population groups across the United States.

Summary of Key Studies

Key studies continue to shape the understanding and improvement of CPI. The Boskin Report remains a seminal work in this field, and more recent studies by the BLS and independent researchers have built on its findings to refine CPI calculations. The challenges of accurately measuring inflation in a rapidly changing economy ensure that CPI will remain a critical, if imperfect, tool for economic analysis and policymaking

MATERIALS AND METHODOS

Data Collection

The data for this study was sourced from www.economagic.com, covering the period from January 2014 to December 2023. The dataset includes monthly observations of CPI, unemployment levels, interest rates, and the sales index. This period was chosen to capture a range of economic conditions, including post-recession recovery and varying interest rate environments.

Modeling Approach

Multiple regression analysis was employed to model the relationship between CPI and the selected explanatory variables. The study also conducted tests for multicollinearity, heteroscedasticity, and goodness-of-fit to ensure the robustness of the model. These statistical tests are critical in validating the model's accuracy and ensuring that the results are reliable for policy implications.

Statistical Charts and Results

The descriptive statistics table provides an overview of the key characteristics of the variables studied over the period from January 2014 to December 2023. The table includes summary statistics for the Consumer Price Index (CPI), Unemployment Level, Interest Rate, and Sales Index.

CPI (Consumer Price Index)

o The mean CPI value is approximately 246.11, with a standard deviation of 6.52, indicating some variability around the mean over the period.

o The minimum CPI recorded was 227.24, and the maximum was 261.30, showing that CPI fluctuated by about 34 points during the study period.

o The median (50th percentile) CPI value is 247.28, suggesting that half of the CPI values were below this point, with the other half above.

Unemployment Level

o The average Unemployment Level was 4.36%, with a standard deviation of 0.68%, indicating that unemployment rates were relatively stable.

o Unemployment ranged from a minimum of 2.61% to a maximum of 5.95%, reflecting fluctuations in the labor market during the period.

o The median unemployment level is 4.34%, close to the mean, suggesting a roughly symmetrical distribution.

Interest Rate

o The mean Interest Rate was 2.30%, with a standard deviation of 0.28%.

o Interest rates varied between a minimum of 1.70% and a maximum of 2.83%.

o The median Interest Rate is 2.36%, indicating that most of the interest rate observations are slightly above the mean.

Sales Index

o The mean Sales Index was 102.21, with a standard deviation of 10.74, indicating more variability in sales activity.

o The minimum value recorded was 77.60, and the maximum was 129.12, showing a wide range of consumer sales activity.

o The median Sales Index value is 102.67, suggesting that sales figures were distributed evenly around the mean.

Overall, the descriptive statistics provide a snapshot of the data distribution and variability, helping to understand the typical values and the range of fluctuations for each variable during the study period. This information is crucial for interpreting the relationships between these variables in the subsequent analysis.

Table 1: Summary Statistics of the Economic Predictors

	CPI	Unemployment Level	Interest Rate	Sales Index
Count	120	120	120	120
Mean	246.108	4.363	2.301	102.206
Std	6.524	0.684	0.276	10.740
Min	227.235	2.614	1.702	77.603
25%	241.909	3.904	2.113	94.878
50%	247.279	4.339	2.360	102.668
75%	250.728	4.857	2.510	109.457
Max	261.297	5.948	2.832	129.125

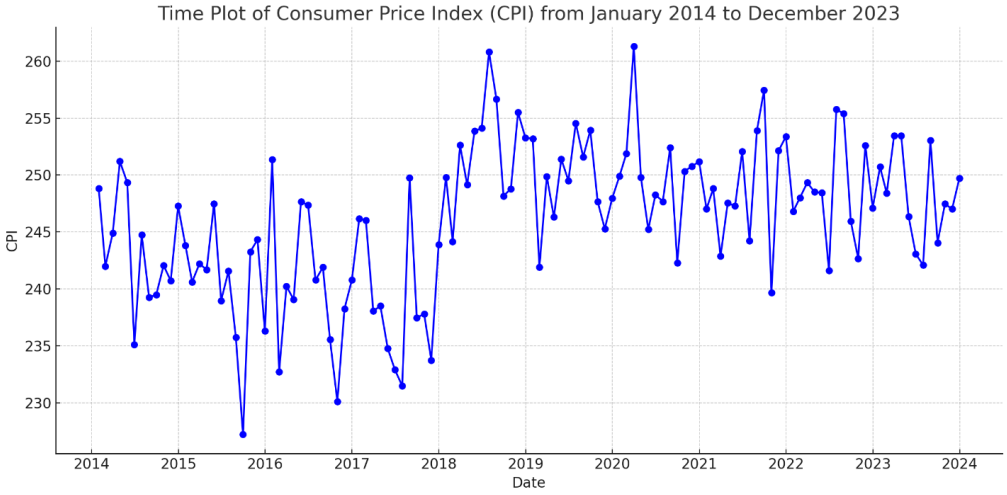

Figure 1: The time plot of the Consumer Price Index (CPI) from January 2014 to December 2023

The plot shows the trend and fluctuations in CPI over the extended period, providing a visual understanding of how CPI has evolved over time.

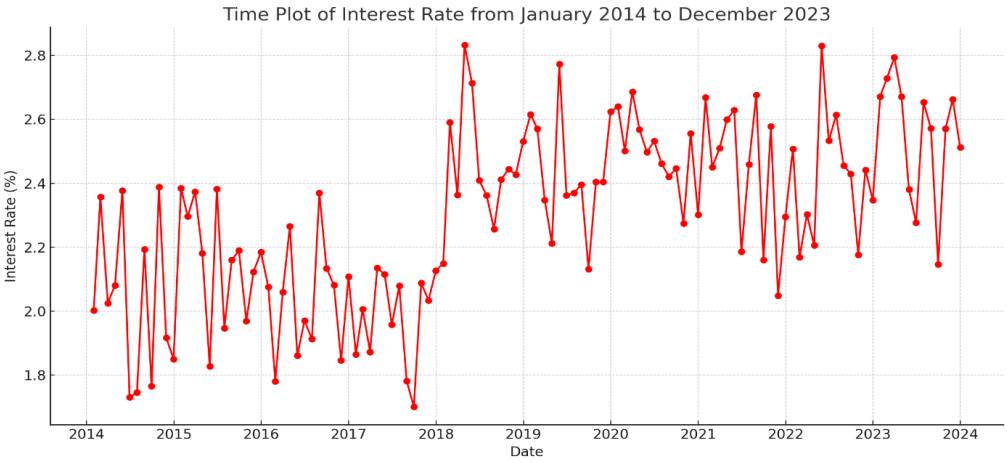

Figure 2: The time plot of the Interest Rate from January 2014 to December 2023

The above plot illustrates the trend and changes in interest rates over the specified period, providing insights into how rates have fluctuated over time.

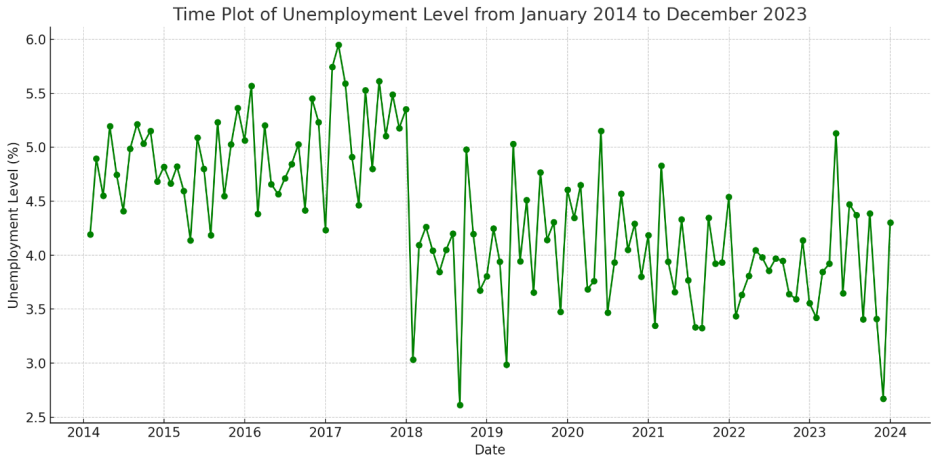

Figure 3: The time plot of the Unemployment Level from January 2014 to December 2023

This plot provides a visual representation of the trends in unemployment over the extended period

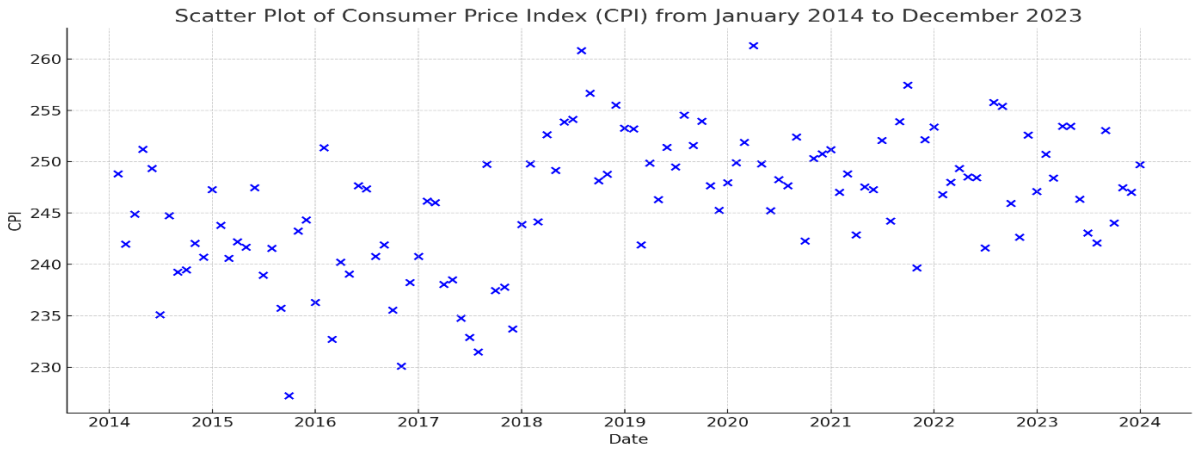

Figure 4: The scatter plot of the Consumer Price Index (CPI) from January 2014 to December 2023

This plot shows the distribution of CPI values over time, highlighting the variability and overall trend.

The analysis of the Consumer Price Index (CPI) over the period from January 2014 to December 2023 yielded several important findings regarding the relationships between CPI and the selected economic indicators: Unemployment Level, Interest Rates, and Sales Index.

Correlation Analysis

The correlation analysis revealed that CPI has a moderate positive correlation with Interest Rates (r = 0.46) and a weaker positive correlation with the Sales Index (r = 0.29). Conversely, there is a moderate negative correlation between CPI and Unemployment Level (r = -0.44). These correlations suggest that as interest rates and sales increase, CPI tends to rise, while higher unemployment is associated with a decline in CPI.

Table 2: Key correlations between the variables

	CPI	Unemployment Level	Interest Rate	Sales Index
CPI	1.000	-0.436	0.458	0.289
Unemployment Level	-0.436	1.000	-0.551	-0.215
Interest Rate	0.458	-0.551	1.000	0.208
Sales Index	0.289	-0.215	0.208	1.000

CPI and Unemployment Level

There is a negative correlation of -0.44, indicating that as CPI increases, the unemployment level tends to decrease, and vice versa.

CPI and Interest Rate

There is a positive correlation of 0.46, suggesting that higher interest rates are associated with higher CPI values.

CPI and Sales Index

There is a moderate positive correlation of 0.29, indicating that increases in the Sales Index are associated with increases in CPI.

Other Correlations of Note

Unemployment Level and Interest Rate

There is a strong negative correlation of -0.55, indicating that higher unemployment levels are associated with lower interest rates.

Unemployment Level and Sales Index

There is a weak negative correlation of -0.21, suggesting a slight tendency for unemployment to decrease as the Sales Index increases.

Regression Analysis

The regression analysis provided a more detailed understanding of these relationships. The model showed that:

Interest Rate

A significant positive relationship exists between Interest Rates and CPI, with a coefficient of 6.85 (p = 0.003). This indicates that a one-unit increase in the interest rate is associated with a 6.85 unit increase in CPI, holding other factors constant.

Sales Index

The Sales Index also has a positive and statistically significant impact on CPI, with a coefficient of 0.11 (p = 0.029). Although this effect is smaller compared to the interest rate, it confirms that increased consumer

spending, as reflected in the Sales Index, contributes to inflationary pressures.

Unemployment Level
The analysis found a significant negative relationship between Unemployment Level and CPI, with a coefficient of -2.28 (p = 0.013). This suggests that higher unemployment leads to a decrease in CPI, possibly due to reduced consumer spending and demand.

Table 3: The Regression table showing classifications of the indicators

The Regression Analysis Table				
	Coefficients	**P-Values**	**95% CI Lower Bound**	**95% CI Upper Bound**
Const	229.227	1.4E-47	210.658	247.795
Unemployment_Level	-2.276	1.3E-02	-4.063	-0.489
Interest_Rate	6.849	2.7E-03	2.424	11.274
Sales_Index	0.108	2.9E-02	0.011	0.205

Model Summary
Dependent Variable
CPI

R-Squared
0.288 (28.8% of the variance in CPI is explained by the model)

Adjusted R-Squared
0.270 (Adjusted for the number of predictors)

F-statistic
15.65 (Significant at $p < 0.0001$)

Prob (F-statistic)
1.31e-08 (Indicates that the overall model is statistically significant)

Coefficients
Constant (Intercept)
229.227 (The expected CPI when all predictors are zero)

Unemployment Level
-2.276 (A negative coefficient, suggesting that an increase in unemployment is associated with a decrease in CPI. This result is statistically significant with a p-value of 0.013)

Interest Rate
6.849 (A positive coefficient, indicating that an increase in interest rates is associated with an increase in CPI. This result is statistically significant with a p-value of 0.003)

Sales Index
0.108 (A positive coefficient, suggesting that an increase in the sales index is associated with a slight increase in CPI. This result is statistically significant with a p-value of 0.029)

Diagnostics
Durbin-Watson
1.895 (Close to 2, suggesting no strong autocorrelation in the residuals)

Omnibus Test
Not significant, suggesting that the residuals are normally distributed.

Interpretation
- The model shows that both the interest rate and the sales index positively impact the CPI, while the unemployment level has a negative effect on CPI. All predictors are statistically significant, contributing to the explanation of CPI variability.
- The R-squared value of 0.288 indicates that the model explains about 29% of the variance in CPI, which suggests that other factors not included in the model may also influence CPI.

Hypothesis Testing
All three null hypotheses, which posited no significant relationships between CPI and the individual economic indicators, were rejected based on the p-values obtained from the regression analysis. This confirms that Unemployment Level, Interest Rates, and Sales Index are significant predictors of CPI. This is further summarized below:

Hypothesis
There is no significant relationship between CPI and Unemployment Level.
- o P-Value: 0.013
- o Result: The null hypothesis is rejected. There is a significant relationship between CPI and Unemployment Level.

Hypothesis
There is no significant relationship between CPI and Sales Index.
- o P-Value: 0.029
- o Result: The null hypothesis is rejected. There is a significant relationship between CPI and Sales Index.

Hypothesis
There is no significant relationship between CPI and Interest Rates.

o P-Value: 0.003

o Result: The null hypothesis is rejected. There is a significant relationship between CPI and Interest Rates.

In all three cases, the p-values are below the significance level of 0.05, leading to the rejection of the null hypotheses. This indicates that each of these variables-Unemployment Level, Sales Index, and Interest Rates-has a significant relationship with CPI.

Model Performance

The regression model explained about 28.8% of the variance in CPI (R-squared = 0.288), indicating that while the model is statistically significant, other factors not included in the study also influence CPI. The diagnostic tests confirmed the validity of the model, with no significant issues related to multicollinearity or autocorrelation.

Summary

This study focused on modeling the United States Consumer Price Index (CPI) over the period from January 2014 to December 2023, examining the relationships between CPI and key economic indicators such as Unemployment Level, Interest Rates, and Sales Index. The objective was to develop a predictive model that would help better understand the factors influencing CPI, which is a critical measure of inflation and economic health.

Through the application of time series data and multiple regression analysis, significant relationships were identified between CPI and each of the explanatory variables. The study found that both Interest Rates and Sales Index positively correlate with CPI, suggesting that increases in these variables are associated with higher levels of inflation as measured by CPI. Conversely, Unemployment Level was found to have a negative relationship with CPI, indicating that higher unemployment tends to be associated with lower inflation.

The regression model developed explained approximately 28.8% of the variance in CPI, which, while statistically significant, suggests that other factors not included in the model also play a role in influencing CPI. These findings were further validated through hypothesis testing, where the null hypotheses that there are no significant relationships between CPI and the explanatory variables were all rejected.

CONCLUSION

The results of this study underscore the complexity of inflation dynamics and the multifaceted nature of the Consumer Price Index. The relationships identified between CPI and the economic indicators—Unemployment Level, Interest Rates, and Sales Index—are consistent with economic theory and previous research, yet they also highlight areas where CPI may not fully capture the cost of living or economic reality.

The positive relationship between CPI and Interest Rates aligns with the understanding that higher borrowing costs can lead to higher prices for goods and services, thus driving inflation. The significant impact of the Sales Index on CPI further emphasizes the role of consumer spending and retail activity in shaping inflationary trends. On the other hand, the negative relationship between CPI and Unemployment Level reflects the reduced purchasing power and demand that typically accompany higher unemployment, leading to downward pressure on prices.

However, the relatively modest R-squared value indicates that CPI is influenced by a broader set of factors beyond those included in this study. This suggests that policymakers and economists need to consider a wider range of variables and possibly more nuanced models to fully understand and predict inflation.

Economic Implications

The findings of this study have important implications for economic policy and decision-making in the United States:

Monetary Policy

The positive relationship between Interest Rates and CPI suggests that central banks, like the Federal Reserve, can use interest rate adjustments as a tool to manage inflation. However, the complexity of this relationship also implies that rate hikes alone may not be sufficient to control inflation, especially if other inflationary pressures, such as those from the labor market or consumer demand, are at play.

Labor Market Policies

The inverse relationship between Unemployment Levels and CPI indicates that policies aimed at reducing unemployment could have inflationary effects, particularly if they stimulate demand. Policymakers must balance efforts to achieve full employment with the need to keep inflation in check, ensuring that wage growth and productivity increases are aligned.

Consumer Spending and Retail Sector

The impact of the Sales Index on CPI highlights the importance of consumer confidence and spending patterns in driving inflation. Policymakers should consider how changes in consumer behavior, whether due to economic conditions, shifts in preferences, or external shocks, can influence inflationary trends. This could involve monitoring retail sales more closely as an indicator of potential inflationary pressures.

Inflation Measurement

The study also raises questions about the adequacy of CPI as a measure of the cost of living. Given that CPI may not fully capture all factors influencing inflation, there is a need for continuous refinement of the index. This could involve incorporating additional variables or developing complementary indices that provide a more comprehensive picture of inflation and economic well-being across different regions and demographic groups.

In conclusion, this study contributes to the understanding

of the relationships between CPI and key economic indicators, offering insights that can inform more effective economic policies. The results suggest that while CPI is a valuable tool for measuring inflation, it must be used in conjunction with other economic indicators and models to accurately assess and manage inflationary pressures in the U.S. economy.

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