The Impact of Macroeconomic Variables on U.S. Treasury Yield Curves: An Analysis Using the Extended Nelson-Siegel Model

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1. Introduction

The modeling and analysis of the yield curve are essential to understanding the term structure of interest rates, a topic of significant interest in both academic and practical financial fields. The yield curve's shape, reflecting expectations of future interest rates, economic activity, and inflation, is influenced by numerous macroeconomic factors. The Nelson-Siegel model and its extensions have emerged as robust frameworks for modeling the yield curve due to their ability to capture its level, slope, and curvature.

This paper aims to explore the relationship between macroeconomic variables and the yield curve by applying an extended version of the Nelson-Siegel model to U.S. Treasury yields across various maturities. Specifically, the yield curves for maturities of 1, 2, 5, 10, 20, and 30 years are analyzed in conjunction with macroeconomic indicators, including the Federal Funds Rate (FEDFUNDS), unemployment rate (UNRATE), gross domestic product (GDP), and inflation. The analysis will provide insights into how these macroeconomic factors correlate with the short-, medium-, and long-term segments of the yield curve.

The literature surrounding yield curve modeling has evolved to incorporate diverse approaches, from parsimonious models like the traditional Nelson-Siegel to more complex frameworks, including time-varying parameter models and arbitrage-free extensions (Christensen et al., 2011). In addition, global yield curve dynamics, as studied by Diebold and Li (2006), suggest that macroeconomic conditions have significant impacts on the level, slope, and curvature factors of yield curves. This paper builds upon these foundational studies and integrates the analysis of macroeconomic variables with the Nelson-Siegel framework.

The relationship between macroeconomic indicators and yield curves has been examined in various contexts. For instance, macroeconomic factors such as inflation and interest rates have consistently shown strong correlations with the yield curve's behavior (Christensen and

Diebold, 2008). This study extends the existing literature by applying a straightforward regression analysis to identify the correlations between the aforementioned macroeconomic variables and the estimated yield curves for different maturities. The results are interpreted in light of existing research to contribute to a clearer understanding of how short- and long-term economic expectations manifest in interest rate movements.

The following sections of the paper are structured as follows: Section 2 presents the data and methodology, including the extended Nelson-Siegel model and macroeconomic indicators employed. Section 3 discusses the regression results for each maturity segment of the yield curve. The implications of the findings are elaborated in Section 4, while Section 5 concludes the study and suggests directions for future research.

2. Data and Methodology

Data Description

The dataset employed in this study comprises monthly observations spanning from January 1996 to April 2024. It includes U.S. Treasury yields for maturities of 1, 2, 5, 10, 20, and 30 years and macroeconomic variables such as the Federal Funds Rate (FEDFUNDS), the unemployment rate (UNRATE), gross domestic product (GDP), and inflation. Table 1 presents the summary statistics of the data.

Table 1: Summary Statistics of Macroeconomic Variables and Yields

Variable	Mean	Std Dev	Min	Max	Skewness	Kurtosis
FEDFUNDS	2.34	2.21	0.05	6.54	0.45	-1.44
UNRATE	5.63	1.95	3.40	14.80	1.65	3.57
GDP	2.60	4.88	-28.10	35.20	0.29	30.64
Inflation	218.39	40.95	154.70	313.21	0.36	-0.56
1Y Yield	2.44	2.11	0.06	6.15	0.39	-1.43
2Y Yield	2.64	2.04	0.13	6.45	0.39	-1.28
5Y Yield	3.14	1.78	0.28	6.76	0.31	-1.02
10Y Yield	3.65	1.56	0.62	6.89	0.17	-0.85
20Y Yield	4.16	1.54	1.06	7.20	0.03	-0.97
30Y Yield	4.20	1.40	1.27	7.09	0.02	-0.85

The dataset encapsulates periods of significant economic changes, including financial crises and policy shifts, allowing for an analysis of how macroeconomic conditions correlate with yield curve variations.

Stationarity of the Data

An Augmented Dickey-Fuller (ADF) test was conducted on the raw data to determine stationarity. The results indicated that the macroeconomic variables and yields were non-stationary, with test statistics above the critical values at 5% significance levels. To address

this, first differences were applied to the data, rendering the time series stationary and suitable for further analysis.

Methodology

This study applies the Nelson-Siegel model, a popular parametric approach for modeling the term structure of interest rates due to its ability to capture different shapes of yield curves, including upward-sloping, downward-sloping, and humped curves. The model expresses the yield at any given maturity τ as:

$$y(\tau) = \beta_0 + \beta_1 \frac{1 - e^{-\lambda\tau}}{\lambda\tau} + \beta_2 \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau} \right)$$

where:

- β0 represents the long-term level of interest rates (level factor),
- β1 captures the short-term component (slope factor),
- β2 accounts for the medium-term curvature,
- λ is the decay factor influencing the exponential decay of the slope and curvature.

The Nelson-Siegel model's flexibility stems from its ability to fit various yield curve shapes with only a few parameters, making it well-suited for empirical analyses of bond market data.

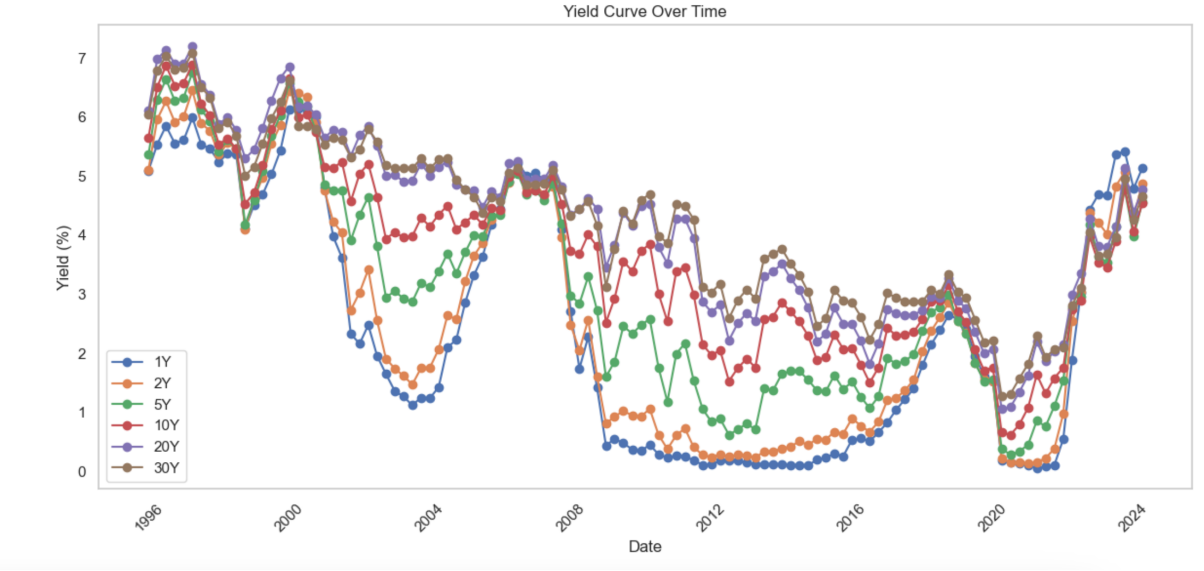
In extending the basic Nelson-Siegel framework, this study incorporates macroeconomic variables into the analysis to assess their correlation with yield curve components. This is motivated by findings from studies such as Diebold and Li (2006), which highlight the importance of macroeconomic factors like inflation and monetary policy in influencing the yield curve dynamics.

The regression analysis is conducted separately for each maturity, where the dependent variable is the yield at a given maturity (e.g., 1Y, 2Y, etc.), and the independent variables are FEDFUNDS, UNRATE, GDP, and inflation. Ordinary least squares (OLS) is used to estimate

the coefficients, providing a straightforward examination of how each macroeconomic variable correlates with different parts of the yield curve.

Exploratory Data Analysis

To better understand the dataset, Figure 1 below shows the yield curves over different periods. These plots highlight the variations and shifts in the shape of the yield curves, reflecting different economic conditions.



3. Results

This section presents the empirical findings from the application of the extended Nelson-Siegel model and the analysis of macroeconomic factors on the U.S. Treasury yield curves for various maturities. The primary objective is to assess the correlation between macroeconomic variables and yield curve shifts across different maturities.

3.1. Regression Analysis for Yield Curves

The results of the Ordinary Least Squares (OLS) regression analyses are summarized in Tables 2 through 4. The dependent variables are the yield levels for different maturities, while the independent variables include the Federal Funds Rate (FEDFUNDS), unemployment rate (UNRATE), GDP, and inflation.

Table 2: OLS Regression Results for 1-Year Yield (Short-Term)

Variable	Coefficient	Std. Error	t-Statistic	P-value
Constant	-0.0701	0.047	-1.492	0.139
FEDFUNDS	0.7245	0.069	10.563	0.000
UNRATE	-0.0013	0.039	-0.034	0.973
GDP	-0.0008	0.009	-0.088	0.930
Inflation	0.0528	0.019	2.733	0.007

R-squared: 0.614, Adjusted R-squared: 0.600

For the 1-year yield, the Federal Funds Rate and inflation have significant positive coefficients, indicating that higher short-term interest rates and inflation are associated with increased yields. The unemployment rate and GDP do not exhibit significant effects in this maturity segment.

Table 3: OLS Regression Results for 10-Year Yield (Medium-Term)

Variable	Coefficient	Std. Error	t-Statistic	P-value
Constant	-0.1510	0.064	-2.377	0.019
FEDFUNDS	0.1658	0.093	1.786	0.077

Variable	Coefficient	Std. Error	t-Statistic	P-value
UNRATE	-0.0171	0.052	-0.327	0.744
GDP	0.0006	0.013	0.046	0.963
Inflation	0.0996	0.026	3.807	0.000

R-squared: 0.218, Adjusted R-squared: 0.189

The results for the 10-year yield reveal that inflation continues to exert a significant positive effect, consistent with findings from previous studies (e.g., Diebold et al., 2008) that show inflation's impact on the level factor of the yield curve. The Federal Funds Rate shows a diminishing effect on medium-term yields compared to short-term yields.

Table 4: OLS Regression Results for 30-Year Yield (Long-Term)

Variable	Coefficient	Std. Error	t-Statistic	P-value
Constant	-0.1424	0.056	-2.557	0.012
FEDFUNDS	0.0929	0.081	1.143	0.256
UNRATE	-0.0179	0.046	-0.392	0.696
GDP	0.0003	0.011	0.024	0.981
Inflation	0.0922	0.023	4.020	0.000

R-squared: 0.206, Adjusted R-squared: 0.177

For the 30-year yield, inflation remains the dominant macroeconomic factor, indicating its sustained influence on long-term expectations of interest rates. The Federal Funds Rate, however, becomes insignificant, aligning with insights from studies such as Diebold and Li (2006), which suggest that short-term policy rates have less impact on long-term yield segments.

Across all maturity segments, inflation consistently exhibits a significant positive correlation with yields, highlighting its critical role in shaping the yield curve. The influence of the Federal Funds Rate is strong in short-term yields but diminishes in longer maturities. Unemployment and GDP do not show significant relationships, suggesting that other macroeconomic or structural factors might better explain movements in medium- and long-term yields.

These findings align with the conclusions drawn by Christensen et al. (2011), which emphasize the importance of inflation and monetary policy in explaining yield curve variations. The extended Nelson-Siegel model used in this study reaffirms the observations by Diebold et al. (2008) regarding macroeconomic influences on the level, slope, and curvature factors of the yield curve.

4. Conclusion

This study set out to investigate the relationship between macroeconomic variables and U.S. Treasury yield curves using the Nelson-Siegel model, extended to incorporate macroeconomic factors. Through the analysis of monthly data spanning from January 1996 to April 2024, we assessed the impact of variables such as the Federal Funds Rate, unemployment rate, GDP, and inflation on yield curves across short-, medium-, and long-term maturities.

Our results reveal that inflation consistently plays a significant role across all segments of the yield curve, confirming its critical influence on interest rate expectations and aligning with previous literature such as the studies by Diebold and Li (2006) and Christensen et al. (2011). The Federal Funds Rate also shows a substantial effect on short-term yields but diminishes in importance for longer maturities. This diminishing influence supports the theory that while monetary policy heavily impacts short-term rates, long-term yields are driven more by long-term inflation expectations and other structural factors.

The findings show that unemployment and GDP do not exert significant direct effects on the yields, suggesting that these macroeconomic indicators might influence yield curve behavior indirectly or in conjunction with other variables not captured in this analysis. This aligns with the results of prior research emphasizing the dominant roles of inflation and monetary policy in yield curve dynamics.

This study contributes to the understanding of how key macroeconomic variables correlate with different segments of the yield curve, providing insights that can inform investment strategies and policy analysis. However, it also highlights areas for further exploration, such as the potential inclusion of other macroeconomic or market sentiment indicators that could affect medium- and long-term yields.

Future research could build on this analysis by incorporating more advanced models, such as dynamic versions of the Nelson-Siegel model with time-varying parameters or models that integrate additional macroeconomic variables and global economic factors.

In conclusion, the extended Nelson-Siegel model proved to be an effective tool for analyzing the relationship between macroeconomic variables and the term structure of interest rates,

reaffirming the significant role of inflation and monetary policy in shaping yield curves and supporting the findings from existing literature.

5. References

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