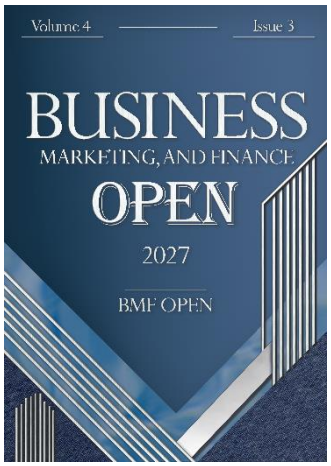
A Meta-Synthesis of Studies on Forecasting the Yield Curve of Islamic Treasury Bills in the Iranian Economy and the Development of a Conceptual Forecasting Framework

Maryam Haghparast [1], Ali Saeedi [2,*] and Moslem Peymany Foroushani [3]



[1] Department of Financial Management, NT.C., Islamic Azad University, Tehran, Iran;
[2] Department of Financial Management, NT.C., Islamic Azad University, Tehran, Iran;
[3] Associate Professor, Department of Finance and Banking, Allameh Tabataba'i University, Tehran, Iran;

* Correspondence: a_saeedi@iau.ac.ir

Citation: Haghparast, M., Saeedi, A., & Peymany Foroushani, M. (2027). A Meta-Synthesis of Studies on Forecasting the Yield Curve of Islamic Treasury Bills in the Iranian Economy and the Development of a Conceptual Forecasting Framework. *Business, Marketing, and Finance Open*, 4(3), 1-18.

Received: 20 February 2026
Revised: 10 June 2026
Accepted: 17 June 2026
Initial Publication: 17 June 2026
Final Publication: 01 May 2027

Abstract: The yield curve is one of the most important indicators in debt market analysis, economic expectations assessment, and monetary policy formulation. With the expansion of Islamic Treasury Bill issuance in Iran, forecasting the term structure of returns on these securities has become increasingly important. However, most existing studies have focused on the application of individual models and have not provided a comprehensive framework for integrating different forecasting approaches. The present study aims to identify and synthesize the theoretical and empirical approaches related to yield curve forecasting and to develop a comprehensive conceptual framework for analyzing Islamic Treasury Bills in the Iranian economy. The research employed a meta-synthesis methodology based on a systematic review of 37 domestic and international studies. The concepts extracted from these studies were classified according to conceptual similarities and organized into analytical categories. The findings indicated that the yield curve forecasting literature can be categorized into several major domains, including structural parametric models, macro-financial models, dynamic time-series models, machine learning and hybrid models, evaluation criteria, and influential macroeconomic factors. The results suggest that parametric models such as the Nelson–Siegel model provide an appropriate framework for explaining the structure of the yield curve; however, under conditions of economic instability, they do not offer sufficient forecasting accuracy when used independently. In contrast, machine learning models and hybrid approaches demonstrate greater capability in identifying nonlinear relationships and improving forecasting performance. Accordingly, integrating structural models with macroeconomic variables and data-driven methods can provide an efficient framework for forecasting the yield curve of Islamic Treasury Bills in the Iranian economy.

Keywords: Yield Curve, Islamic Treasury Bills, Return Rate Forecasting, Meta-Synthesis, Iranian Economy.

1. Introduction

The yield curve is one of the most important analytical tools in modern financial economics and plays a central role in understanding the dynamics of interest rates, debt markets, monetary policy transmission, and macroeconomic expectations. By illustrating the relationship between the yields of fixed-income securities and their maturities, the yield curve provides valuable information about investors' expectations regarding future economic conditions, inflation, and interest rate movements. As a result, policymakers, financial institutions, investors, and researchers have long relied on the yield curve as a key

indicator for assessing economic prospects and evaluating financial market conditions [1, 2]. The significance of the yield curve extends beyond the bond market because its structure reflects the collective expectations of market participants regarding future economic developments and serves as a bridge between financial markets and the real economy [3, 4].

Theoretical explanations of the yield curve have evolved considerably over time. Traditional theories, including the expectations hypothesis, liquidity preference theory, and market segmentation theory, have attempted to explain why interest rates vary across maturities and how the shape of the yield curve emerges. More recent developments have emphasized the role of central bank interventions, macroeconomic fundamentals, and financial market frictions in determining the term structure of interest rates. In particular, the implementation of yield curve control policies by several central banks has renewed interest in understanding the mechanisms through which monetary authorities influence the shape and dynamics of the yield curve. These developments have highlighted the importance of studying both the theoretical foundations and practical implications of yield curve behavior in contemporary financial systems [2, 5].

The economic importance of the yield curve is closely associated with its forecasting capabilities. Numerous studies have demonstrated that the slope, curvature, and level of the yield curve contain valuable information regarding future economic activity, inflation, and recessionary periods. In many economies, yield curve inversions have historically preceded economic downturns and financial crises, making the yield curve one of the most widely used leading indicators of economic performance. Recent evidence suggests that the predictive power of the yield curve remains significant even in the presence of changing monetary policy frameworks and evolving financial market structures [2, 4, 6]. Consequently, understanding and forecasting the yield curve has become a major research area within financial economics and quantitative finance.

The forecasting of yield curves presents substantial methodological challenges due to the complex and dynamic nature of interest rate movements. Yield curves are influenced by a wide range of factors, including macroeconomic conditions, monetary policy decisions, inflation expectations, market liquidity, investor behavior, and financial uncertainty. These influences often interact in nonlinear and time-varying ways, making accurate forecasting difficult. As a result, researchers have developed a variety of modeling approaches ranging from traditional parametric methods and econometric models to advanced machine learning techniques and hybrid frameworks [7-9].

Among the most influential approaches to yield curve modeling are parametric term structure models. The Nelson–Siegel model and its extensions have become standard tools for representing the shape of the yield curve through a small number of interpretable factors corresponding to level, slope, and curvature. The Svensson model further extends this framework by introducing additional flexibility to capture complex yield curve shapes. These models have been widely adopted by central banks, financial institutions, and researchers because of their simplicity, interpretability, and empirical effectiveness. Recent studies continue to confirm the usefulness of these models for fitting and analyzing yield curves across different markets and economic environments [7, 10, 11]. Nevertheless, concerns remain regarding their ability to capture rapidly changing market conditions and nonlinear dynamics, particularly during periods of economic uncertainty.

In parallel with the development of parametric models, equilibrium interest rate models have provided another important framework for understanding the behavior of the yield curve. Models such as Vasicek and Cox–Ingersoll–Ross focus on the stochastic evolution of short-term interest rates and explain the term structure through mean-reverting processes. These models have contributed significantly to the theoretical understanding of interest

rate dynamics and have been widely applied in bond pricing, risk management, and yield curve estimation. Their relevance remains particularly important in studies examining the long-run determinants of interest rate behavior and equilibrium market conditions [12].

The growing availability of financial data and computational resources has encouraged the use of dynamic econometric and time-series models for yield curve forecasting. Vector autoregressive models, autoregressive integrated moving average models, dynamic Nelson–Siegel frameworks, and time-varying parameter models have demonstrated considerable potential in capturing the temporal evolution of yield curves. These approaches enable researchers to model dynamic relationships among yield factors and incorporate changing market conditions into forecasting procedures. Recent studies have shown that models with time-varying parameters often outperform static specifications because they can adapt to structural changes and evolving economic environments [7, 8, 13, 14]. Similarly, advanced forecasting frameworks based on functional principal component analysis and vector autoregression have expanded the methodological toolkit available for analyzing high-dimensional yield curve data [15].

Another major trend in contemporary yield curve research is the increasing application of machine learning techniques. Machine learning algorithms provide powerful tools for extracting nonlinear patterns and complex relationships from large datasets. Studies have demonstrated that machine learning methods frequently outperform traditional econometric models, particularly in environments characterized by nonlinear dynamics, structural breaks, and high-dimensional information sets. Applications of recurrent neural networks, long short-term memory architectures, ensemble learning methods, and robust machine learning algorithms have generated promising results in yield curve forecasting and recession prediction [9, 16-18]. The growing popularity of these methods reflects a broader transformation within financial analytics toward data-driven forecasting approaches.

Recent research has also emphasized the advantages of hybrid modeling frameworks that integrate traditional financial theory with modern machine learning techniques. Such approaches seek to combine the interpretability of economic models with the predictive power of advanced algorithms. Evidence suggests that hybrid models often achieve superior forecasting performance by capturing both linear and nonlinear relationships within financial data. For example, combinations of factor models and machine learning methods have been shown to improve yield curve forecasts by leveraging complementary information from different modeling paradigms [19]. Likewise, hybrid dynamic Nelson–Siegel and LSTM frameworks have demonstrated significant forecasting improvements in Treasury markets by incorporating both economic structure and deep learning capabilities [17].

In addition to methodological developments, numerous studies have examined the economic determinants of yield curve behavior. Macroeconomic variables such as inflation, economic growth, monetary policy, and output gaps are widely recognized as key drivers of yield curve movements. Dynamic stochastic general equilibrium models and New Keynesian frameworks have provided valuable insights into how macroeconomic fundamentals influence the term structure of interest rates and the transmission of monetary policy effects across maturities [20, 21]. Furthermore, empirical evidence indicates that uncertainty regarding future interest rates can significantly alter the shape and predictive content of the yield curve, underscoring the importance of incorporating uncertainty measures into forecasting models [22].

The relationship between financial market structures and the yield curve has also attracted considerable scholarly attention. Research has demonstrated that factors such as intermediary balance sheets, market liquidity, credit conditions, and maturity-specific information can significantly influence yield curve dynamics. For instance, the balance sheets of financial intermediaries affect both the level and slope of Treasury yield curves, while specific

maturities, such as the five-year Treasury segment, may play a disproportionately important role in information transmission across the curve [23, 24]. Moreover, recent quantile-based analyses have revealed substantial nonlinear dependencies across different segments of the yield curve, highlighting the complexity of yield curve interactions under varying market conditions [25].

Within the Iranian financial system, the development of Islamic Treasury Bills has substantially increased the importance of yield curve analysis and forecasting. Islamic Treasury Bills have emerged as a critical instrument for government financing and debt market development, contributing to the expansion of fixed-income markets and enhancing fiscal policy implementation [26]. The issuance of these securities has important implications for fiscal sustainability, monetary policy effectiveness, and financial market development in Iran [27]. Consequently, understanding the behavior of their yield curve has become increasingly important for policymakers, investors, and financial institutions.

Several domestic studies have examined different aspects of Islamic Treasury Bills in Iran. Research has investigated factors influencing the acceptance of these securities among contractors and market participants, determinants of demand in over-the-counter markets, and the risks associated with holding these instruments. These studies have demonstrated that economic conditions, institutional characteristics, liquidity considerations, and market risks play important roles in shaping the performance and acceptance of Islamic Treasury Bills [28-30]. In addition, empirical evidence indicates that the yields of Islamic Treasury Bills influence capital market returns and contribute to the broader interconnectedness of Iran's financial system [31].

Despite these developments, significant gaps remain in the literature on forecasting the yield curve of Islamic Treasury Bills in Iran. Most domestic studies have focused primarily on estimating and fitting yield curves using parametric models such as Nelson–Siegel and Svensson rather than systematically evaluating forecasting performance across alternative methodologies [10, 11]. Moreover, while international research has increasingly adopted machine learning algorithms, hybrid forecasting frameworks, and advanced dynamic models, the application of these approaches to the Iranian debt market remains limited. Existing studies often examine isolated aspects of yield curve modeling without providing a comprehensive framework that integrates theoretical foundations, forecasting methodologies, macroeconomic influences, and evaluation criteria [9, 15, 19].

Furthermore, the international literature demonstrates a growing emphasis on incorporating time-varying parameters, macroeconomic information, financial uncertainty measures, and machine learning techniques into yield curve forecasting models [7, 8, 18]. At the same time, advances in yield curve reconstruction, dynamic estimation methods, and nonlinear connectedness analysis have expanded the range of available forecasting tools [14, 25, 32]. However, a systematic synthesis of these developments and their relevance to forecasting the yield curve of Islamic Treasury Bills in Iran remains largely absent from the existing literature.

Given the growing significance of Islamic Treasury Bills in Iran's financial system, the increasing methodological sophistication of yield curve forecasting research, and the absence of an integrated conceptual framework that synthesizes existing knowledge, a comprehensive review and meta-synthesis of previous studies is both timely and necessary. Therefore, the aim of the present study is to synthesize and integrate the theoretical and empirical literature on yield curve forecasting and to develop a comprehensive conceptual framework for forecasting the yield curve of Islamic Treasury Bills in the Iranian economy based on the findings of domestic and international studies.

2. Methodology

In this study, a meta-synthesis method was used to present a conceptual framework for forecasting the yield curve of Islamic Treasury Bills in the Iranian economy. Meta-synthesis is a qualitative and systematic approach that integrates and interprets the findings of previous studies in order to identify patterns, similarities, differences, and gaps in the literature and ultimately provide a more comprehensive and coherent understanding of the phenomenon under investigation. In this method, rather than generating new data, the findings of existing studies are analytically and interpretively integrated, thereby producing new knowledge at a level higher than that of individual studies. The application of meta-synthesis in finance and economics, particularly in the field of yield curve forecasting, makes it possible to systematically compare and evaluate the dispersed findings of domestic and international studies on different models, including parametric models, structural models, and modern statistical methods. Through this approach, the factors affecting forecasting accuracy, the conditions under which each model can be applied, their strengths and limitations, and existing research gaps can be extracted. Such an approach contributes to evidence-based policy and analytical decision-making and provides the foundation for designing more localized and efficient models for Iran's debt market. By providing a systematic framework for integrating qualitative and empirical studies, meta-synthesis enables the discovery of key concepts, recurring patterns, and fundamental relationships among variables and, through the reinterpretation of existing findings, advances current knowledge and creates a comprehensive and integrated perspective on the structure and forecasting of the yield curve of Islamic Treasury Bills.

3. Findings and Results

In general, two perspectives dominate meta-synthesis. The first approach, referred to as the "integrative" approach, emphasizes collecting, compiling, and integrating previous studies in such a way that the commonalities among the findings of prior studies are identified and integrated on the basis of highly reliable variables. This approach also leads to conclusions regarding causal relationships among phenomena and the generalizability of findings. The second perspective, referred to as "interpretive synthesis," emphasizes the interpretation and hermeneutic reading of previous studies. In this perspective, comparison and interpretation are important because, through a form of induction, it predicts what may occur under similar conditions and how categories are related to or interact with one another.

Noblit and Hare (1988) introduced three main phases for meta-synthesis, namely the selection of studies, the synthesis of translations, and the presentation of the synthesis, while Sandelowski and Barroso (2007) introduced a seven-step method. In this study, the seven-step method of Sandelowski and Barroso was used. The steps followed in this research are as follows:

Stage One) In the present study, the fundamental question is: "How can the conceptual model for forecasting the yield curve of Islamic Treasury Bills in the Iranian economy be explained based on the synthesis and analysis of previous studies?" This question was posed with the aim of identifying the most important models, approaches, and factors affecting yield curve forecasting, as well as extracting a coherent framework from the findings of domestic and international studies.

Stage Two) Systematic review of the literature: At this stage, the research literature was systematically reviewed. The study population included all scientific research articles, theses, and scientific reports published between 2015 and 2026 in the fields of financial economics, the debt market, and yield curve modeling that

examined or forecasted the yield curve of debt securities, particularly Islamic Treasury Bills. To identify relevant studies, a set of related keywords was used, including "yield curve," "yield curve forecasting," "Islamic Treasury Bills," "term structure of profit rates," "Nelson–Siegel model," "Svensson model," "interest rate models," "Vasicek model," "Cox–Ingersoll–Ross model," and "yield curve modeling." Sources were searched in domestic and international scientific databases and search engines, the most important of which included IranDoc, Noormags, Magiran, Civilica, ScienceDirect, Google Scholar, Emerald, and ERIC. After the initial search and collection of sources, relevant studies were screened based on inclusion and exclusion criteria, and the selected sources were ultimately used for analysis and synthesis in the meta-synthesis process.

The inclusion and exclusion criteria for articles are presented in Table 1.

Table 1. Inclusion and Exclusion Criteria for Articles

Inclusion Criteria	Exclusion Criteria
Research language: Persian and English	Studies in other languages
Research period: studies published between 2015 and 2026	Studies published before 2015
Research method: empirical, quantitative, qualitative-analytical studies, and studies addressing yield curve modeling or forecasting	Studies unrelated to yield curve modeling or forecasting
Field of study: research related to the debt market, the term structure of profit rates, debt securities, and especially Islamic Treasury Bills	Studies outside the scope of the debt market and yield curve
Subject under investigation: studies related to models and methods for estimating or forecasting the yield curve, such as the Nelson–Siegel model, Svensson model, interest rate models, and related statistical methods	Studies addressing topics other than yield curve modeling or analysis
Type of study: scientific articles published in reputable journals, university theses, and citable scientific reports	Personal opinions, non-scientific sources, unpublished articles, or sources lacking scientific credibility

Stage Three) Search and selection of appropriate articles: At this stage, in order to identify and select studies related to the research topic, the source-searching process was conducted systematically. First, using a rule-based approach, the general trend of studies conducted on the yield curve and its forecasting in debt markets was examined in order to determine the scientific scope and research orientation of studies in this field. In the first step, Google Trends was used to examine changes in searches for keywords related to the topic, including "yield curve," "yield curve forecasting," "Islamic Treasury Bills," and "term structure of profit rates" in recent years, in order to determine the level of attention paid by researchers and users to this field. In the next step, by referring to databases and indexing systems of scientific journals, including the citation database of the Ministry of Science and other reputable scientific databases, journals and articles related to the topic were identified and reviewed in order to extract the main and credible sources in this field. Then, by searching keywords related to yield curve modeling and forecasting in domestic and international scientific databases, a set of initial studies was collected. Subsequently, the retrieved articles were screened based on the inclusion and exclusion criteria of the study, and ultimately the studies most closely related to forecasting the yield curve of debt securities, especially Islamic Treasury Bills, were selected for analysis and synthesis in the meta-synthesis process.

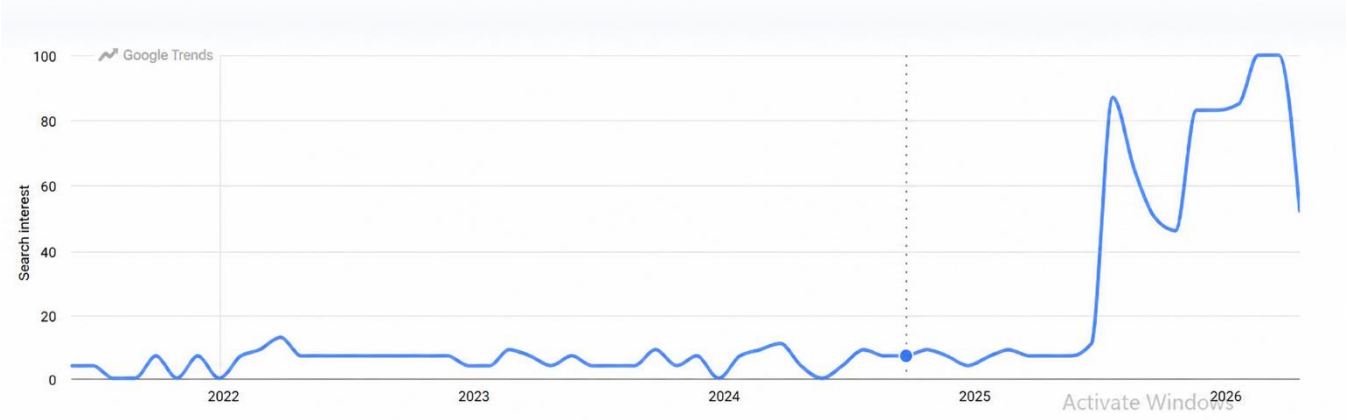


Figure 1. Search Trend for the Keyword "Yield Curve Forecasting" from 2022 to 2026

Accordingly, to benefit from reliable domestic and international sources, more than 140 articles were examined based on topic and title through searches in information sources such as Scopus, Elsevier, Google Scholar, and other databases. Of these, 38 documents were excluded after screening and separating the documents based on titles focused on the topic, because their titles and subject areas were not related to the topic of the present study. The abstracts of the remaining 102 scientific documents were then reviewed in order to more precisely identify studies that could provide the required analytical content. During the review of the research abstracts, another 45 articles were excluded. Finally, after a rapid review of the content and key themes of the articles, 20 additional articles were rejected. Ultimately, 37 articles remained for analysis, and the results of their review formed the findings of the present study.

Stage Four) Extraction of information from selected studies: At this stage, an in-depth and systematic review of the selected studies began. In order to answer the research question and identify models, approaches, influential variables, and indicators for evaluating the forecasting accuracy of the yield curve, the data extraction process was conducted. Since the data used in this study were primarily textual and qualitative, including the findings, results, methodologies, and analyses of previous studies, open coding was used to analyze them. At this stage, key concepts related to yield curve forecasting—including the type of model used, such as the Nelson–Siegel or Svensson model, estimation method, input variables, performance evaluation indicators such as RMSE and MAE, market conditions, and the study period—were extracted and recorded. This process made it possible to identify recurring patterns and conceptual differences among the studies.

Stage Five) Analysis and synthesis of qualitative findings: To analyze the extracted data, the process of classifying concepts into subcategories and core categories was used. Coding began with repeated reading of the texts and the development of a general understanding of the content of each study. The texts were then examined carefully and line by line in order to identify the main concepts and themes and convert them into initial codes. After the codes were identified, similar and related concepts were organized into common classes. This classification led to the formation of subcategories such as "parametric models," "structural interest rate models," "statistical and machine learning methods," and "forecast evaluation indicators." Subsequently, the subcategories were integrated at higher conceptual levels, and core categories were formed, constituting the final framework for explaining yield curve forecasting. Finally, through the systematic synthesis and interpretation of these categories, a coherent conceptual framework was extracted for forecasting the yield curve of Islamic Treasury Bills in the Iranian economy, reflecting the relationships among model type, market conditions, influential variables, and forecasting accuracy.

Table 2. Characteristics of the Selected Studies in the Meta-Synthesis of Yield Curve Forecasting

No.	Author / Year	Country or Market	Study Objective	Evaluation Criteria / Analytical Method	Main Model or Method	Main Result or Finding
1	Gabin and Stenfors (2024)	United States	Examining linkages in the Treasury yield curve	Quantile analysis	Quantile-on-quantile connectedness	Nonlinear dependence exists among different maturities of the yield curve.
2	Du et al. (2023)	United States	Examining the role of financial intermediaries' balance sheets in the yield curve	Econometric analysis	Structural financial models	The balance sheets of financial intermediaries affect the slope and level of the curve.
3	Liu and Wu (2021)	United States	Reconstructing the yield curve	Statistical fitting	Kernel smoothing	A new method was proposed for accurate yield curve estimation.
4	Chen (2023)	United States	Analyzing the role of the five-year maturity in the yield curve structure	Statistical models	Maturity connectedness analysis	The five-year maturity plays a key role in transmitting information across the curve.
5	Mohammadi Aghdam et al. (2025)	Iran	Forecasting Iran's yield curve	RMSE, MAE	Factor model and machine learning	Combining a factor model with machine learning increases forecasting accuracy.
6	Noufail and Alloui (2024)	Morocco	Forecasting economic conditions using the yield curve	Econometric analysis	Economic forecasting models	The yield curve contains informational content for economic forecasting.
7	Paglia and Tucker (2020)	United States	Forecasting recession using the yield curve	Forecasting criteria	Machine learning	Machine learning models have higher predictive power.
8	Nia and Hamzeh (2020)	Government bond market	Forecasting the yield curve of government bonds	RMSE, MAE	Time-series models	Time-series models are suitable for short-term forecasting.
9	Amamiya (2017)	Japan	Yield curve control	Theoretical analysis	Yield curve control framework	Monetary policy can manage the shape of the yield curve.
10	Sain et al. (2026)	International	Comparing yield curve forecasting methods	Forecast error	Machine learning and econometrics	Machine learning models often show greater accuracy.
11	Liu and Cheng (2026)	United States	Yield curve forecasting using robust machine learning	Error criteria	Robust machine learning	Algorithms resistant to uncertainty perform better.
12	Firdausanti and Shafira (2026)	United States	Forecasting the yield curve	RMSE	Dynamic Nelson–Siegel + long short-term memory recurrent neural network	The hybrid DNS-LSTM model has high accuracy.
13	Sain (2024)	United States	Multi-step forecasting of the yield curve	Forecast analysis	Machine learning and econometrics	Combining methods provides better performance.
14	White (2024)	United States	Modeling the term structure	Time-series analysis	Geometric term-structure model	The geometric model enables better interpretation of interest rate structure.
15	Chatterjee et al. (2024)	United States	Analyzing yield curve inversion	Empirical analysis	Econometric models	Yield curve inversion may signal recession.

16	State (2025)	International	Examining the predictive power of the yield curve	Empirical analysis	Forecasting models	The yield curve provides important information about the future economy.
17	Caldeira et al. (2025)	International	Forecasting the yield curve	RMSE	Time-varying parameter models	Time-varying parameters increase forecasting accuracy.
18	Susan et al. (2026)	International	Forecasting the daily yield curve	Functional analysis	FPCA-VAR	Functional models are appropriate for curve data.
19	Bayar and Kutan (2024)	United States	Examining the effect of interest rate uncertainty on the yield curve	Empirical analysis	Econometric models	Interest rate uncertainty changes the shape of the yield curve.
20	Castello and Resta (2025)	BRICS countries	Modeling and forecasting the yield curve	Simulation analysis	Time-varying parameter models	Dynamic parameters improve forecasting accuracy.
21	Vasquez and Paniagua (2024)	Latin America	Estimating the Treasury yield curve	Econometric analysis	Dynamic models, VAR, DNS	Dynamic models are suitable for curve estimation.
22	Navarro and Orazzi (2025)	International	Forecasting the yield curve	Error criteria	Hybrid machine learning	Hybrid models perform better.
23	Dadashi and Omidi (2026)	Iran	Examining the effect of Islamic Treasury Bill returns on the capital market	Quantile analysis	Quantile-on-quantile connectedness	The returns on Treasury Bills are related to capital market returns.
24	Sepahvand et al. (2023)	Iran	Determining the demand for Islamic Treasury Bills	Statistical analysis	Econometric models	Economic factors affect demand for these securities.
25	Sepahvand et al. (2022)	Iran	Examining factors affecting the acceptance of Islamic Treasury Bills	Empirical analysis	Statistical analysis	Economic and institutional characteristics affect the acceptance of these securities.
26	Peymani and Houshangi (2017)	Iran	Estimating the short-term profit rate of Islamic Treasury Bills	Model comparison	Equilibrium interest rate models	Equilibrium models are applicable in estimating profit rates.
27	Nazarpour and Sadraei (2017)	Iran	Identifying risks of Islamic Treasury Bills	Decision-making methods	Risk analysis	Market and liquidity risks are the most important factors.
28	Kianpour et al. (2020)	Iran	Examining the term structure of interest rates	Macroeconomic analysis	New Keynesian model	Macroeconomic variables affect the yield curve.
29	Sadraei et al. (2020)	Iran	Examining the effect of Treasury Bill issuance on government fiscal sustainability	Macroeconomic simulation	DSGE model	The issuance of these securities affects fiscal sustainability.
30	Khardyar et al. (2020)	Iran	Examining Islamic Treasury Bills as a financing instrument	Descriptive analysis	Financial analysis	These securities are important instruments in the debt market.
31	Masoudi et al. (2024)	Iran	Presenting an appropriate model for the yield curve of Islamic Treasury Bills	RMSE, MAE	Nelson–Siegel and Svensson models	The Svensson model fits better than the Nelson–Siegel model.
32	Mousavi Samarin et al. (2025)	Iran	Fitting the yield curve of government bonds	MSE, MAE	Nelson–Siegel and spline models	Parametric models have acceptable performance.

33	Kianpour et al. (2023)	Iran	Examining the relationship between macroeconomic variables and the yield curve	Macroeconomic analysis	DSGE model	Inflation and monetary policy affect the yield curve.
34	Dadashi and Omidi (2026)	Iran	Examining the effect of Islamic Treasury Bill maturity returns on the capital market	Quantile analysis	Quantile-on-quantile approach	The effects depend on market conditions.
35	Collin (2022)	International	Reviewing the fundamentals of the government bond yield curve	Conceptual review	Educational analysis	Basic concepts of the yield curve are presented.
36	Dash and Nag (2022)	India	Examining the predictive power of the yield curve	Empirical analysis	Forecasting models	The yield curve is an indicator for forecasting recession.
37	Kumar et al. (2021)	Canada	Reviewing the literature on the term structure of interest rates	Theoretical analysis	Financial models	Theories of the yield curve are developed.

Table 2 presents a summary of the selected studies extracted in the meta-synthesis process that were reviewed in the areas of modeling, estimation, and forecasting of the yield curve of debt securities, particularly Islamic Treasury Bills. These studies were selected using the inclusion criteria determined in the screening stage, including direct relevance to the term structure of profit rates, the application of yield curve modeling or forecasting methods, publication within the specified time period, and scientific credibility. Accordingly, 37 selected studies from domestic and international sources were identified and analyzed.

The reviewed studies show that the literature related to the yield curve can be categorized into several main approaches. First, classical and parametric approaches to the term structure of interest rates, such as the Nelson–Siegel model, the Svensson model, and other equilibrium interest rate models, have been widely used to fit and interpret the shape of the yield curve. Second, econometric and time-series models, such as VAR, time-varying parameter models, and macroeconomic frameworks such as DSGE, have been used to analyze temporal dynamics and the effects of macroeconomic variables on the yield curve. Third, modern data-driven methods, including machine learning algorithms and hybrid models, have received increasing attention from researchers in recent years because of their greater ability to extract nonlinear patterns and improve forecasting accuracy. In addition, some studies have used advanced methods such as quantile analysis, quantile-on-quantile connectedness, functional principal component analysis, and smoothing methods to analyze the structure and intra-curve dependencies of the yield curve. A review of the findings of the selected studies indicates that, in the international literature, considerable attention has been paid to developing more accurate yield curve forecasting methods, combining econometric models with machine learning algorithms, and examining the role of macroeconomic factors, financial uncertainties, and monetary policies in shaping the yield curve. By contrast, in the domestic literature, a significant portion of studies has focused on analyzing Iran's debt market, examining the characteristics of Islamic Treasury Bills, identifying factors affecting the demand for and risks of these securities, and estimating the yield curve using parametric models such as Nelson–Siegel and Svensson. Overall, the results of this table indicate that although numerous studies have been conducted on yield curve fitting and analysis, studies that simultaneously address forecasting the yield curve of Islamic Treasury Bills using hybrid approaches and advanced data-driven methods remain limited. Therefore, the present study, by focusing on the systematic extraction and

synthesis of findings from previous studies, can help identify appropriate frameworks for forecasting the yield curve in Iran's debt market and partially address the existing gap in this field of literature.

The results of the meta-synthesis of the conducted studies are presented in Table 3.

Table 3. Final Categorization of Yield Curve Forecasting Studies

Core Category	Subcategory	Extracted Concepts / Codes	Number of Sources	Sample Sources
Parametric models of the term structure	Nelson–Siegel (NS)	Level, slope, curvature	3	Masoudi (2024), Mousavi (2025), Firdausanti (2026)
Parametric models of the term structure	Nelson–Siegel–Svensson (NSS)	Second curvature parameter, flexible fitting	2	Masoudi (2024), Castello (2025)
Parametric models of the term structure	Spline and smoothing	Spline method; kernel smoothing method	2	Mousavi (2025), Liu and Wu (2021)
Equilibrium interest rate models	Vasicek	Mean reversion; short-term interest rate	1	Peymani (2017)
Equilibrium interest rate models	Cox–Ingersoll–Ross (CIR)	Stochastic short-term interest rate	1	Peymani (2017)
Dynamic time-series models for forecasting	ARIMA / VAR	Coefficient dynamics, multi-step forecasting	4	Nia (2020), Susan (2026), Vasquez (2024), Sain (2024)
Dynamic time-series models for forecasting	FPCA-VAR	Functional curve analysis	1	Susan et al. (2026)
Dynamic time-series models for forecasting	Time-varying parameter	Time-varying decay rate	2	Caldeira (2025), Castello (2025)
Machine learning and hybrid models	LSTM	Recurrent neural network	2	Firdausanti (2026), Sain (2026)
Machine learning and hybrid models	Hybrid learning	Combination of multiple models	1	Navarro (2025)
Machine learning and hybrid models	Factor + ML	Factor model + machine learning	1	Mohammadi Aghdam (2025)
Machine learning and hybrid models	Robust ML	Robust learning	1	Liu and Cheng (2026)
Model performance evaluation criteria	RMSE / MAE / MSE	Mean squared error	9	Masoudi, Mousavi, Nia, Sain, Caldeira, and others
Model performance evaluation criteria	Diebold–Mariano test	Comparison of forecasting accuracy	1	Masoudi (2024)
Model performance evaluation criteria	Out-of-sample forecasting	Out-of-sample forecasting	2	Sain (2026), Caldeira (2025)
Factors affecting the shape and forecasting accuracy of the yield curve	Macroeconomic variables	Inflation, output, monetary policy	3	Kianpour (2024), Caldeira (2025), Noufail (2024)
Factors affecting the shape and forecasting accuracy of the yield curve	Interest rate uncertainty	Interest rate uncertainty	1	Bayar (2024)
Factors affecting the shape and forecasting accuracy of the yield curve	Monetary policy and curve control	Yield curve control	1	Amamiya (2017)
Economic functions of the yield curve	Recession forecasting	Yield curve inversion and recession signal	3	Paglia (2020), Chatterjee (2024), Dash and Nag (2022)
Economic functions of the yield curve	Effect on Iran's capital market	Returns on Islamic Treasury Bills versus stock market returns	1	Dadashi and Omidi (2026)
Economic functions of the yield curve	Demand and risk of Islamic Treasury Bills	Liquidity, market risk	2	Sepahvand (2022) and Nazarpour (2020)

Table 3 shows the result of the coding process and conceptual synthesis of the selected studies in the present research. After key concepts were extracted from the reviewed sources, initial codes were first identified and then categorized into subcategories and ultimately core categories based on conceptual similarities. This process was conducted with the aim of identifying the main patterns in the literature related to yield curve modeling and forecasting.

Based on the results of the meta-synthesis, the most important research themes in the literature of this field can be classified into seven core categories. The first category consists of parametric models of the term structure, including Nelson–Siegel, Nelson–Siegel–Svensson, and spline- and smoothing-based methods, which are widely used to fit the shape of the yield curve and extract the factors of level, slope, and curvature. The second category consists of equilibrium interest rate models, such as the Vasicek and Cox–Ingersoll–Ross models, which mainly focus on the stochastic behavior of short-term interest rates and the mechanism of mean reversion. The third category concerns dynamic time-series models, which are used to forecast changes in the yield curve over time. This category includes methods such as ARIMA, VAR, functional principal component analysis, and time-varying parameter models, which make it possible to examine temporal dynamics and conduct multi-step yield curve forecasting. The fourth category includes modern approaches based on machine learning and hybrid models. Using algorithms such as recurrent neural networks, factor models combined with machine learning, and algorithms robust to uncertainty, these methods have demonstrated a greater ability to identify nonlinear relationships and improve forecasting accuracy. Alongside the models used, another part of the literature focuses on model performance evaluation criteria. Indicators such as RMSE, MAE, and MSE have been widely used to measure forecasting error, while some studies have also used comparative tests, such as the Diebold–Mariano test, and out-of-sample forecasting evaluation to compare model performance. In addition, some studies have examined factors affecting the shape and dynamics of the yield curve, among which macroeconomic variables, interest rate uncertainty, and monetary policies have been identified as the most important influencing factors. Finally, the results of the meta-synthesis show that the yield curve, in addition to its application in modeling and forecasting interest rates, also has important economic functions, including forecasting economic cycles and recessions, analyzing the relationship between the debt market and the capital market, and examining the characteristics of the Islamic Treasury Bill market in the Iranian economy. Therefore, the classification presented in this table provides a coherent picture of the main research streams in the field of the yield curve and can serve as a basis for developing the analytical framework of the present study for forecasting the yield curve of Islamic Treasury Bills.

Despite the significant expansion of the literature related to the term structure of interest rates and the yield curve, the results of the meta-synthesis show that several important research gaps still exist in this field. First, most domestic studies have focused on the static fitting of the yield curve of Islamic Treasury Bills using parametric models such as Nelson–Siegel and Svensson, while less attention has been paid to dynamic out-of-sample forecasting and comparative evaluation of model performance. Second, although the international literature has extensively addressed the use of advanced time-series models, time-varying parameters, and machine learning algorithms, the transfer and localization of these approaches to Iran's debt market and Islamic Treasury Bills have remained very limited. Third, most studies have either focused on traditional econometric models or merely applied machine learning algorithms, and there are few studies that systematically combine term-structure models with modern data-driven methods within the framework of the Iranian market. Accordingly, the main gap identified in this study is the absence of an integrated and coherent framework for forecasting the yield curve of Iranian Islamic Treasury Bills by simultaneously using term-structure models, dynamic time-series methods, and

machine learning algorithms, as well as the precise evaluation of their performance based on standard out-of-sample forecasting criteria. Drawing on the findings extracted from the meta-synthesis of previous studies, the present research seeks to address this gap and provide an analytical and practical framework for improving forecasting accuracy in Iran's debt market.

Stage Six) Quality control: In order to determine the reliability of the research data, the strategy of peer debriefing was used.

Stage Seven) Presentation of findings.

In this study, the components and variables related to forecasting the yield curve of Islamic Treasury Bills were extracted from the selected studies and considered as initial concepts. These concepts were then classified into homogeneous categories based on conceptual and functional similarities, which resulted in the formation of analytical categories. In the next step, these categories were organized and synthesized within an integrated framework in order to present a comprehensive picture of the approaches used in yield curve forecasting. The outcome of this process was the formation of the main dimensions of models, methods, and factors affecting the forecasting of the yield curve of Islamic Treasury Bills, which constitute the conceptual model of the study. This model is presented in Figure 2.

Figure 2. Model of Methods and Factors Affecting the Forecasting of the Yield Curve of Islamic Treasury Bills

4. Discussion and Conclusion

The purpose of the present study was to synthesize and integrate the existing literature on yield curve forecasting and to develop a comprehensive conceptual framework for forecasting the yield curve of Islamic Treasury Bills in the Iranian economy. The findings of the meta-synthesis revealed that the literature can be organized into seven major dimensions, including parametric term-structure models, equilibrium interest rate models, dynamic time-series forecasting models, machine learning and hybrid approaches, model evaluation criteria, factors influencing the shape and forecasting accuracy of the yield curve, and the broader economic functions of the yield curve. Collectively, these findings indicate that yield curve forecasting is a multidimensional phenomenon that cannot be adequately explained through a single methodological perspective. Rather, accurate forecasting requires the integration of theoretical, econometric, macroeconomic, and data-driven approaches.

One of the most important findings of the present study is the continued prominence of parametric term-structure models, particularly the Nelson–Siegel and Nelson–Siegel–Svensson frameworks, in both international and Iranian studies. The results demonstrated that these models remain the dominant tools for estimating and interpreting yield curve dynamics because they provide economically meaningful factors that capture the level, slope, and curvature of the curve. This finding is consistent with studies conducted in Iran, which reported satisfactory performance for Nelson–Siegel and Svensson models in fitting the yield curve of Islamic Treasury Bills and government securities [10, 11]. The widespread adoption of these models can be attributed to their parsimonious structure and interpretability. However, the findings also indicate that while these models are effective for curve fitting and descriptive analysis, they may not always provide the highest forecasting accuracy, particularly under conditions characterized by economic volatility and structural changes. This observation aligns with the arguments of researchers who have emphasized the limitations of static parametric structures when confronted with nonlinear market dynamics and rapidly changing economic environments [7, 8].

Another significant finding concerns the role of equilibrium interest rate models, such as Vasicek and Cox–Ingersoll–Ross, in explaining the underlying mechanisms of yield curve formation. The meta-synthesis revealed that although these models are less frequently used in contemporary forecasting studies, they continue to provide an important theoretical foundation for understanding the stochastic behavior of short-term interest rates and the process of mean reversion. These results support earlier evidence suggesting that equilibrium models remain valuable for analyzing the structural determinants of interest rates and for providing economic interpretations of yield curve movements [12]. Their continued relevance demonstrates that theoretical models retain an important place in the broader framework of yield curve analysis, even as more sophisticated forecasting techniques emerge.

The findings also highlight the growing importance of dynamic time-series models in yield curve forecasting. Methods such as ARIMA, VAR, dynamic Nelson–Siegel specifications, functional principal component analysis, and time-varying parameter models were found to constitute a major stream of research. This result reflects the recognition that yield curves evolve over time and are influenced by changing economic conditions. Dynamic models offer advantages because they capture temporal dependencies and permit the incorporation of evolving relationships among variables. The prominence of these methods in the selected studies is consistent with the findings of Nia and Hamzah, who demonstrated the usefulness of time-series models for short-term forecasting, as well as with the work of Vásquez and Paniagua, who emphasized the value of dynamic estimation techniques for Treasury yield curves [13, 14]. Furthermore, studies investigating time-varying parameter models reported significant improvements in forecasting accuracy, suggesting that flexible specifications are better suited to

environments characterized by structural change and economic uncertainty [7, 8]. The results of the present study therefore support the view that incorporating dynamic elements is essential for improving yield curve forecasts.

A particularly noteworthy finding is the increasing influence of machine learning and hybrid forecasting approaches. The meta-synthesis demonstrated that recent studies have increasingly adopted algorithms such as long short-term memory networks, ensemble learning frameworks, factor-based machine learning models, and robust machine learning techniques. These methods were consistently associated with improved forecasting performance, especially when compared with traditional econometric approaches. This finding is highly consistent with contemporary research indicating that machine learning models are capable of identifying nonlinear relationships and complex interactions that conventional models often fail to capture [16, 18]. Similarly, studies employing hybrid frameworks reported superior performance because they combine the theoretical strengths of financial models with the predictive capabilities of advanced computational algorithms [9, 17]. The results of Mohammadiaghdam and colleagues further support this conclusion by demonstrating that combining factor models with machine learning methods substantially improves the forecasting accuracy of Iran's yield curve [19]. These findings collectively suggest that the future of yield curve forecasting is likely to be characterized by increasing integration between economic theory and artificial intelligence techniques.

The results of the present study also emphasize the importance of rigorous model evaluation. Across the reviewed literature, RMSE, MAE, and MSE emerged as the most widely used indicators for assessing forecasting performance. Additionally, comparative methods such as the Diebold–Mariano test and out-of-sample forecasting evaluation were frequently employed to determine whether one model significantly outperformed another. The widespread use of these measures reflects the growing recognition that model selection should be based not only on theoretical plausibility but also on empirical forecasting performance. This finding is consistent with studies comparing alternative yield curve specifications in Iran and abroad, which relied heavily on these evaluation criteria to identify superior forecasting frameworks [7, 10]. Consequently, the results suggest that future research should continue emphasizing out-of-sample predictive performance rather than relying solely on in-sample goodness-of-fit measures.

Another important finding relates to the factors influencing the shape and forecasting accuracy of the yield curve. The meta-synthesis identified macroeconomic variables, monetary policy actions, and interest rate uncertainty as the most influential determinants. This result reinforces the view that yield curves cannot be understood independently of broader economic conditions. Studies conducted in both domestic and international contexts have consistently shown that inflation, output, monetary policy decisions, and macroeconomic expectations significantly affect the term structure of interest rates [3, 20, 21]. Similarly, evidence regarding interest rate uncertainty suggests that periods of heightened uncertainty alter the shape of the yield curve and reduce forecasting stability [22]. The importance of monetary policy was also evident in studies examining yield curve control frameworks, which demonstrated that central bank interventions can directly influence yield curve configurations [5]. These findings imply that forecasting models that fail to incorporate macroeconomic and policy-related variables may suffer from reduced predictive accuracy.

The findings further revealed that financial market structures and information transmission mechanisms play a significant role in yield curve dynamics. Studies examining intermediary balance sheets, maturity-specific effects, and quantile-based connectedness measures showed that financial market conditions influence yield curve behavior in ways that are often nonlinear and heterogeneous. The work of Du and colleagues demonstrated that the balance sheets of financial intermediaries affect the level and slope of Treasury yield curves, while Chen

highlighted the central role of five-year Treasury securities in transmitting information across maturities [23, 24]. Likewise, Gabauer and Stenfors found substantial nonlinear connectedness among different segments of the Treasury yield curve, indicating that shocks are transmitted differently across maturities depending on market conditions [25]. These results suggest that yield curve forecasting models should account for market microstructure factors and cross-maturity interactions in order to achieve greater accuracy.

The meta-synthesis also confirmed the broader economic significance of the yield curve beyond forecasting interest rates. The reviewed studies consistently identified the yield curve as a powerful predictor of future economic activity and recessionary conditions. Research conducted in various countries demonstrated that yield curve inversion remains one of the most reliable indicators of economic downturns [4, 6]. Furthermore, studies examining the relationship between the yield curve and economic activity showed that yield spreads contain valuable information regarding future growth prospects and macroeconomic performance [2, 3]. These findings reinforce the idea that yield curve forecasting is not merely a technical exercise but also a valuable tool for economic policy analysis and strategic decision-making.

Within the Iranian context, the findings underscore the increasing importance of Islamic Treasury Bills as a key component of the debt market. The reviewed studies revealed that these securities play a significant role in government financing, fiscal sustainability, and financial market development [26, 27]. At the same time, factors such as market risk, liquidity conditions, investor acceptance, and demand dynamics significantly influence their performance [28-30]. The evidence indicating a relationship between Islamic Treasury Bill yields and capital market returns further highlights the interconnected nature of Iran's financial system [31]. Consequently, improving the forecasting of Islamic Treasury Bill yield curves has important implications for debt management, investment decisions, and financial stability.

Overall, the findings of the present study suggest that no single model can fully capture the complexity of yield curve dynamics. Instead, the most promising approach appears to be the integration of structural term-structure models, macroeconomic variables, dynamic forecasting techniques, and machine learning algorithms within a unified analytical framework. Such an approach can benefit from the interpretability of traditional financial models while simultaneously exploiting the predictive capabilities of modern data-driven methods. The conceptual framework developed through the present meta-synthesis therefore provides a comprehensive foundation for future forecasting models in the Iranian debt market and contributes to bridging the gap between international methodological advances and domestic financial applications.

One limitation of the present study is that it relied exclusively on published academic studies and scientific reports, which may have introduced publication bias into the findings. Studies with significant or positive results are more likely to be published than studies reporting insignificant outcomes, potentially affecting the comprehensiveness of the synthesis. In addition, although both domestic and international studies were included, the availability of research specifically focused on forecasting the yield curve of Islamic Treasury Bills remains limited. Another limitation is that the study employed a qualitative meta-synthesis approach and therefore did not conduct a quantitative meta-analysis of forecasting performance indicators across different models.

Future studies should conduct empirical testing of the conceptual framework proposed in this research using actual market data from Islamic Treasury Bills. Researchers may compare the forecasting performance of traditional econometric models, machine learning algorithms, and hybrid approaches under different market conditions. Additional studies could also examine the role of alternative macroeconomic indicators, sentiment measures, and financial uncertainty indices in improving forecasting accuracy. Furthermore, comparative investigations across

different emerging debt markets may provide valuable insights into the generalizability of forecasting frameworks developed for the Iranian context.

Policymakers and financial authorities should consider integrating macroeconomic information, market indicators, and advanced forecasting techniques into debt management and monetary policy analysis. Financial institutions and investment firms may improve risk management and portfolio allocation decisions by utilizing hybrid forecasting models that combine traditional yield curve structures with machine learning methods. Market regulators can also benefit from enhanced yield curve forecasting systems by improving the monitoring of debt market conditions and identifying potential financial vulnerabilities at an earlier stage. Finally, the development of comprehensive yield curve forecasting platforms could support greater transparency, efficiency, and stability within Iran's debt market.

Authors' Contributions

Authors equally contributed to this article.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

Acknowledgments

Authors thank all participants who participate in this study.

Conflict of Interest

The authors report no conflict of interest.

Funding/Financial Support

According to the authors, this article has no financial support.

References

[1] V. Collin, "Government Bond Yield Curve," 2022. [Online]. Available: https://www.fe.training/freeresources/financial-markets/government-bond-yield-curve.

[2] R. R. Kumar, P. J. Stauvermann, and H. T. T. Vu, "The Relationship between Yield Curve and Economic Activity: An Analysis of G7 Countries," *Journal of Risk and Financial Management,* vol. 14, no. 2, p. 62, 2021, doi: 10.3390/jrfm14020062.

[3] O. S. Noufail and M. H. Alaoui, "Role of the Information Content of the Moroccan Treasury Securities Real Yield Curve in Forecasting the Future Economic Situation in Morocco," *International Journal of Accounting, Finance, Auditing, Management and Economics,* 2024.

[4] K. G. Das and B. Nag, "Predictive Power of the Yield Curve: Evidence from India," *IIMB Management Review,* pp. 1-14, 2022, doi: 10.1016/j.iimb.2022.03.001.

[5] M. Amamiya, "History and Theories of Yield Curve Control," Bank of Japan, 2017.

[6] U. K. Chatterjee, A. Zirgulis, M. Hüttinger, and J. J. French, "Reassessing the Inversion of the Treasury Yield Curve as a Sign of US Recessions: Insights from the Housing and Credit Markets," *The North American Journal of Economics and Finance,* vol. 73, p. 102173, 2024, doi: 10.1016/j.najef.2024.102173.

[7] J. F. Caldeira, W. C. Cordeiro, E. Ruiz, and A. A. Santos, "Forecasting the Yield Curve: The Role of Additional and Time-Varying Decay Parameters, Conditional Heteroscedasticity, and Macro-Economic Factors," *Journal of Time Series Analysis,* vol. 46, no. 2, pp. 258-285, 2025, doi: 10.1111/jtsa.12769.

[8] O. Castello and M. Resta, "Optimal Time Varying Parameters in Yield Curve Modeling and Forecasting: A Simulation Study on BRICS Countries," *Computational Economics,* vol. 65, no. 4, pp. 2081-2113, 2025, doi: 10.1007/s10614-024-10619-z.

[9] M. M. Navarro and P. Orazi, "A Machine Learning Ensemble Framework to Forecast the Yield Curve," 2025, p. 157.
[10] M. Masoudi and S. M. Mirbergkar, "Providing an Appropriate Model of the Islamic Treasury Bills Yield Curve Based on Nelson-Siegel and Svensson Models in Iran's Financial Market," *Investment Knowledge,* vol. 14, no. 53, pp. 687-716, 2024.
[11] S. Mousavi Samarin, S. Z. Kiaolhosseini, S. M. Sajjadi, and M. Rezaei, "Fitting the Yield Curve of Government Islamic Securities in Iran: A Comparison of Nelson-Siegel and Spline Models," *Economic Studies and Policies,* vol. 11, no. 2, pp. 7-54, 2025, doi: 10.22096/esp.2025.2072880.1842.
[12] M. Peymani and Z. Houshangi, "Estimation and Comparison of Equilibrium Models of Short-Term Profit Rates of Islamic Treasury Bills," *Financial Engineering and Securities Management,* no. 33, pp. 1-89, 2017.
[13] V. M. Nia and H. Hamzah, "Forecasting of Government Yield Curve in Post-Corona Pandemic," *Jurnal Manajemen Dan Organisasi,* vol. 11, no. 3, pp. 143-157, 2020, doi: 10.29244/jmo.v11i3.33968.
[14] M. C. Vásquez and L. M. Paniagua, "Dynamic Models for Estimating the US Treasury Yield Curve for the Costa Rica Central Bank," 2024: IEEE, pp. 1-6, doi: 10.1109/CONCAPAN63470.2024.10933853.
[15] M. Sözen, F. Kabakcı, and Ç. Sözen, "Distribution-Free Uncertainty Quantification for Daily Treasury Yield Curves with Functional Principal Component Forecasting and Vector Autoregression," *AIMS Mathematics,* vol. 11, no. 3, pp. 5692-5718, 2026, doi: 10.3934/math.2026234.
[16] M. Puglia and A. Tucker, "Machine Learning, the Treasury Yield Curve and Recession Forecasting," 2020.
[17] N. A. Firdausanti and A. Shafira, "Forecasting the US Treasury Yield Curve Using the Hybrid Dynamic Nelson-Siegel and Long Short-Term Memory (LSTM) Method," *Indonesian Journal of Applied Statistics,* vol. 9, no. 1, 2026.
[18] J. Liu and M. Y. Cheng, "Forecasting the US Treasury Yield Curve: A Distributionally Robust Machine Learning Approach," *arXiv preprint,* p. arXiv:2601.04608, 2026, doi: 10.2139/ssrn.6017574.
[19] S. Mohammadiaghdam, M. Peymany Foroushany, M. Amiry, and M. Bahrani, "Predicting Iran's Yield Curve: Combining Factor Model with Machine Learning Approach," *Financial Management Perspective,* vol. 15, no. 1, pp. 9-39, 2025.
[20] Kianpour, "The Term Structure of Interest Rates within a New Keynesian Model," *Quarterly Journal of Quantitative Economics,* vol. 17, no. 4, p. 60, 2020.
[21] P. Kianpour, A. Aminifard, H. Zare, and M. Ebrahimi, "Investigating the Relationship between Macroeconomic Variables and the Yield Curve of Islamic Treasury Bills in Iran: A Dynamic Stochastic General Equilibrium Approach," *Economic Studies and Policies,* vol. 10, no. 2, pp. 9-130, 2023, doi: 10.22096/esp.2024.535320.1553.
[22] Y. Bayaa and M. Qadan, "Interest Rate Uncertainty and the Shape of the Yield Curve of US Treasury Bonds," *Eurasian Economic Review,* vol. 14, no. 4, pp. 981-1003, 2024, doi: 10.1007/s40822-024-00278-8.
[23] W. Du, B. Hébert, and W. Li, "Intermediary Balance Sheets and the Treasury Yield Curve," *Journal of Financial Economics,* vol. 150, no. 3, p. 103722, 2023, doi: 10.1016/j.jfineco.2023.103722.
[24] Y. L. Chen, "The Crucial Role of the Five-Year Treasury in the US Yield Curve," *International Review of Financial Analysis,* vol. 90, p. 102828, 2023, doi: 10.1016/j.irfa.2023.102828.
[25] D. Gabauer and A. Stenfors, "Quantile-on-Quantile Connectedness Measures: Evidence from the US Treasury Yield Curve," *Finance Research Letters,* vol. 60, p. 104852, 2024, doi: 10.1016/j.frl.2023.104852.
[26] S. Khordyar, "Islamic Treasury Bills: A Modern Financing Instrument," *Accounting and Auditing Studies,* no. 34, pp. 6-8, 2020.
[27] M. H. Sadraei, "Investigating the Effect of Issuing Islamic Treasury Bills on the Fiscal Sustainability of the Iranian Government Using a Dynamic Stochastic General Equilibrium Model," *Economic Research and Policies,* vol. 28, no. 94, pp. 39-333, 2020.
[28] M. Sepehvend, S. Gershasbi Fakhr, and H. Asayesh, "Determining the Factors Affecting Contractors' Acceptance of Islamic Treasury Bills in Different Regions of Iran," *Islamic Economics and Banking,* no. 41, pp. 277-306, 2022.
[29] M. Sepehvend, S. Gershasbi Fakhr, and H. Asayesh, "Determining the Demand for Islamic Treasury Bills in Iran's Over-the-Counter Market," *Islamic Economics and Banking,* no. 45, pp. 135-157, 2023.
[30] M. N. Nazarpour and M. H. Sadraei, "Identifying and Ranking the Risks of Islamic Treasury Bills in Iran's Securities Market," *Islamic Financial Research,* vol. 6, no. 2, Serial 12, pp. 133-166, 2017.
[31] I. Dadashi and V. Omidi, "Examining the Impact of Islamic Treasury Bill Yields on Iran's Capital Market Returns Using the Quantile-on-Quantile Connectedness Model," *Financial Research Journal,* vol. 28, no. 1, pp. 27-55, 2026, doi: 10.22059/FRJ.2025.388616.1007693.
[32] Y. Liu and J. C. Wu, "Reconstructing the Yield Curve," *Journal of Financial Economics,* vol. 142, no. 3, pp. 1395-1425, 2021, doi: 10.1016/j.jfineco.2021.05.059.