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Research Article

Exploring the Nexus Between Short- and Long-Run Rate of Interests in Turkey's Bond Market[a]

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This research analyzes the correlation between long- and short-term rate of interests in Turkey's government bond market, assessing the evidence in support of the Market Segmentation Theory (MST) and Expectations Hypothesis (EH). The research implements linear and nonlinear autoregressive distributed lag (ARDL and NARDL, respectively) approaches to address linearity, asymmetric effects, and structural breaks. The results indicate that short-term rate of interests have a substantial impact on mid-term (two-year and five-year) bond rates, backing the EH, while long-term (ten-year) rates conform to the MST and suggest the presence of segmented markets. Inflation, as measured by the Consumer Price Index, demonstrates a pronounced Fisher effect across various maturities, characterized by asymmetric responses to both positive and negative shocks. The error correction terms indicate that mid-term rates exhibit rapid adjustment, whereas long-term rates adjust more slowly. The findings of the Granger causality test provide further confirmation of the dynamic interactions by showing that changes in short-term interest rates and inflation have predictive power over the long-term rate of interests.

JEL codes: E40, E43, B22, C32

Keywords: Rate of interest; Term structure; Government bonds; Expectations Theory; Market Segmentation Theory

1 Introduction

Economics literature generally concurs that fluctuations in rate of interests influence the behaviors of all economic decision-making entities. A change in rate of interests can significantly and immediately influence firms' investment decisions concerning production equipment, household savings formation, and the decision-making processes of politicians

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managing debt policy in future periods. Monetary policy decision-makers can exert substantial and prompt effects on various economic variables via a transmission mechanism. In an economic system, multiple rate of interests exist rather than a single rate due to the existence of various government bonds, bills, and investment options that differ in maturities and risk levels. The rates may vary based on timing and the differing levels of repayment risk linked to each case. The primary reason for examining rate of interests involves the possible effects on the overall economy, as each of these rates can influence economic conditions differently. Furthermore, the analytical techniques applied to one rate of interest may be helpful to better understand the dynamics in other rate of interests.

This article examines the relationship between Turkey's short- and long-term government bond rate of interests. The study investigates the impact of short-term rate of interests, indicative of monetary policy, on long-term rates of interests of government bonds and whether this relationship demonstrates linear or non-linear features over time. The major objective of the research is to confirm if the Expectations Hypothesis (EH) holds in Turkey and to assess how strong and in what direction unexpected changes or nonlinear effects are, which are commonly ignored. This study uses Autoregressive Distributed Lag (ARDL) and Nonlinear Autoregressive Distributed Lag (NARDL) methods at various time periods to examine how the rate of interests behaves, particularly how short- and long-term bond rate of interests react to changes in the bond market's rate of interests.

Asset prices offer significant clues on the dynamics of the financial sector and the shifts occurring in the production side of the economy at large. The relationship between the two types of interest rates is significant, as it influences macroeconomic policy (Mankiw & Summers, 1984). Since their direct impact on all economic units, short-term rate of interests are crucial economic indicators for financial markets. Anticipations regarding fluctuations in the nominal rate of interests will affect investments, personal savings, government debt management, and various economic activities. The state of the national economy will be determined by individual economic activity. The term structure of rate of interests connects nominal rate of interests across both long- and short-term durations. Monetary and financial theories that investigate the relationship between rate of interests and different term structures reveal a correlation across the term structure of rate of interests. Theories indicate that the term structures of rate of interests, known as the yield curve, are founded on expectations, liquidity preferences, and market segmentation theories. Every single one of these emphasizes different aspects of the fundamental framework for the rates of yields. Theories clarify how elements, including market circumstances and behavior of investors, affect the form and slope of the yield curve. The term structure serves as a conduit for monetary policy, illustrating the incorporation of current policy positions and anticipated future rate of interests into government debt securities across various maturities.

In emerging markets like Turkey, the yield curve is particularly significant due to its relationship with high inflation dynamics, exchange rate volatility, and geopolitical risks, all of which considerably influence monetary policy. Examining the relationship between horizons of interest rates in a national economy helps to confirm the theories of expectations, liquidity preferences, and market segmentation, clarifying the yield curve. Short-term rate of interest are determined by central banks, whereas long-term rate of interests are influenced by market participants' expectations and risk assessments regarding future rate of interest trends. Changes in long- and short-term rates of return in direction and size set the monetary transmission procedure, therefore defining yield curves as a crucial measure for central banks and governments as well. Usually shown by the rate of return curve, the fundamental structure of rates of interest depicts the association between bond rates and their time lengths. Considering investor expectations, the health of the economy, and the course of monetary regulation all depend upon the returns curve.

A yield curve in finance illustrates the relationship between rate of interests (yields) on bonds of identical credit quality across varying maturities. The yield curve critically indicates market expectations concerning future rate of interests, economic growth, and inflation. The upward-sloping curves imply that longer-term securities provide greater rates compared to shorter-term securities, which demonstrates expectations of economic strength and potential inflationary threats. A reversed yield curve characterized by higher short-term yields compared to long-term yields typically signals an expected economic downturn and has historically preceded recessions (Estrella & Mishkin, 1996).

The recent inversion of the yield curve in Turkey has prompted requests about the impact and legitimacy of monetary policy amid substantial inflationary pressures and macro-financial instabilities. Short-term bonds (2-year bonds) produced over 47% by April 2025; longer-dated instruments (e.g., 10-year bonds) dropped to around 33%, generating a high negative slope. This reversal is not simply a mechanical consequence of higher policy rates but rather a reflection of forward-looking market concerns about domestic demand contraction, fiscal sustainability, and external financing conditions. The decline in long-term yields may indicate expectations of disinflation and economic slowdown, or, conversely, raised risk aversion and a demand for duration as a hedge against short-term volatility.

The Market Segmentation Theory (MST) claims that decision-makers can set horizons of rates of interest independently of one another as bond markets with different maturities function independently (Culbertson, 1957). Market demand and supply dynamics influence the rate of interest for both long- and short-term bonds, which markets exhibit autonomous supply and demand (Egert & MacDonald, 2009). According to the MST theory, the link between the current and future rate of interest is either absent or non-existent. In contrast to the MST, Expectations Theory (ET)[1] analyzes the impact of borrower and investor expectations on the rates of interest. Monetary policy influencing long-term interest rates by changing market expectations through to short-term rates, demonstrates a cointegration relationship between these two (Carrieroa et al., 2006; Guidolin & Thornton, 2018).

Kagraoka & Moussa (2013) offered strong proof supporting the ET in relation to the Japanese term control of rates of interest throughout financial ease. Weber & Wolters (2013) found a notable time effect of policy on both long- and short-term rates of return in the USA between 1979 and 2008. Moreover, the US term structure displayed a modest association and a gradual shift in the long-term relationship. According to Akram & Mamun (2023), an increase (decrease) in the rate of short-term interest payments corresponds to an increase (decrease) in the rate of return on long-term sovereign bonds. Sunal (2020) explored the dynamics of rates of interest in Turkey, revealing that variations in rates for short periods impact the rate of interests for lending and deposits set by banks.

A significant amount of literature investigates the response and co-movement of the long-term rate of interest following alterations in the policy rate. Pointing to a little negative correlation in recent times, Thornton (2012) examined private US riskless pure reduction

[1] This study uses Expectations Theory (ET) and Expectations Hypothesis (EH) interchangeably.

bonds and notes and finds that they react less and less to movements in Federal Funds. Akhtar (1995) and Mehra (1996) contended that the impacts of monetary policy are observable solely in the short term, while remaining constant in the long term; the real rate of interest is dictated by the return on capital. Hadi et al. (2019) found an unusual opposite association between both medium and long-term rate of returns in Malaysia. Özdemir & Özel (2012) conducted an analysis of Turkey's rate of interest term framework during the period from 2003 to 2010, and identified the foundational basis for the rate of interest, demonstrating its correspondence with the EH. The paper investigates the longer-term reliability of Turkey's Expectation Hypothesis of the Term Structure (EHTS), indicating that the yield curve has an opportunity to predict future interest rate changes depending on current economic circumstances.

The available studies show an insufficient investigation of the relationship between the two types of interest rate mechanisms. This research is expected to make a substantial contribution to the existing body of knowledge on the topic, using new evidence from Turkey to shed light on how interest rate horizons are connected by dividing the Turkish sovereign bond market into three markets with different maturities. This paper also investigates the validity of the link between the two types of rates of interest on sovereign debt instruments through the perspectives of market segmentation and expectation theories. Since the government bond rates of interest act as a benchmark for other interest rates and significantly impact the real economy, policymakers frequently utilize them as an effective intervention instrument. Financial institutions, such as banks, use government bond interest rates as a measure for determining lending rates. This study contrasts with prior research in Turkey by analyzing the relationship between the rate of interests on government bonds, emphasizing their term structure. The observed cointegration in the empirical research exploring the long- and short-term yields of return for bonds with government rates of interest reveals a pass-through effect of the rates of return.

The remainder of the study is structured as follows. Section 2 provides a summary of the related literature. Section 3 explains the data and the results of the diagnostic tests, and Section 4 provides the methodologies used in the empirical analyses and discusses the results. Section 5 concludes.

2 Related Literature

Studies have concentrated on the dynamics and main elements shaping the association between the two types of rate of interest. Hadi et al. (2019) and Mustafa & Rahman (1995), utilizing error correction models (ECM) to investigate this relationship, confirm the MST, indicating that long- and short-term bond markets exhibit distinct characteristics. The decisions and risk tolerance of investors significantly influence the interactions within these rates. Shrestha & Tan (2005) conducted additional research employing wavelet analysis in conjunction with ECM to investigate the relationships among G-7 countries. The findings show both short-term and long-term links; yet, the rigorous rate of interest parity theory is not supported. This suggests that, while correlations are present among the rates over various time horizons, additional variables also affect their variations.

Furthermore, some studies examine the relationship from a historical perspective. Mankiw & Summers (1984) did a regression analysis on data from 1963Q1 to 1983Q4 and discovered compelling evidence that the EH regarding the conceptual framework for rates of interest is not valid. For most of the 19 nations included in the sample, Arize et al. (2002) found a persistent relationship in both the short and long term (except for the United Kingdom). The research highlights the significant correlations among these rates across various economies. Economic conditions and policy decisions can influence the relationship, resulting in fluctuations in the strength of the connection and the interactions between these rates.

The country-specific historical context and economic structure significantly influence the relationship between the two interest rates. Aklan & Nargeleçekenler (2008) investigated the relationship in Turkey and concluded that there was no significant statistical association between long-term government debt securities and the rate of interest decisions of the Central Bank of the Republic of Turkey (CBRT). Arslan (2012) established that the shorter-term rate of interest has a significant impact on the longer-term rate of interest in the Turkish fixed-income securities market. The positive correlation between long- and short-term rates of interest, especially apparent in the post-2002 period (Sarac & Ucan, 2013), has improved the performance of monetary policy transmission mechanisms. Eroğlu & Yıldırım Karaman (2018), unlike other research in the literature, looked at how monetary policy shocks from the CBRT and the US Federal Reserve (Fed) affected Turkish financial markets between 2010 and 2016. The findings indicate that the yield curve was steepened by the expansionary monetary policy shocks carried out by the CBRT, which had more effect on the short-term rate of interests than on the long-term ones. The study also found that the CBRT's policy efficacy has declined in the post-2010 era, largely due to the lack of a clear and consistent monetary policy framework and increasing uncertainty about long-term goals.

Kose et al. (2012) studied the relationships between interest rates and inflation in Turkey and found that short-term rates have a positive impact on longer-term rates. Additionally, within Turkey's inflation targeting framework, the EH holds. Özdemir & Özel (2012) found that Turkey's long-term rate of interests conform to the EH, suggesting that these rates are signs of expected future short-term rates. Kutlar & Sarıkaya (2003) established a sustained positive correlation between loan and deposit rates, as well as short-term deposit rates. Kutlar & Sarıkaya (2003) demonstrated a positive correlation between short-term deposit rates and both deposit and loan rates over time. The findings indicate a complex relationship between long- and short-term rate of interests. Broadened observations frequently demonstrate a consistent negative correlation.

The reviewed literature on the case of Turkey is extensive and points to the need for ongoing research and analysis to achieve a comprehensive understanding of the complexities within the rate of interest structure. This research seeks to address this need.

3 Data and diagnostics

This study uses monthly Turkish sovereign bond yield data (from February 2010 to June 2024) for three different maturities. The ten-year (10Y) sovereign bond rates indicate the long-term interest rate, while the two-year (2Y) and five-year (5Y) bond yields refer to the short-term interest rates. The following covariates are used to estimate the yields of these bonds: the interest rates on three- and six-month Treasury bills (3M and 6M, respectively) and the monthly Consumer Price Index (CPI). All variables are expressed in logarithms to remove conventional patterns and different levels of variability in economic data, thereby enhancing stability and approximating a normal distribution (Koop, 2013). We sourced the information from Investing.com. Two separate techniques are employed to highlight the connection between the long- and short-term rates of return.

The CPI is used as a control variable for evaluating the effect of inflation on the long- and short-term rates of interest. High inflation leads to a depreciation of currencies and prompts investors to anticipate greater real returns, resulting in an increase in nominal interest rates (Mishkin, 2016). According to the Fisher hypothesis (Fisher, 1930), adjustments in the forecast inflation rate lead to nominal interest rates to fluctuate over time; throughout the sample period, in cases of uncontrollable inflation, the nominal rate of interest is observed to be significantly elevated. Central banks in inflation targeting countries systematically modify the interest rate to influence inflation expectations and attain price stability (Taylor, 1993). The Turkish economy has experienced periods of high inflation characterized by a substantial rate of interest. The central bank regulates inflation alongside the rate of interest as its policy tool. This includes inflation as a control parameter, allowing the model to distinguish between how it influences the rate of interest on both long- and short-term.

Table 1: The correlation matrix

	3M	6M	2Y	5Y	10Y	CPI
3M	1					
6M	0.9474	1				
2Y	0.9706	0.9191	1			
5Y	0.9284	0.8898	0.9728	1		
10Y	0.9085	0.8745	0.9634	0.9901	1	
CPI	0.4596	0.4563	0.5196	0.5418	0.5573	1

Table 1 illustrates a substantial positive and statistically significant relationship among the several interest rate variables. The temporal co-movement of variables depicted in Figure 1 suggests potential co-integration among them.

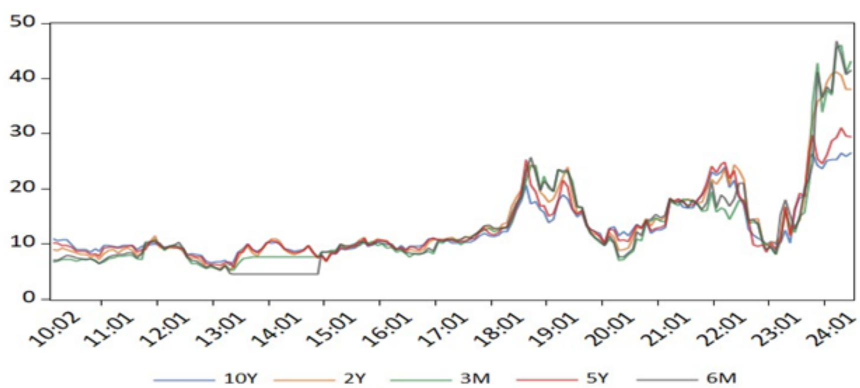

Figure 1: Graphical representation of rate of interests applied to government bonds

Figure 1 demonstrates the way government bond term structures for interest rates have shifted. Whereas rates on 2Y, 5Y, and 10Y government bonds reveal intermediate and long-term rates of interest, respectively, the rates of interest on all three- and six-month government bills show shorter-term rates of interest. Government bonds with maturities of three and six months, two years, five and ten years exhibited a stable trend in nominal interest rates. In 2013 and 2014, short-term rate of interest curves consistently positioned below those of long-term rate of interest lines. In previous years, the rates of interest on short- and long-term sovereign bonds frequently exhibited comparable changes. The macroeconomic fluctuations in the Turkish economy may account for the observed growth in all periods since 2018. A rapid shift in the value of currencies and important inflation in 2018 posed a clear threat to the Turkish Lira (TL) assets and triggered a quick rise in the rates of interest. Figure 1 indicates that the series is non-stationary and exhibits mutual movement, implying potential cointegration among the variables. The following phases of the investigation utilize the unit root and cointegration examinations.

3.1 Unit root tests

Specifically, the ADF (Augmented Dickey-Fuller) and (PP) Phillips-Perron tests for unit roots show that the variables are unstable at their level; stability occurs at their first differences, and these results are demonstrated in Table 2.

Table 2: Results for Augmented-Dickey Fuller and Phillips–Perron unit root tests

	ADF			**PP**		
Variables	Constant	Trend	Constant & Trend	Constant	Trend	Constant & Trend
Level						
2Y	-0.778	-2.420	0.806	-1.012	-2.818	0.806
5Y	-1.288	-3.018	0.501	-1.288	-3.097	0.473
10Y	-1.094	-2.925	0.551	-1.293	-3.246	0.578
3M	-0.529	-1.950	1.084	-0.815	-2.395	0.990
6M	-0.689	-2.096	0.870	-0.889	-2.386	0.796
CPI	-2.316***	-8.893	-0.044	-6.737***	-8.845***	-2.049**
1. Difference						
Δ2Y	-11.840***	-11.864***	-11.815***	-11.857***	-11.896***	-11.812***
Δ5Y	-13.706***	-13.730***	-13.704***	-13.695***	-13.719***	-13.703***
Δ10Y	-13.647***	-13.686***	-13.643***	-13.635***	-13.671***	-13.631***
Δ3M	-11.580***	-11.606***	-11.527***	-11.580***	-11.606***	-11.532***
Δ6M	-12.584***	-12.608***	-12.543***	-12.600***	-12.618***	-12.573***
ΔCPI	-10.818***	-10.777***	-10.820***	-48.181***	-48.536***	-44.765***

Note: ***, ** and * represent 1%, 5% and 10% significance level, respectively.

The ADF and PP unit root tests demonstrate that all variables, except for CPI, display a unit root at the level. In the constant model of the ADF, CPI demonstrates stationarity, while it is nonstationary in the trend and constant & trend models. On the other hand, CPI is stationary in the PP test, across models that include constant, trend, and constant & trend models. The study aimed to address potential unit root issues in the series by utilizing the first differences of the data. The ADF and PP unit root tests presented in Table 2 indicate that following the first difference, all variables get stationarity, indicating an integration of order one, or I(1).

Since the PP and ADF tests do not adequately account for structural breaks, taking into account breaks in structure may lead to the attainment of stationarity in the series. The Bai-Perron test (Bai & Perron, 2003) for unit root is employed for unit root analysis, accepting multiple structural breaks in the series. Over time, economic time series—especially variables affected by monetary policy, like rate of interests, can be impacted by both internal factors (e.g., changes in policy or fiscal reforms) and external factors (e.g., global crises or capital movements), which may lead to changes in their parameters. The Bai-Perron method can identify multiple points where changes occur at unknown times and tests how significant these changes are using F-statistics through a series of model comparisons. The use of the test sets a specific trimming rate (e.g., 15%) and maximum number of breaks to avoid outliers affecting the model and to boost the dependability of the findings. The results of the main Bai-Perron tests are shown in Table 3.

Table 3: Bai-Perron multiple structural break estimated test results

Model	Number of Breaks	Break Dates	F-statistic	Critical value (0.05)
2Y	2	2015M8; 2022M6	26.6570	16.19
5Y	2	2022M6; 2018M10	35.7058	16.19
10Y	2	2018M12; 2022M6	42.4530	16.19

The Bai-Perron test is useful for looking at how events such as changes in monetary policy, financial crises, or shifts in market behavior affect the series by finding periods when there are important changes in the series' parameters over time. The findings presented in Table 3 indicate structural breakdowns in both long- and short-term rate of interest series in Turkey. A series strategy entails testing from one to the maximum number of breakpoints until the null hypothesis is no longer rejected, yielding two breakpoints for all models. According to test results, the statistically significant breakpoints are 2015M8, 2022M6, 2018M10, and 2018M12.

After the June 7 elections, political uncertainty in August 2015 was reflected in the markets as well. In the atmosphere of two months of failed negotiations, the Turkish lira plunged to record lows on consecutive days between August 13 and 25; the USD/TRY exchange rate approached 2.95 on August 24 and crossed the 3.05 threshold a month later. This climb in the currency pushed up inflation expectations and the sovereign debt risk premium, driving the nominal rate of interests to a permanent high. Finally, on August 11-12, China's successive devaluations of the Yuan shook emerging markets across the globe; the global wave of risk aversion also hit Turkey, multiplying the pressure on the already fragile lira and bond rates.

The structural break seen in Turkey's rate of interest series in October 2018 corresponds to the direct aftermath of the serious currency crisis peaking in August 2018. The crisis was influenced by increasing global debt, a significant current account deficit, geopolitical tensions, particularly the dispute regarding Pastor Brunson with the United States, and the belief that monetary policy was insufficient for controlling inflation. In September 2018, the CBRT focused on the crisis by considerably raising its policy rate to prevent a further decline and decrease the declining value of the Turkish lira (TRY). Rising 625 base points, the one-week repo rate shifted from 17.75% to 24%.

Examining the break dates, the 2022M6 time frame emerges as a shared break point for 2Y, 5Y, and 10Y rates of interest. Intense inflationary pressures, a defining feature of the macroeconomic environment, dominated the Turkish economy in June 2022. Official annual CPI rose to 73.5%, which was a level not seen in over two decades and remained on an upward trajectory throughout the year. Despite this alarming inflation rate, the CBRT kept its main policy rate of interest (one-week repo rate) unchanged at 14% in its Monetary Policy Committee meeting at the end of the month, adhering to the government's "New Economy Model" that prioritizes growth and exports through low borrowing costs. This decision verified that the CBRT would not turn to conventional monetary policy to combat inflation, which kept the TL under pressure and raised the rate of interests much more than the policy rate, indicating higher inflation expectations and risk premia. These actions significantly changed the rate of interest behavior and set the basis for the structural breaks.

In the subsequent cointegration analysis, dummy variables will be created for the dates 2015M8 and 2022M6 for the 2Y model, 2018M10 and 2022M6 for the 5Y model, and 2018M12 and 2022M6 for the 10Y model to illustrate the data changes as indicated by the results of the Bai-Perron test. The unit root tests provided in Table 2 show that the variables are non-stationary, which suggests that cointegration is needed for the model choice. Table 4 displays the F-bound test results, demonstrating cointegrated relationships between short- and long-run interest rates in both ARDL (autoregressive distributed lag) and NARDL (nonlinear autoregressive distributed lag) models, as illustrated in equations (1–6) that incorporate structural breaks. The following sections provide a description of the ARDL and NARDL models employed.

3.2 ARDL and NARDL cointegration and structural breaks

The ARDL methodology facilitates the examination of both the long- and short-term links among appropriate factors. The transition from the long-term relationship and the adjustment rate toward the long-term equilibrium are clearly demonstrated. The ARDL approach illustrates the interactions among variables and demonstrates the speed at which imbalances are fixed, facilitating a return to equilibrium.

To improve the investigation of cointegration, Pesaran et al. (2001) proposed the ARDL limits test. Compared to the conventional methods set by Johansen & Juselius (1990) and Engle & Granger (1987), this approach has multiple advantages. Unlike the conventional cointegration approach, which uses a system of equations, the cointegrated ARDL methodology makes use of a single reduced-form formula to investigate long-term trends. Whether the underlying series is purely stationary (I(0)), integrated of order 1 (I(1)), or a mix of both, the cointegrated ARDL model is essential with regard to its stationarity (Pesaran et al., 2001). The following models were used when carrying out the ARDL bounds test.

$$\Delta IR_{2t} = \sum_{i=1}^{a-1} \alpha_{1i} \Delta IR_{2,t-i} + \varphi_1 IR_{2,t-1} + \delta_1 Dum_{2015M8,c} + X + \epsilon_t \tag{1}$$

$$\Delta IR_{5t} = \sum_{i=1}^{a-1} \alpha_{1i} \Delta IR_{5,t-i} + \varphi_1 IR_{5,t-1} + \delta_1 Dum_{2018M10,c} + X + \epsilon_t \tag{2}$$

$$\Delta IR_{10t} = \sum_{i=1}^{a-1} \alpha_{1i} \Delta IR_{10,t-i} + \varphi_1 IR_{10,t-1} + \delta_1 Dum_{2018M12,c} + X + \epsilon_t \tag{3}$$

with the following common covariates

$$X = \alpha_0 + \sum_{j=0}^{c-1} \beta_{1j}\, \Delta IR_{3m,t-j} + \sum_{k=0}^{d-1} \beta_{2k}\, \Delta IR_{6m,t-k} + \sum_{s=0}^{h-1} \gamma_l\, \Delta CPI_{t-l} + \varphi_2\, IR_{3m,t-1} + \varphi_3\, IR_{6m,t-1} + \varphi_4\, CPI_{t-1} + \delta_2 Dum_{2022M6,t}$$

where Δ is the initial difference operator. $\varphi_1, \varphi_2, \varphi_3, \varphi_4$ are the coefficients for the long runs. The null hypothesis states there is no evidence of cointegration; $H_0 = \varphi_1 = \varphi_2 = \varphi_3 = \varphi_4 = 0$. An F-statistic, which is compared with the critical values forecast by Pesaran et al. (2001), determines the overall importance of the lagged level parameters.

According to Shin et al. (2014), a linear combination of unstable series represents the cointegrating relationship between series; however, this might not be correct. The ARDL findings rest on the presumption that the series is linear. Nevertheless, one should also take into account the asymmetries or nonlinearities of these series. The NARDL approach effectively integrates nonlinearities within the longer-term relationship of the series and the error correction system. This study will employ the NARDL method by following Shin et al. (2014) to analyze the nonlinear features of the series. To address the asymmetric (nonlinear) effects, the variables in the models have been categorized into asymmetries by utilizing the components of positive and negative changes of the variables as follows:

$$\begin{aligned} Positive\ changes:\ x_t^+ &= \sum_{i=1}^{t} \Delta x_i^+ = \sum_{i=1}^{t} max(\Delta x_i, 0) \\ Negative\ changes:\ x_t^- &= \sum_{i=1}^{t} \Delta x_i^- = \sum_{i=1}^{t} min(\Delta x_i, 0) \end{aligned}$$

where x covers dependent and independent variables. We conducted the NARDL bounds test using the following models.

$$\begin{gathered} \Delta IR_{2t} = \sum_{i=1}^{a} \gamma_1 \Delta IR_{2,t-i} + \sum_{i=1}^{j} \gamma_8 Dum^+_{2015M8,c,t-i} + \sum_{i=1}^{k} \gamma_9 Dum^-_{2015M8,c,t-i} + \\ \delta_{12} IR_{2,t-1} + \delta_{19} Dum^+_{2015M8,c,t-1} + \delta_{20} Dum^-_{2015M8,c,t-1} + \varphi_t + Y \end{gathered} \tag{4}$$

$$\begin{gathered} \Delta IR_{5t} = \sum_{i=1}^{a} \gamma_1 \Delta IR_{5,t-i} + \sum_{i=1}^{j} \gamma_8 Dum^+_{2018M10,c,t-i} + \sum_{i=1}^{k} \gamma_9 Dum^-_{2018M10,c,t-i} + \\ \delta_{12} IR_{5,t-1} + \delta_{19} Dum^+_{2018M10,c,t-1} + \delta_{20} Dum^-_{2018M10,c,t-1} + \varphi_t + Y \end{gathered} \tag{5}$$

$$\begin{gathered} \Delta IR_{10t} = \sum_{i=1}^{a} \gamma_1 \Delta IR_{10,t-i} + \sum_{i=1}^{j} \gamma_8 Dum^+_{2018M12,c,t-i} + \sum_{i=1}^{k} \gamma_9 Dum^-_{2018M12,c,t-i} + \\ \delta_{12} IR_{10,t-1} + \delta_{19} Dum^+_{2018M12,c,t-1} + \delta_{20} Dum^-_{2018M12,c,t-1} + \varphi_t + Y \end{gathered} \tag{6}$$

with the following common covariates

$$\begin{gathered} Y = \gamma_0 + \sum_{i=1}^{b} \gamma_2 \Delta IR^+_{3m,t-i} + \sum_{i=1}^{d} \gamma_3 \Delta IR^-_{3m,t-i} + \sum_{i=1}^{e} \gamma_4 \Delta IR^+_{6m,t-i} + \sum_{i=1}^{f} \gamma_5 \Delta IR^-_{6m,t-i} + \\ \sum_{i=1}^{g} \gamma_6 CPI^+_{t-i} + \sum_{i=1}^{h} \gamma_7 CPI^-_{t-i} + \sum_{i=1}^{j} \gamma_{10} Dum^+_{2022M6,c,t-i} + \sum_{i=1}^{k} \gamma_{11} Dum^-_{2022M6,c,t-i} + \\ \delta_{13} IR^+_{3m,t-1} + \delta_{14} IR^-_{3m,t-1} + \delta_{15} IR^+_{6m,t-1} + \delta_{16} IR^-_{6m,t-1} + \delta_{17} CPI^+_{t-1} + \delta_{18} CPI^-_{t-1} + \\ \delta_{21}\ Dum^+_{2022M6,c,t-1} + \delta_{22}\ Dum^-_{2022M6,c,t-1} \end{gathered}$$

Based on the limit test results of the ARDL and NARDL given in Table 4, we can reject the assumption that all models' variables lack cointegration. A cointegration relationship between the series suggests an ongoing association within the variables (Pesaran et al., 2001).

The following section of the study will estimate a cointegrated ARDL model by identifying the appropriate lag length.

Table 4: ARDL-NARDL F Bound test results considering structural breaks

		ARDL Test Results			NARDL Test Results	
Model		2Y	5Y	10Y	2Y	5Y	10Y
Selected model		ARDL (9,1,11,11)	ARDL (1,1,5,5)	ARDL (4,0,5,7)	ARDL (4,5,5,5)	ARDL (6,1,1,0)	ARDL (1,0,0,0)
F-Statistics		**4.764****	**12.686*****	**5.443****	**4.980*****	**4.801****	**4.038****
C.V	(I(0))	2.72	2.72	3.47	1.99	2.53	2.49
10%	(I(1))	3.77	3.77	4.45	2.94	3.59	3.38
C.V	(I(0))	3.23	3.23	4.01	2.27	2.87	2.81
5%	(I(1))	4.35	4.35	5.07	3.28	4.00	3.76
C.V	(I(0))	4.29	4.29	5.17	2.88	3.6	3.5
1%	(I(1))	5.61	5.61	6.36	3.99	4.9	4.63
Cointegration decision		YES	YES	YES	YES	YES	YES

Note: ***, ** and * represent 1%, 5% and 10% significance level, respectively.

4 Empirical analysis

This section will utilize ARDL and NARDL model to carry out empirical examinations of the link between long- and short-term rates of interest. Previous results demonstrate a long-term cointegration connection among the examined variables, suggesting that they demonstrate linked movement and sustain a shared equilibrium over time. The ARDL model is suitable in this context when variables have stationarity at different levels (I(0) and I(1)), due to its flexibility and capacity to estimate both long- and short-term dynamics simultaneously. Moreover, if the influence of the rates of interest on economic agents is asymmetrical in response to positive or negative shocks, the NARDL technique effectively allows the identification of the potential nonlinear relationship associated with it. The ARDL model will evaluate the direction and strength of the relationship within this framework. Subsequently, the NARDL model will examine asymmetric adjustment mechanisms, addressing the link between both long- and short-term rates of interest from numerous perspectives.

4.1 Error correction model for ARDL and NARDL models

The error-correction model (ECM) will analyze and quantify the dynamics of short- and longer-term equilibrium relationships between cointegrated (non-stationary) long- and short-term rates of interest as follows

$$\begin{aligned}\Delta IR_{nt} = \psi_0 + \sum_{i=1}^{p-1}\psi_{1i}\Delta IR_{n,t-i} + \sum_{j=0}^{q-1}\theta_{1j}\Delta IR_{3m,t-j} + \sum_{k=0}^{r-1}\theta_{2k}\Delta IR_{6m,t-k} + \\ \sum_{s=0}^{s-1}\eta_l\Delta CPI_{t-l} + \lambda\, ECM_{t-1} + \delta_1 Dum_{2022,t} + \delta_2 Dum_{2022,c} + \omega_t\end{aligned} \quad (7)$$

The error correction term, ECM_{t-1}, is a residual of the long-run models.

$$\begin{aligned}ECM_{t-1} = IR_{n,t-1} - (\phi_0 + \phi_1 IR_{3m,t-1} + \phi_2 IR_{6m,t-1} + \phi_3 CPI_{t-1} + \\ \delta_1 Dum_{2022M6,t} + \delta_2 Dum_{2022M6,c})\end{aligned} \quad (8)$$

where λ stands for the speed of the adjustment coefficient, which is expected to be negative and statistically significant (Engle & Granger, 1987). Short run ECM_{t-1} models are given in equations (9-11);

$$\Delta IR_{2t} = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \, \Delta IR_{2,t-1} + \sum_{j=0}^{q} \beta_1 \, \Delta IR_{3m,t-j} + \sum_{k=0}^{r} \beta_2 \, \Delta IR_{6m,t-k} + \sum_{l=0}^{s} \Delta\gamma_l \, \Delta CPI_{t-l} + Dum_{2015M8,c} + Dum_{2022M6,t} + \varphi ECM_{t-1} + \epsilon_t \tag{9}$$

$$\Delta IR_{5t} = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \, \Delta IR_{5,t-1} + \sum_{j=0}^{q} \beta_1 \, \Delta IR_{3m,t-j} + \sum_{k=0}^{r} \beta_2 \, \Delta IR_{6m,t-k} + \sum_{l=0}^{s} \Delta\gamma_l \, \Delta CPI_{t-l} + Dum_{2018M12,c} + Dum_{2022M6,t} + \varphi ECM_{t-1} + \epsilon_t \tag{10}$$

$$\Delta IR_{10t} = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \, \Delta IR_{10,t-1} + \sum_{j=0}^{q} \beta_1 \, \Delta IR_{3m,t-j} + \sum_{k=0}^{r} \beta_2 \, \Delta IR_{6m,t-k} + \sum_{l=0}^{s} \Delta\gamma_l \, \Delta CPI_{t-l} + Dum_{2018M12,c} + Dum_{2022M6,t} + \varphi ECM_{t-1} + \epsilon_t \tag{11}$$

Developed by Shin et al. (2014), NARDL-ECM improves the traditional ARDL framework by allowing the modeling of both longer- and short-term asymmetries in the interactions between economic variables. Separating independent variables into both their positive and negative parts allows the NARDL model to identify possible nonlinearities and asymmetric adjustment directions that traditional linear models might miss. In macroeconomic and financial studies, where variables like interest rates, inflation, or exchange rates might show different effects depending on their upward or downward trends, this approach is particularly beneficial. A wrong correction element lets the model assess the speed and trajectory of long-run equilibrium deviations over time, therefore offering insights into both sides. The NARDL-ECM is a useful and widely applicable approach in empirical research, demonstrating stability to mixed orders of integration (i.e., I(0) and I(1)) and suitability for cases involving structural breaks or regime changes Bahmani-Oskooee & Fariditavana (2016). The NARDL-ECM model is constructed as follows:

$$\Delta IR_{2t} = \varphi \left(IR_{2,t-1} - \theta_4 Dum_{2015M8,t-1} \right) + \sum_{i=1}^{d-1} \Psi_i \Delta IR_{2,t-i} + K \tag{12}$$

$$\Delta IR_{5t} = \varphi \left(IR_{5,t-1} - \theta_4 Dum_{2018M12,t-1} \right) + \sum_{i=1}^{d-1} \Psi_i \Delta IR_{5,t-i} + K \tag{13}$$

$$\Delta IR_{10t} = \varphi \left(IR_{10,t-1} - \theta_4 Dum_{2018M12,t-1} \right) + \sum_{i=1}^{d-1} \Psi_i \Delta IR_{10,t-i} + K \tag{14}$$

with the following common covariates

$$K = \varphi\,(-\theta_1^{+} IR_{3,t-1}^{+} - \theta_1^{-} IR_{3,t-1}^{-} - \theta_2^{+} IR_{6,t-1}^{+} - \theta_2^{-} IR_{6,t-1}^{-} - \theta_3 CPI_{t-1} - \theta_5 Dum_{2022M6,t-1}) + \sum_{j=1}^{n-1} (\lambda_{1j}^{+} \Delta IR_{3,t-j}^{+} + \lambda_{1j}^{-} \Delta IR_{3,t-j}^{-} + \lambda_{2j}^{+} \Delta IR_{6,t-j}^{+} + \lambda_{2j}^{-} \Delta IR_{6,t-j}^{-} + \lambda_{3j}^{+} \Delta CPI_{t-j}^{+} + \lambda_{3j}^{-} \Delta CPI_{t-j}^{-}) + \epsilon_t$$

where φ is the error correction coefficient representing the speed of adjustment, and "–" and "+" signs indicate the short-run asymmetric effects of variables.

Table 5: Estimated ARDL and NARDL long-term coefficients

ARDL Test Results				NARDL Test Results			
	Model1: 2Y	Model2: 5Y	Model3:10Y		Model4: 2Y	Model5: 5Y	Model6: 10Y
Variables	Coefficients	Coefficients	Coefficients	Variables	Coefficients	Coefficients	Coefficients
3M	0.643***	0.031	0.105	3M (+)	0.831***	–0.024	0.014
6M	0.146	0.443	0.526*	3M (–)	0.491***	0.019	0.059
CPI	0.862***	0.567**	0.631***	6M (+)	–0.004	0.060***	0.023
C	0.290*	0.349	0.023	6M (–)	0.317**	0.013	-0.027
				CPI(+)	1.240***	0.0222	0.0298*
				CPI (–)	1.237***	0.056***	0.065***
				C	8.955***	1.155	1.005

Note: ***, ** and * represent 1%, 5% and 10% significance level, respectively.

While the dependent variables are yields of Turkish government bonds with two-year (2Y), five-year (5Y), and ten-year (10Y) maturities, the independent variables in Models 1 to 6 consist of three-month (3M) and six-month (6M) Treasury bill rates and the CPI.

In the ARDL 2Y model, the 3M and CPI have significant positive coefficients; a 1-unit increase in the 3M interest rate (CPI) generates a 0.643 (0.862) rise in the interest rate of 2Y bonds. The notable influence of the 3M emphasizes that the ET holds that long-run rates of interest are the mean of projected future years' short-run interest rates. The 3M rate of interest, as a sign of monetary policy, drives yield changes at short and midterms by shaping investors' expectations about future policy courses. Similarly, the CPI coefficient supports the Fisher Effect, which holds that nominal rates preserve real returns and stabilize projected inflation. The size of the coefficient suggests an inflation risk premium mirroring Turkey's past of high inflation. The results we obtained align with those of Arize et al. (2002), which looked at 19 countries; Shrestha & Tan (2005), which looked at the G-7 countries; Akram & Uddin (2021), which looked at Brazil; and also with those of on Turkey Kutlar & Sarıkaya (2003); Özdemir & Özel (2012); Arslan (2012); Sarac & Ucan (2013). The findings indicate that the short-term rate of interest significantly affects the rate of interest on 2Y bonds within the Turkish bond market. The structure of Turkey's sovereign bond rate of interest supports expectation theory.

The ARDL long run findings in the 5Y model reveal a positive and significant CPI coefficient, supporting the Fisher Effect. The coefficients for 3M (0.031) and 6M (0.443) are statistically insignificant, indicating that the short-term rate of interest does not affect the mid-term rate of interest. In the ARDL 10Y model, the 6M interest rate (0.526) and CPI (0.631) significantly positively impact the long-run sovereign rate, respectively, correlating with the previously referenced EH and Fisher effect.

In the NARDL results for the 2Y model, the 3M(+) coefficient (0.831) exceeds the 3M(-) coefficient (0.491). An increase of 1 unit in the 3M rate of interest results in a 0.831 increase in the rate of interest on 2Y government bonds, hence backing the EH. Conversely, a 1 unit decrease in the 3M rate leads to a 0.491 increase in 2Y rate of interest. Thus, depending on the results, one could say that rate hikes suggest permanent monetary tightening and generate stronger market responses given the expectation that future rates of interest will be higher; on the other hand, rate cuts are viewed as temporary and generate fewer reactions.

The comparable values of CPI(+) (1.240) and CPI(-) (1.237) coefficients suggest that the bond market reacts with equal strength to inflation surprises in either direction, and there's no significant asymmetry between how bond markets price inflation versus disinflation shocks. The policy implication indicates that the central bank responds similarly to influence markets when addressing either inflation or deflation. The NARDL results for the 5Y model demonstrate that the coefficients of 3M(+) and 3M(-) lack statistical significance, indicating that fluctuations in interest rates within the 3M sovereign bond market do not influence the yield of 5Y government bonds. This result is consistent with the MST, which posits that the 5Y market is largely protected from shorter-term policy revisions.

The coefficient of 6M(-) (0.014) is statistically insignificant, whereas the coefficient of 6M(+) (0.060) displays a small impact on 5Y yields, confirming the EH dynamics in which only tightening signals affect medium-term expectations. An insignificant and a significant coefficient of CPI(+) and CPI(-), respectively, means that mid-term bond rates fall as CPI falls, reflecting market participants' increased demand for bonds with mid-term maturity which, in turn, reduces yields on 5Y bond. The findings of the NARDL 10Y model show no impact of 3M and 6M short-term interest rates of government bonds on the long-term rate of interest. Long-term yields emphasize long-horizon expectations, such as inflation and risk and indicate that the influence of shorter-term interest rates is not helpful in the long term, which is consistent with the MST. The coefficient on CPI(-) (0.059) exceeds the coefficient on CPI(+) (0.014), indicating stronger disinflationary effects in line with the Fisher Effect.

The findings from ARDL and NARDL indicate that short-term rates of interest (3M and 6M) affect 2Y bond rates, but do not impact 5Y and 10Y rates. This suggests that the ET applies to the 2Y bond market, while the SMT is relevant for the 5Y and 10Y bond markets. The results demonstrate that inflation (CPI) considerably affects all rates of return in ARDL and NARDL, showing the significant Fisher effect in Turkey. The findings are consistent with Arize et al. (2002), Akram & Uddin (2021), and studies on Turkey (e.g., Sarac & Ucan, 2013) and show that while short-term rates of interest and inflation guide shorter horizons, only inflation rules longer horizons.

For the monthly data, the value of the ECT coefficient indicates the speed of adjustment. To correct 90% of the shock, its value smaller than 0.10 indicates that the adjustment takes more than 22 months, values between -0.10 and -0.20 are considered moderate, which takes 11–22 months, values between -0.20 and -0.40 are considered fast, which takes 6-11 months, and, lastly, values bigger than -0.40 are considered very fast, which takes less than 6 months.[2]

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[2] Note that the periods are calculated using the following formula:

$$\frac{ln(1-0.9)}{ln(1-\ ECT\ Coefficient)}$$

Table 6: ARDL-short-term coefficients of error correction model

Model 1: Short-term results of the 2Y model:											
Variable/Lag order	0	1	2	3	4	5	6	7	8	9	10
ECM_{t-1}	–0.365***	–0.368***	0.187**	–0.018	0.319***						
$\Delta 3M$	0.504***	0.398***	–0.118	0.037	–0.341***						
$\Delta 6M$	0.245***										
ΔCPI	0.100**										
$DUM2015M8$	0.883										
$DUM2022M6$	0.411										
C	0.749***										
Model 2: Short-term results of the 5Y model:											
ECM_{t-1}	–0.275***										
$\Delta 3M$	0.357***	–0.427***	–0.039	–0.288***	0.241**	–0.005	0.137**				
$\Delta 6M$	0.109	0.344***	–0.038	0.170*	–0.309***						
$\Delta 5Y$		0.012	0.081	0.335***							
ΔCPI	0.156**										
$DUM2018M10$	–1.348										
$DUM2022M6$	–4.000***										
C	1.155***										
$Trend$	0.006***										
Model 3: Short-term results of the 10Y model:											
ECM_{t-1}	–0.185***										
$\Delta 3M$	0.350***	–0.488***	–0.011	–0.065	0.152	–0.207	0.074	0.038	–0.078	0.370**	0.616***
$\Delta 6M$	0.207**	0.234**	–0.081	–0.003	–0.335***	0.026	–0.076	–0.019	–0.002	–0.266*	–0.744***
$\Delta 5Y$		0.188*	0.110	0.296***	–0.052	0.186*	0.109	–0.032	0.188**		
ΔCPI	0.107**										
$DUM2018M12$	0.607										
$DUM2022M6$	–2.314*										
C	1.566***										

Note: ***, ** and * represent 1%, 5% and 10% significance level, respectively.

The values for the ECTs in the models are -0.365 for 2Y, -0.275 for 5Y, and -0.185 for 10Y models. All ECM coefficients demonstrate statistically significant effects at the 1% level, indicating a steady longer-term link between both longer- and shorter-term interest rates. The coefficients of the ECTs indicate a rapid adjustment toward equilibrium following any deviation from it. The slower speed of adjustments in the long-run models (10Y) is smaller than that of the 2Y and 5Y models. Long-term investors like pension funds and insurers are less affected by shorter-term monetary policy changes, which results in slower adjustments and clarifies this result. Conversely, short- to mid-term investors (2Y and 5Y) respond more rapidly to policy changes, consistent with the EH and aligns with Egert & MacDonald (2009), who argue that segmented markets exhibit weaker arbitrage linkages, delaying convergence to equilibrium.

The positive contemporaneous coefficient for 3M in the ARDL in the short-run 2Y model suggests that a 1% rise in the 3-month rate of interest raises the 2Y rate of interest by 0.504%. The negative first (-0.368), positive second (0.187), and positive fourth (0.319) lags indicate distinct market reactions to monetary policy signals and liquidity premia. The long-term transmission suggests persistent effects of short-rate changes on long-run rates through monetary policy credibility or institutional adjustments. The sum of the coefficients ($0.642 = 0.504_{t=0} - 0.368_{t=1} + 0.187_{t=2} + 0.319_{t=4}$) gauges the cumulative short-run impact of a sustained 1-unit rise in 3M. The positive CPI coefficient (0.100) confirms the Fisher effect, by which the 2Y rate of interest increases with inflation expectations. High and variable inflation in Turkey may have amplified this effect, as investors seek greater returns to reduce inflation risk.

The 5Y model's ECT (-0.275) coefficient is a fast adjustment, indicating efficient arbitrage, which means investors quickly align 5Y rates with the 3M rate changes. For 3M, the strong initial response (0.353) is offset by both negative and positive delays, suggesting that while there was a quick reaction, it was followed by a partial reversal, likely because of shifting expectations and some ongoing effects in the 5Y bond market related to 3M rate of interest changes. The notable first lag (0.344) and negative fourth lag (-0.309) suggest lagged effects, suggesting a nonlinear association between the 6M and the 5Y rate of yields. The term "trend" highlights the influence of ongoing inflationary pressures characterizing the Turkish economy throughout the 2010s and 2020s.

The ECT of -0.185 suggests that 10Y rate of interest changes lightly to deviations from equilibrium, with 18% of the imbalance corrected each month. This rate is slower than the 2Y and 5Y models, indicating notable differences in the responsiveness of long-term compared to intermediate rates to fluctuations in the short-term rates. The notable influence of changes in the 3M indicates that short-term monetary policy rapidly impacts long-term rates, likely due to expectations of higher future rates. However, a strong reversal at a 1-month lag of –0.49% drops the 10Y rate, implying markets may initially overprice rate hikes, then adjust. Lags 2–8 do not have significance, indicating an absence of constant medium-term effects. After a duration of 9 to 10 months, the 3M rate significantly influences the 10Y rate positively (0.3% and 0.62% at the 9^{th} and 10^{th}, respectively), which may imply long-term rates eventually adjust to short-term trends (consistent with the Expectations Hypothesis). Notice that monetary policy transmission takes nearly a year to fully impact the 10Y long-term rate in Turkey, which is the longest compared to the 2Y and 5Y rates. The CPI (0.107) indicates that the 10Y rate is not greatly influenced by inflation. The ARDL method's decisions are dependent on the presumptions of a linear relationship between the series, a premise that might not be true. Used to examine the nonlinearities of long-short-run rate of return in the bond market, the NARDL approach is founded on the ARDL structure developed by Shin et al. (2014).

Table 7: NARDL-short-term coefficients of error correction model

Lag order						
Model 1: Short-term results of the 2Y model:						
Variable	0	1	2	3	4	5
$\Delta 2Y$		0.232**	0.244***	0.201**		
$\Delta 3M(+)$	0.506***	–0.526***	0.157	–0.332***	0.354***	
$\Delta 3M(-)$	0.428**	–0.167	–0.037	0.2920*	–0.101	
$\Delta 6M(+)$	0.067	0.313***	–0.071	–0.030	–0.329***	
$\Delta 6M(-)$	0.751***	–0.087	–0.186	–0.380**	0.091	
$\Delta CPI(+)$	0.090	–0.260**	–0.454***	–0.019	–0.297**	
$\Delta CPI(-)$	0.211**	–0.373***	–0.108	–0.349***	–0.181*	
$DUM2015:M8$	0.848					
$DUM2022:M6$	–1.068					
C	0.005***					
ECM_{t-1}	-0.564***					
Model 2: Short-term results of the 5Y model:						
$\Delta 5Y$		–0.035	0.108	0.170**	–0.090	0.172**
$\Delta 3M(+)$	0.025***					
$\Delta 3M(-)$	0.018					
$\Delta 6M(+)$	–0.003					
$\Delta 6M(-)$	0.017					
$\Delta CPI(+)$	0.007					
$\Delta CPI(-)$	0.017***					
$DUM2018:M10$	–0.091					
$DUM2022:M6$	–0.147					
C	0.635***					
ECM_{t-1}	-0.310***					
Model 3: Short-term results of the 10Y model:						
$\Delta 10Y$		-0.160*	0.033	-0.086	-0.147*	
$\Delta 3M(+)$	0.004	-0.012				
$\Delta 3M(-)$	0.016	-0.010				
$\Delta 6M(+)$	0.006	0.002*				
$\Delta 6M(-)$	-0.007	-0.025				
$\Delta CPI(+)$	0.008					
$\Delta CPI(-)$	0.017***					
$DUM2018:M12$	-0.006					
$DUM2022:M6$	-0.099					
C	0.573***					
ECM_{t-1}	-0.267***					

Note: ***, ** and * represent 1%, 5% and 10% significance level, respectively.

The ECM coefficient of -0.564 in your 2Y NARDL model shows an exceptionally rapid adjustment of the 2Y rates to deviations from their long-run equilibrium with 3-month rates (3M). This ECM coefficient is a faster adjustment than those of all models examined in the ARDL and NARDL models reported in Tables 6 and 7. A 1% deviation from equilibrium is halved in less than a month (approximately 24 days). Moreover, it is far faster than typical financial or macroeconomic adjustments. In the short run, positive 3M rate of interest changes have a higher simultaneous effect (0.506) on the 2Y rate than negative ones (0.428). 1% increase in the 3M rate raises 2Y rate by 0.506%, whereas a 1% decrease reduces it by 0.428%. Raising rates has 18% higher impact than cutting them (0.506 vs. 0.428). Positive

6M rate of interest changes, 6M(+), is not statistically significant, while 6M(-) is significant at 1% significance level, implying the 2Y rate of interest does not respond to positive 6M rate of interest hikes, while its response to negative 6M cuts. The lags of the short-run rate of interest and inflation in the 2Y model exhibit significant positive and negative coefficients, indicating volatile adjustments following the impacts. Positive inflation rises CPI(+) are not affecting the 2Y rate, while falls in inflation reduce the 2Y rate, consistent with asymmetry found in Bahmani-Oskooee & Saha (2019) for inflation-yield relationships.

The 5Y model indicates that the coefficients of Δ3M (+) 0.025 and ΔCPI (-) 0.017 are statistically significant. This implies that an increase in the 3M rate elevates the mid-term rate, while a decrease in CPI diminishes it, consistent with the ET and Fisher effects. The ECT coefficient of the 10Y model, with the slowest adjustment, is (-0.267), which shows that 26% of the deviation from the former period will be corrected in the subsequent period, so driving the series back to equilibrium over the long run. Outcomes of the model show that the longer-term rate (10Y) cannot be influenced by the interest rate of short-term bonds.

Results from the NARDL short-run model of the 10Y model point to 3- and 6-month interest rates, together with CPI(+), not much influencing the return rate of 10Y bonds issued by the government within the sample period, therefore supporting the existence of the SMT in Turkey. Overall, the results show that while the 3M policy-sensitive rate of interest's direct impact on the 2Y yield is strong, it decreases notably for 5Y and 10Y yields, in line with the Rational Expectations Hypothesis being stronger at shorter horizons in ARDL and NARDL models. This implies that elements outside immediate policy expectations, such as risk premiums, are increasingly influencing longer-term returns, therefore supporting the concepts of market segmentation, whereby various factors drive various maturity segments.

At all models of NARDL, inflation CPI(-) is significant and positive while CPI(+) is insignificant, indicating that a fall in CPI reduces the rate of interest on all maturities; however, an increase in the CPI(+) does not affect them. This suggests that while markets do not react similarly to a rise in the CPI, they cope with a drop in the CPI by awaiting a decrease in the policy rate by the central bank. This indicates that market participants perceive the central bank as liable to lower the policy rate rather than raise it in response to fluctuations in the CPI.

4.2 Toda and Yamamoto causality test

The ARDL and NARDL systems used in previous studies are efficient ways to estimate both long- and short-run associations among variables demonstrating mixed integration orders (I(0) or I(1)). These models need the Toda and Yamamoto (TY) causality tests since they have no information on the direction of causality between variables. The subsequent phase will consist of causality analysis to verify the coherence of our earlier results. Causality tests, such as Granger and TY, are useful for determining whether one variable influences another over the long term. The standard Granger causality test is ineffective because the series is combined into multiple series. This procedure permits using the TY causality test (Toda & Yamamoto, 1995). For examining Granger causality in non-stationary or cointegrated time series data, the TY causality test offers a powerful econometric tool. The TY approach differs from the standard Granger causality test by adapting variables with varying degrees of integration (I(0), I(1), or I(2)). This is achieved through the estimation of a Vector Autoregression (VAR) model at augmented lagged levels.

Table 8 presents the results of the TY causality test, which examines the pattern and importance of cause and effect between short- and long-run rates of return. Indicators associated with significance levels, the χ^2 statistic, and its accompanying p-values have been used for analyzing the test outcomes. Strong evidence suggests a causal relationship from the CPI to the 2Y rate of return, revealing that significant fluctuations in inflation significantly shape the 2Y rates of interest. The findings reveal that the short-term rate of interest (3M) Granger-causes the 2Y rate of interest, hence supporting the ET by suggesting their forecasting function. Particularly from 2Y to 3M, there is significant reverse causality, which suggests a feedback mechanism with inflation patterns and the rate of interest. At both the 5% and 1% significance levels, the null hypothesis that CPI and 3M do not Granger-cause 5Y is rejected. While the latter shows slight significance at the 10% level, CPI forecasts the 5Y rate of interest. The 6M rate demonstrates a causal influence on the 5Y rate, suggesting that it can serve as a predictor for the 5Y rate of interest. Furthermore, the 5Y rate appears to exhibit causal effects on both CPI and short-term interest rates.

Table 8: Results of the Toda and Yamamoto causality test

Dependent Varibles	Independent Variables					
Model1: 2Y						
	3M χ^2	6M χ^2	CPI χ^2	2Y χ^2	5Y χ^2	10Y χ^2
3M→	-	0.389	6.259**	4.044**		
		(0.533)	(0.012)	(0.044)		
6M→	1.135	-	3.119*	2.493		
	(0.287)		(0.077)	(0.114)		
CPI→	3.497*	5.843***	-	10.927***		
	(0.062)	(0.016)		(0.001)		
2Y→	14.805***	1.642	7.136***	-		
	(0.000)	(0.200)	(0.008)			
Model2: 5Y						
3M→	-	1.947	9.365**		6.573*	
		(0.583)	(0.025)		(0.087)	
6M→	3.521	-	5.574		9.016**	
	(0.318)		(0.134)		(0.029)	
CPI→	9.692**	10.809**	-		8.349**	
	(0.021)	(0.013)			(0.039)	
5Y→	12.293**	6.714 *	15.762***		-	
	(0.026)	(0.082)	(0.001)			
Model3: 10Y						
3M→	-	1.915	7.487**			8.934*
		(0.166)	(0.024)			(0.082)
6M→	3.923	-	4.560			5.693*
	(0.141)		(0.102)			(0.058)
CPI→	8.088 **	10.627***	-			7.820**
	(0.018)	(0.005)				(0.020)
10Y→	10.708	8.165**	16.966***			-
	(0.105)	(0.017)	(0.120)			

Note: ***, ** and * represent 1%, 5% and 10% significance level, respectively.

The model demonstrates a bidirectional relationship, wherein the 5Y rate affects both CPI and 3M, subsequently improving the links between inflation and expected shifts in monetary policy. At the 10% significance level, the 3M and 6M rates exhibit minimal influence on the 10Y rate and do not Granger-cause the 10Y rate. CPI demonstrates a significant causal relationship with the long-term rate of interest, indicating that the behavior of long-run yields is influenced by inflationary trends and long-term policy rates. Conclusions of the causality test indicate the CPI is crucial and shapes the interest rate dynamics in all maturities. This emphasizes an interaction in which fluctuations in the rate of interest result from inflation expectations. Especially the 3M rate is frequently the Granger cause in longer maturities, hence confirming the ET of the yield curve and the central bank's role in future periods' interest rate movements. The finding that 3M and 6M rates of interest Granger-cause longer-term rates (2Y, 5Y, and 10Y) supports the EH of the yield curve, which posits that current and expected future short-term rates influence long-term rates of interest. It also suggests that messages from monetary authorities included in rates for short periods of time change through the rate of return curve, forming expectations for investors on the future of the economy.

Table 9: Results of diagnostic tests

	ARDL Test Results			NARDL Test Results		
Test	Model1:2Y	Model2: 5Y	Model3: 10Y	Model1:2Y	Model2: 5Y	Model3: 10Y
Adjusted R-squared	0.485	0.955	0.967	0.849	0.429	0.189
F-statistic	70.469***	152.011***	98.840***	16.576***	5.803***	3.545***
LM Test	(0.975)	0.081*	(0.958)	(0.664)	(0.893)	(0.770)
ARCH Test	(0.501)	(0.091)*	(0.208)	(0.568)	(0.745)	(0.199)
Ramsey Test	(0.371)	(0.199)	(0.094)*	(0.083)*	(0.080)	(0.257)

Note: ***, ** and * represent 1%, 5% and 10% significance level, respectively.

The diagnostic tests reveal that the models lack any model construction error, heteroscedasticity and autocorrelation problems. When the structural break was taken out of the analysis, heteroscedasticity and the cumulative sum (CUSUM) tests were found outside the confidence interval. Econometrics literature highlights the misleading characteristics and biases of estimated coefficients, attributable to heteroscedasticity and model misspecification. Two of the three ARDL and NARDL models incorporate structural break dummies. This enhances the accuracy of coefficient estimates and improves the outcomes of the heteroscedasticity and CUSUM tests.[3] The subsequent graphs depict the outcomes of the CUSUM tests, which show the stability of the coefficients in ARDL and NARDL models.

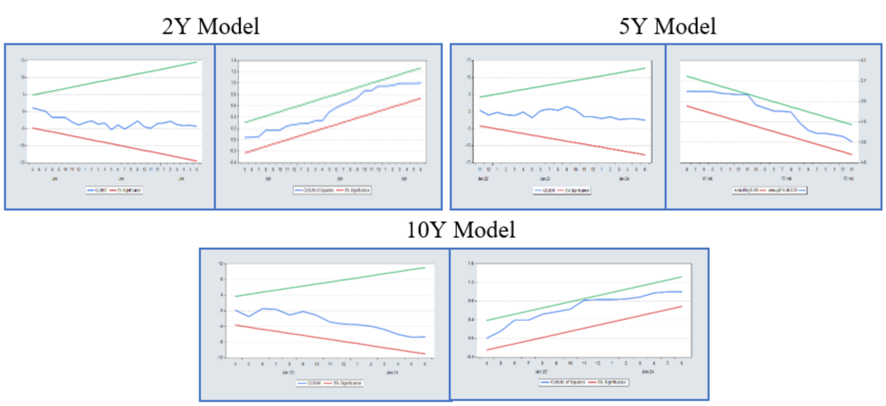

Figure 2: Stability of the ARDL Model

[3] The results of these tests are available upon request.

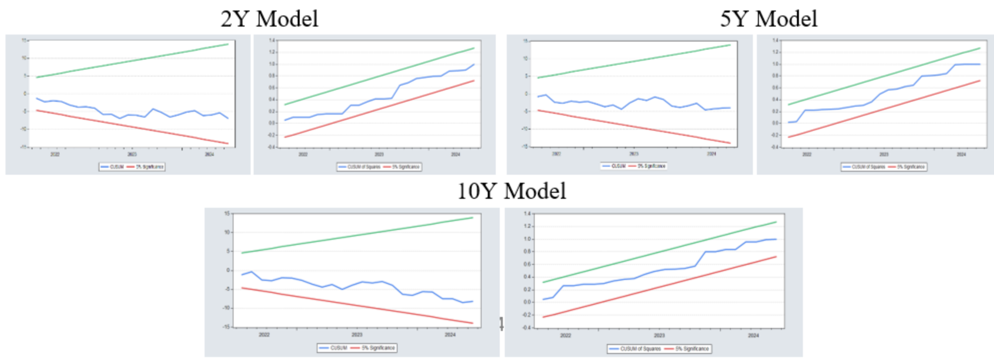

Figure 3: Stability of the NARDL Model

5 Conclusion

This study analyses the impact of short-run interest rates, indicating monetary policy, on long-run interest rates in Turkey by using ARDL and NARDL models to address structural breaks and asymmetric effects. The results indicate that the short-term interest rates significantly influence the two-year bond yields, thereby supporting the Expectations Hypothesis (EH). This finding aligns with the results of Özdemir & Özel (2012) and Arslan (2012), who similarly demonstrated that the Efficient Market Hypothesis has validity in Turkey's bond market. Longer-term (five-year and ten-year) rates seem to conform to the Market Segmentation Theory (MST), consistent with the findings of Aklan & Nargeleçekenler (2008): long-term rates in Turkey exhibit less responsiveness to changes in monetary policy.

The ARDL and NARDL models indicate a strong Fisher effect across all maturities, which means that inflation (CPI) significantly affects bond yields. This aligns with the findings of Kose et al. (2012) and Sunal (2020), who emphasized the importance of inflation expectations for the rates of interest in Turkey. The way rate of interests respond differently to changes in inflation, where falling inflation reduces yields more than rising inflation increases them, resembles the nonlinear effects identified by Bahmani-Oskooee & Saha (2019) in other emerging markets.

Error correction models indicate that the mid-term (2Y and 5Y) rates exhibit rapid adjustments, whereas longer-term rates, such as the 10Y rate, demonstrate slower corrections. The results align with Thornton's (2012) findings regarding U.S. bonds, indicating that long-term yields are more significantly affected by macroeconomic factors than by short-term policy changes. The Granger causality results indicate that short-term rates and inflation influence long-term yields, supporting the findings of Akram & Mamun (2023) and Arize et al. (2002), who identified similar relationships across different economies. The policy suggestion is that these findings highlight how important structural breaks like those seen during the 2018 currency crisis and the 2022 inflation surge are, as well as how short-run rates affect mid-term rates differently than they do very long-run rate of interests.

Future studies will look at how external shocks, including global risk and geopolitical tensions, affect the link between long and short-run rates of interest in Turkey. By adding nonlinearities and structural breaks into the analysis of Turkey's long- and short-run interest dynamics, this paper extends the literature and offers a more thorough knowledge of the rate of interest transmission.

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