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RESEARCH ARTICLE

Interaction Between Stock Exchange And Interest Rate in Turkey: A Hidden Cointegration and Asymmetric Causality Analysis

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ABSTRACT
This study reveals the relationship between stock markets and interest rates. In this study, the Borsa Istanbul-100 Index (BIST-100) is used to represent the stock market, and the Turkish Lira Overnight Reference Rate (TLREF) is used to represent the interest rate. To investigate the relationship between the series, daily data between 28.12.2018- 20.10.2022 are discussed. In the analysis, the traditional co-integration tests of Engle and Granger (1987) and Johansen (1988) were used to determine the long-term relationships between the series. A long-term relationship could not be detected using the traditional co-integration test. Therefore, Granger and Yoon (2002) and Hatemi and Irandoust (2012) conducted hidden co-integration tests. The series is decomposed into positive and negative components to apply the hidden co-integration analysis. As a result of the Granger and Yoon (2002) test, a long-term relationship could not be determined between the series; As a result of the Hatemi and Irandoust (2012) test, it was observed that the cumulative positive shocks of the BIST-100 series and the positive and negative cumulative shocks of the TLREF series were associated in the long term. Hatemi-J (2012) investigated the causality relations between the series decomposed into positive and negative shocks with asymmetric causality analysis.

Keywords: BIST-100, TLREF, Hidden Co-integration Test, Asymmetric Causality Test, Unit Root Test.
JEL classification Codes : C51, C55, C58.

1. Introduction

Macroeconomic variables are statistical indicators that reflect the general economic situation of a country over a certain period (Roger, 1998). Today, a wide range of macroeconomic variables are regularly published to indicate various trends in both the private and public spheres (Pilinkus and Boguslauskas, 2009). Movements of changes in macroeconomic indicators impact financial markets in particular. In this context, academic and business circles have been discussing the extent to which macroeconomic variables affect financial markets for years. In particular, stock exchanges provide long-term capital for sectors that need financing through the issuance of company shares, and this situation supports economic growth (Onasanya and Ayoola, 2012).

One of the basic principles of finance theory is that the value of stocks is equal to this value of expected future cash flows. Since companies pay dividends out of earnings related to real economic activity, stock prices should reflect current and expected future real economic activity. Macroeconomic theory also requires that there should be a strong relationship between stock prices and macroeconomic policies because macroeconomic policies and expected future economic activity are strongly related (Lee, 1997). The relationship between macroeconomic variables and stock returns can also be interpreted in terms of market efficiency. The efficiency of the stock market depends on the speed and accuracy with which information is incorporated into stock prices. The speed at which information flow and accuracy are incorporated into stock prices is important for stock market efficiency. Well-functioning stock markets are closely related to information efficiency. Fama (1970) categorises information into three levels: weak, semi-strong, and strong in terms of the speed and efficiency of security participation. In an efficient stock market, information and developments regarding macroeconomic activities are rapidly integrated. On the other hand, in the absence of information efficiency, an environment may arise where market participants can earn above-average returns by developing a profitable trading rule (Barbic and Jurkic, 2011). If the stock market is information efficient with respect to macroeconomic policies, stock prices should quickly incorporate changes in macroeconomic policies when this information becomes publicly available. Past information

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on these policies cannot be used to explain current fluctuations in stock prices in an efficient market because this information is already incorporated into past prices. On the other hand, in an informationally inefficient market, past information on these policies is useful in explaining current movements in stock prices because there is a lag in the adjustment of stock prices to new information (Lee, 1997).

The stock market and interest rates are among the important indicators that provide information about a country's economy. The interest rate affects many variables in a country's economy, both at the macro and micro levels. It has important effects in many areas such as interest rates, monetary policy, risk management, financial policies, stock market, and securities valuation (Alam and Uddin, 2009). The level of interest rates is probably the most important macroeconomic factor to consider in investment analysis. Interest rate estimations directly affect return expectations in fixed-income markets (Bodie et al., 2018). In general terms, different approaches in the literature examine the relationship among interest rates, macroeconomic variables, and stock market indexes. The semi-strong efficient market hypothesis of Fama (1970) and the arbitrage pricing theories of Ross (1976) are among the pioneering studies on this subject. Fama (1970) defines an efficient market as "a market where prices always reflect all available information". According to the semi-strong form of the efficient market hypothesis, since macroeconomic factors are fully reflected in the stock price, it can be used to investigate the negative or positive relationship between stock returns and macroeconomic variables. Ross (1976), on the other hand, proposes a multi-factor approach to explain asset pricing through the arbitrage pricing theory. Arbitrage pricing theory states that stock returns are not only dependent on their own internal dynamics but also closely interact with national and international macroeconomic dynamics (Roll and Ross, 1995). For example, unexpected movements in the term structure of interest rates, unexpected changes in risk premiums, fluctuations in exchange rates, and changes in inflation and industrial production. Many macroeconomic variables have effects on stock returns. All macroeconomic variables that affect cash flows and the expected rate of return of companies indirectly affect stock prices and may create pressure on stock prices. Especially in an environment with high interest rates, investors may turn to fixed-income investment instruments with lower risk, such as bonds instead of stocks (Prempeh, 2016).

Because of the inverse relationship between investments and interest rates, increases or decreases in interest rates can deeply affect the entire economy (Lin et al., 2018). There are different interest rates for different types of debt in the markets. These interest rates are shaped by conditions such as the repayment risk of the lenders, type of collateral received against the loan, purpose of use, and maturity of the borrowed funds (Bringham and Houston, 2016). Although there are many different interest types in Turkey, such as TRLIBOR (Turkish Lira interbank sales rate), policy interest, loan interest, deposit interest, and bond-bill interest, a reference interest rate calculated based on the transactions in the market does not exist until TLREF is calculated. In addition, since the use of LIBOR (London Inter-Bank Offered Rates) interest rates will cease in the world by the end of 2021, countries are working to announce national reference interest rates (Kartal, 2019). The transition process to TLREF for the post-LIBOR period has been initiated to address this deficiency. TLREF was created to establish a reference interest rate as a benchmark for various contracts involving debt instruments, financial derivatives, and other financial agreements used in short-term transactions with the Turkish Lira. The main purpose of the TLREF is to measure the TL borrowing/lending interest rate of Turkish banks under conditions where credit, liquidity, or other risks are minimal. The dates for the calculation and publication of the TLREF ratio are 28.12.2018 and 17.06.2019, respectively (Borsa Istanbul, 2022). Recently in Turkey, the level of interest rates and the debates on interest rates and investment relations has been remarkable. This research contributes to the analysis of the relationship between interest rates and stock market investments. What makes this research unique is the revealing of the hidden co-integration and asymmetric causality relationships between TLREF, which has a calculation history of approximately three years, and the BIST-100 index.

The remainder of this study is designed as follows. In the following second section, a literature review is provided. In the third section, econometric methods are explained, and in the fourth section, the dataset and empirical findings are detailed. The last section concludes presenting the results and policy recommendations.

2. Literature Review

Modigliani (1971) and Mishkin et al. (1977) concluded in their studies that stock prices increase when interest rates are low and that this situation has a supportive effect on investments. On the other hand, Fama and Schwert (1977) revealed a negative relationship between treasury bill interest rates and stock returns. Fama (1981) revealed that expected inflation rates negatively affect expected real activities, and stock returns should be negatively correlated with expected inflation rates, which are generally expressed in short-term interest rates. Akella and Chen (1990) investigated the interest rate sensitivity of bank stock returns and the variation in sensitivity over time under alternative econometric specifications. The periods of 1974-1979 and 1980-1984 were investigated by taking banks on the New York Stock Exchange (NYSE) as a sample. While long-term government security returns are positively related to stock returns; short-term returns show a positive relationship only in the 1980-1984 period. Lee (1992) used the Multivariate Vector Autoregressive Model (VAR) to investigate the relationships among stock returns, interest rates, real activity, and inflation in the United States between 1947 and 1987. Findings partially support Fama's (1981) hypothesis.

Mukherjee and Naka (1995) analysed the relationship between the Tokyo stock market and macroeconomic indicators using the Vector Error Correction Model (VECM). The findings determined that the Tokyo stock market was negatively correlated with loan interest rates and positively correlated with government bond interest rates. Durukan (1999) analysed the macroeconomic factors affecting ISE in the 1986-1998 period. In the research findings, it was determined that only the interest rate has statistical significance with a negative coefficient. Similarly, Zügül and Sahin (2009) found a negative relationship between the interest rate and the ISE 100 index in their research, in which they applied the linear regression method. Dritsaki- Bargiota and Dritsaki (2004) investigated long-term relationships and causality between the Greek securities market index, industrial production index, inflation, and interest rate. In the findings, one-way Granger causality from interest rates to the Greek Stock Exchange Index was determined. Leon (2008) modelled the relationship between the Korean KOSPI index and precious deposit certificates with GARCH in the 1992-1998 period and found a significant and negative relationship. Omağ (2009) examined the effects of changes in long-term interest rates, inflation, and money supply (M1) on the ISE 100 Index and Financial Index in Turkey from 1991 to 2006 using a linear regression model. Findings show that both indexes are negatively affected by interest rates. Saylgan and Süslü (2011) examined the relationship between macroeconomic factors and stock returns in developing countries in the 1999-2006 period using the balanced panel data analysis method. In the findings, no statistically significant relationship was found between the interest rate and stock returns. Mukit (2013) confirmed the co-integration and negative relationship between the variables in his research, which he repeated for the Bangladesh economy between 1991 and 2012. In addition, a one-way causality relationship between interest rates and the stock market index was determined. Cetin and Bitirak (2015), within the framework of the Arbitrage Pricing Model, analysed the relationship between stocks traded in the ISE between 2000 and 2009 and macroeconomic indicators using the regression method. In the findings, it has been determined that stock returns are negatively affected by the saving deposit interest rate. Uyar et al. (2016) analysed the relationship between the benchmark interest rate and BIST indexes (BIST-100, BIST-30, BIST Financial, BIST Banking, and BIST All) between 2006 and 2015 using the quantile regression method. In the analysis findings, it has been determined that the benchmark interest rate harms all indexes. Eyüboğlu and Eyüboğlu (2018) examined the relationship between the American 10-year bond rates and emerging market stock markets (Turkey, Russia, S. Africa, Brazil, India, Poland, and Malaysia) using the Seemingly Unrelated Regression (SUR) method between 2006 and 2016. The findings indicate that there is a negative relationship between the stock market indexes of Brazil, South Africa, Malaysia, Poland, Russia, and the US 10-year bond rates. Yeşildağ (2021), the co-integration relationship between the BIST-100 index and macroeconomic indicators in the 2009-2019 period was tested using the ARDL limit test. The results of the analysis showed a co-integration between stock and gold, interest, unemployment, and money supply variables. In addition, significant long- and short-term relationships were found between share prices, interest rates, and money supply. In this relationship, interest rates affect stock prices negatively and the money supply positively. Karaca et al. (2022) analysed the relationship between the BIST-100 index and macroeconomic indicators between 2009 and 2019. The ARDL bound test was used to determine the long-term relationship, and the Toda-Yamamoto test was used for causality. In the findings, a long-term relationship was determined between the interest rate, inflation, unemployment rate, and stock market index. In addition, there is one-way causality from the stock market index to interest rates. Ulu et al. (2022) examined the relationship between the BIST-100 index and TLREF within the framework of the VAR model, Granger causality. In the findings, a two-way Granger causality relationship was determined between the series.

When examining the national and international literature on the relationship between stock returns and macroeconomic indicators, it is observed that there are numerous studies. With the aim of contributing to these studies, this research investigates the relationship between the TLREF interest rate, which was published in Turkey in 2019, and the BIST-100 stock through analyses of co-integration and asymmetric causality.

3. Econometric Method

In the case of a stationary composition of two series integrated at the same level, Engle and Granger and Johansen tests are frequently used in the literature to test the co-integration relationship between the two series. In traditional co-integration tests, the effect of positive and negative shocks is considered the same when examining the relationship between the series (Mert and Çağlar, 2019). Criticising this situation, Granger and Yoon stated in their research that when economic series react to shocks jointly, they will be cointegrate, but if they give different responses, there will be no such relationship. Therefore, they developed a new co-integration approach, arguing that the series can contain positive and negative shocks and that different responses can be given to these shocks. They stated that even if there is no long-term relationship between the series used in the models, there may be a co-integration relationship between different nonstationary shocks of the series.

The Granger and Yoon hidden co-integration approach is an analysis based on the Engle and Granger co-integration test. In the Engle and Granger test, a singular integration relationship is obtained. However, we can analyse more than one co-integration or equilibrium relationship vectorially by examining possible systems of equations between series. Hatemi J, Irandoust, and Johansen addressed this gap in the literature by employing a method based on the co-integration approach (Mert and Çağlar, 2019). In the general operation of the hidden co-integration approach, the series is first separated into positive and negative shocks, and then the long-term relationships between these shocks are investigated. For the X_t and Y_t series, the hidden co-integration relationship between them will be investigated. The decomposition process starts with the assumption that these two nonstationary series have a random walk process (Granger and Yoon, 2002).

$$X_t = X_{t-1} + \varepsilon_t = X_0 + \Sigma_{i=1}^{t}\varepsilon_i \quad t = 1, 2, \ldots, T \tag{1}$$

$$Y_t = Y_{t-1} + \eta_t = Y_0 + \Sigma_{i=1}^{t}\eta_i \quad t = 1, 2, 3 \ldots, T \tag{2}$$

In equations (1) and (2), X_0 and Y_0 indicate the initial values. ε_i and η_i symbolise error terms with a zero-mean clean sequence feature. X_t and Y_t are series between which co-integration is researched. Positive and negative shocks are shown in equations (3) and (4) to investigate the co-integration relationship.

$$\varepsilon_i^+ = max(\varepsilon_i, 0), \quad \varepsilon_i^- = min(\varepsilon_i, 0) \tag{3}$$

$$\eta_i^+ = max(\eta_i, 0), \quad \eta_i^- = min(\eta_i, 0) \tag{4}$$

In addition, shocks can be expressed as $\varepsilon_i = \varepsilon_i^+ + \varepsilon_i^-$ and $\eta_i = \eta_i^+ + \eta_i^-$. If the positive and negative shocks are changed in equations (1) and (2), the X_t and Y_t series can be described with equations (5) and (6).

$$X_t = X_{t-1} + \varepsilon_t = X_0 + \Sigma_{i=1}^{t}\varepsilon_i^+ + \Sigma_{i=1}^{t}\varepsilon_i^- \tag{5}$$

$$Y_t = Y_{t-1} + \eta_t = Y_0 + \Sigma_{i=1}^{t}\eta_i^+ + \Sigma_{i=1}^{t}\eta_i^- \tag{6}$$

Eq. (7) expresses the unit shocks of the series.

$$X_t^+ = \Sigma_{i=1}^{t}\varepsilon_i^+, X_t^- = \Sigma_{i=1}^{t}\varepsilon_i^-, Y_t^+ = \Sigma_{i=1}^{t}\eta_i^+, Y_t^- = \Sigma_{i=1}^{t}\eta_i^- \tag{7}$$

Then, assuming X_0 and Y_0 are constant, the series X_t and Y_t are arranged as in equation (8) under the assumption that $X_t = X_0 + X_t^+ + X_t^-$ and $Y_t = Y_0 + Y_t^+ + Y_t^-$.

$$\Delta X_t^+ = \varepsilon_t^+, \Delta X_t^- = \varepsilon_t^-, \Delta Y_t^+ = \eta_t^+, Y_t^- = \eta_t^- \tag{8}$$

The shocks obtained by Eq. (8) constitute the initial stage of the hidden co-integration approach. If Engle and Granger co-integration analysis is performed on the decomposed series, the Granger and Yoon approach is used. If Johansen co-integration analysis is performed on the decomposed series, the Hatemi J and Irandoust approach is used.

Hatemi J (2012) stated that investors in financial markets exhibit heterogeneous characteristics rather than a homogeneous structure. Investors do not have the same reaction to a random shock in the markets. He argues that because the effect of random shocks on the market will not be the same, shocks should be analysed by dividing them into positive and negative. He also bases his opinion on the studies of Akerlof (1970), Spence (1973), and Stiglitz (1974), who pioneered the issue of asymmetric information, which has a wide place in the literature. When determining causality relationships in a time series, it is assumed that the effect of positive and negative shocks is the same. Asymmetric causality tests, on the other hand, argue that hidden relationships may exist between apparently unrelated series and that these relationships can only be revealed by considering the asymmetry between the components. Positive and negative shocks obtained as a result of asymmetric decomposition in the Hatemi J (2012) asymmetric causality test and the Granger and Yoon (2002) hidden co-integration approach are included in the causality analysis.

$$Y_{1t} = Y_{1t-1} + \varepsilon_{1t} = Y_{1,0} + \Sigma_{i=1}^{t}\varepsilon_{1t} \quad t = 1, 2, \ldots .T \tag{9}$$

$$Y_{2t} = Y_{2t-1} + \varepsilon_{2t} = Y_{2,0} + \Sigma_{i=1}^{t}\varepsilon_{2t} \quad t = 1, 2, \ldots .T \tag{10}$$

In equations (9) and (10), Y_{1t} and Y_{2t} series show initial values as two integrated series. The error terms ε_{1t} and ε_{2t} were determined as the clean sequences. Positive and negative shocks can be represented as $\varepsilon_{1i}^{+} = max(\varepsilon_{1i}, 0), \varepsilon_{2i}^{+} = max(\varepsilon_{2i}, 0), \varepsilon_{1i}^{-} = min(\varepsilon_{1i}, 0), \varepsilon_{2i}^{-} = min(\varepsilon_{2i}, 0)$. It can also be represented as $\varepsilon_{1i} = \varepsilon_{1i}^{+} + \varepsilon_{1i}^{-}$ and $\varepsilon_{2i} = \varepsilon_{2i}^{+} + \varepsilon_{2i}^{-}$. With this information, the equations of Y_{1t} and Y_{2t} can be expressed as follows:

$$Y_{1t} = Y_{1t-1} + \varepsilon_{1t} = Y_{1,0} + \Sigma_{i=1}^{t}\varepsilon_{1i}^{+} + \Sigma_{i=1}^{t}\varepsilon_{1i}^{-} \tag{11}$$

$$Y_{2t} = Y_{2t-1} + \varepsilon_{2t} = Y_{2,0} + \Sigma_{i=1}^{t}\varepsilon_{2i}^{+} + \Sigma_{i=1}^{t}\varepsilon_{2i}^{-} \tag{12}$$

As a result, the positive and negative shocks of each series can be shown cumulatively as follows:

$$Y_{1t}^{+} = \Sigma_{i=1}^{t}\varepsilon_{1i}^{+}, Y_{1t}^{-} = \Sigma_{i=1}^{t}\varepsilon_{1i}^{-}, Y_{2t}^{+} = \Sigma_{i=1}^{t}\varepsilon_{2i}^{+}, Y_{2t}^{-} = \Sigma_{i=1}^{t}\varepsilon_{2i}^{-} \tag{13}$$

The next step is to determine the causality relationship between the acceptance of equation $Y_t^{+} = Y_{1t}^{+} + Y_{2t}^{+}$ and the positive components $(Y_{1t}^{+} and\, Y_{2t}^{+})$ and tested with the p-lag VAR (Vector Autoregression) model. Equation (14) is used for the causal relationship between positive shocks.

$$Y_t^{+} = \vartheta + A_1 Y_{t-1}^{+} + \cdots + A_p Y_{t-1}^{+} + \mu_t^{+} \tag{14}$$

In equation (14), Y_t^{+} denotes 2x1 variable vector and ϑ denotes 2x1 constant vector. μ_t^{+} represents 2x1 error term vector. The optimal lag is determined. The hypothesis to be tested is "The k-th element of Y_t^{+} is not the Granger cause of the ω-th element of Y_t^{+}. Similarly, the same process applies to negative shocks.

4. Data Set and Findings

In this study, the relationships between stock markets and interest rates were examined. The Borsa stanbul-100 Index (BIST-100) is used to represent the stock markets and the Turkish Lira Overnight Reference Rate (TLREF) is used to represent the interest rate. There were 946 observations in the study, in which daily data were used between 28.12.2018 and 20.10.2022. In the study, long-term relationships and causality between the BIST-100 Index and TLREF were attempted to be revealed. Engle- Granger and Johansen conventional co-integration tests and Granger - Yoon and Hatemi J - Irandoust hidden co-integration tests were used to identify long-run relationships. The causality relationships between the series were investigated by Hatemi-J asymmetric causality analysis. The relevant series were provided through the Central Bank Electronic Data Distribution System. In this study, the series was used in natural logarithmic form to reduce variability in scale differences and variances. In the related research, Gaussian and R package programmes were used for analysis.

Table 1. *Series and Shortcodes*

Series	*Shortcode*	*Reference*
BIST − 100	lnBIST	*Electronic Data Distribution System of the Central Bank*
TLREF	lnTLREF	*Electronic Data Distribution System of the Central Bank*

The descriptive statistics of the series are shown in Table 2 before entering the empirical finding process in the research. In the related table, the means, medians, maximum and minimum values, standard deviations, Jarque-Bera test statistics and probability values of the series, and the number of observations belonging to each series are given. Although the standard deviations of the series in descriptive statistics are close to each other; It is seen that the deviation from the average in the BIST-100 index is higher than TLREF. According to the probability values of the Jarque-Bera statistic, which is an indicator of the normal distribution, the probability value of both series is less than the 5% significance level, and the H_0 hypothesis, which states that the series is normally distributed, was rejected and it was determined that the series did not comply with the normal distribution.

Table 2. *Descriptive Statistics*

Series	Mean	Maximum	Minimum	Median	Standard Deviation	Jarque-Bera (Prob.)	n
lnBIST	7.238041	8.268950	6.729529	7.188881	0.361300	123.8221 (0.0000)	946
lnTLREF	2.71804	3.23862	2.01490	2.70597	0.304731	22.7736 (0.0000)	946

The time path graphs of the series are given in Figure 1. When the time path graphs of the series are examined, the existence of breaks in the series draws attention. Although the BIST-100 series shows fluctuations, it is seen that it is upwards. Although there were downward breaks in the initial period of the TLREF series, it is observed that it continues its course with upward and downward fluctuations in the ongoing process.

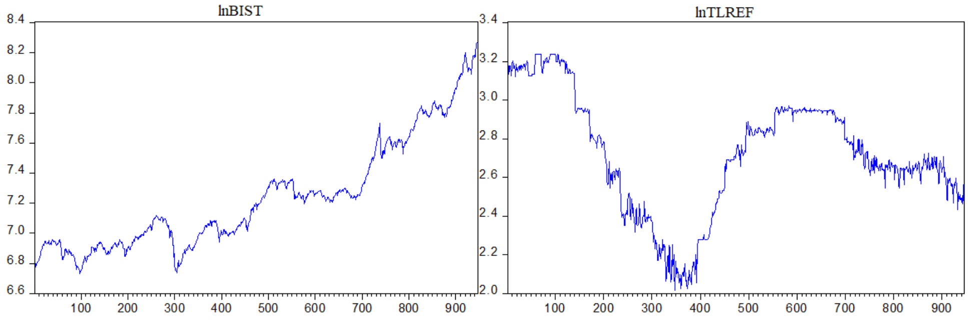

Figure 1. Time Path Indicators of the Series (2018-2022)

In the next step of the research, the stationarity properties of the series were tested using Augmented Dickey Fuller (ADF) and Philips-Perron traditional unit root tests and Zivot-Andrews (ZA) structural break unit root tests. Considering the unit root test results, Engle and Granger and Johansen traditional co-integration tests were applied. Since a long-term relationship could not be determined with the help of traditional co-integration tests, the hidden co-integration relationship between the series was investigated. In this process, firstly, both series were separated into positive and negative components. The stationarity properties of the separated series were determined by ADF and PP unit root tests. Granger and Yoon and Hatemi J and Irandoust hidden co-integration tests were applied to determine the long-term relationships between the positive and negative components of the series. In the last stage, asymmetric causality relationships between the series that were decomposed into positive and negative components were tested with the Hatemi J approach.

Table 3. *ADF and PP Unit Root Test Results*

Series		ADF		PP	
		With Constant	With Constant & Trend	With Constant	With Constant & Trend
lnBIST	At Level	1.7458 (0.9997)	-0.4079 (0.9872)	1.4828 (0.9993)	-0.6918 (0.9726)
	At First Difference	-19.2336 (0.0000)	-19.3395 (0.0000)	-30.9640 (0.0000)	-31.0334 (0.0000)
lnTLREF	At Level	-1.4847 (0.5412)	-1.3501 (0.8745)	-1.5813 (0.4918)	-1.4197 (0.8549)
	At First Difference	-23.3350 (0.0000)	-23.3416 (0.0000)	-36.9906 (0.0000)	-37.0279 (0.0000)

***Notes**: Contents in parentheses ( ) indicate probabilities. In the ADF and PP unit root tests, the critical values were -3.4370 (1%), -2.8643 (5%), and -2.5683 (10%) for the fixed model; for the fixed and trend model, it is -3.9677 (1%), -3.4145 (5%) and -3.1294 (10%). The optimal delay in all tests was decided by Schwarz Information Criterion (SIC). In addition, in the PP test, the Bartlett kernel is decided for the Spectral estimation method, while the Bandwith options are used for the Newey-West method.*

In time series research, it is necessary to check the stationarity properties of the series in the first phase of econometric analysis. The degree of stationarity of the series affects the progress of the research. In the ADF and PP unit root tests, two hypotheses are tested: "H_0: The series is not stationary and the series contains a unit root" and "H_1: The series is stationary and the series does not contain a unit root". By comparing test statistics and critical values, it can be tested whether the series contains a unit root. If the calculated test statistic is greater than the critical values, the H_0 null hypothesis cannot be rejected. This shows that the series contains a unit root, that is, it is not stationary. Stationarity can also be tested by looking at probability values at significance levels.

According to Table 3, at 1%, 5%, and 10% significance levels, lnBIST, and lnTLREF series contain unit roots in their level values and become stationary when the first difference is taken. To control the results of ADF and PP unit root tests, ZA unit root test results, which take into account a single break, are given in Table 4. The basic hypothesis of this test is "H_0: The series has a unit root with a structural break, that is, there is no stationarity". According to Model A and Model C results, at all significance levels (1%, 5%, and 10%), the series have unit roots at the level. These results are consistent with traditional unit root tests, ADF, and PP. It is seen that the breaks found according to the ZA unit root test are not significant structural breaks.

Table 4. *ZA Unit Root Test Results*

Model	*Model A*		*Model C*	
Series	***Test Statistic***	***Breaking Date***	***Test Statistic***	***Breaking Date***
lnBIST	-2.473954	24/02/2022	-3.335952	11/06/2021
lnTLREF	-3.441433	09/09/2020	-4.388502	05/08/2020
ΔlnBIST	-19.45507	06/10/2021	-19.52481	17/12/2021
ΔlnTLREF	-20.30472	02/07/2020	-20.29423	02/07/2020

Notes: *The "Δ" notation indicates the first difference of the series. Model A critical values were -5.34 (1%), -4.93 (5%), and -4.58 (10%); Critical values for Model C are -5.57 (1%), -5.08 (5%) and -4.82 (10%).*

Since the series are stationary at the first difference (I(1)), Engle and Granger and Johansen co-integration tests were used to determining the long-term relationships. Table 5 shows the results of Engle and Granger co-integration test. In the model where the lnBIST series is the dependent variable, *tau*=1.414701 (*p*=1.414701>0.05) and z=2.239973 (*P*=0.9994>0.05) were calculated. Similarly, in the model where the lnTLREF series is the dependent variable, *tau*= -1.443697 (*P*=0.7842>0.05) and z=-3.121065 (*P*=0.8702). According to both models, it was determined that the null hypothesis of "no co-integration" could not be rejected and there was no long-term relationship between the series.

Table 5. *Engle and Granger Co-integration Test Results*

Null hypothesis (H_0):	***The series are not cointegrated.***				
Dependent Variable	***Independent Variable***	***tau − statistic***	***Prob.*** *	***z***	***Prob.*** *
lnBIST	*lnTLREF*	*1.414701*	*0.9998*	*2.239973*	*0.9994*
lnTLREF	*lnBIST*	*-1.443697*	*0.7842*	*-3.121065*	*0.8702*

Notes: **MacKinnon (1996) p-values.*

The concept and theory of co-integration were first developed by Engle and Granger. The Engle and Granger test is based on a single equation and uses the Least Squares Method (LSM). This method, although practical, is not powerful at parsing multiple cointegrated vectors. Because of these difficulties, Johansen has developed a method that calculates the estimation of the vectors that provide co-integration with the Error Correction Model (ECM) method and allows the estimation of all the different co-integration relationships that may exist between the series (Tarı, 2010). In the application of Johansen co-integration test, first of all, the stationarity levels of the series should be I(1). With the help of the VAR model, the number of lags is determined and the appropriate model is selected. Trace and Maximum Eigenvalue (Max-Eigen) statistics are used to determine the number of cointegrating vectors. If the Trace and Maximum Eigenvalue (Max-Eigen) statistics are greater than the critical values, the null hypothesis of "no co-integration" is rejected. This proves that there is a co-integration relationship between the series participating in the analysis (Sevüktekin and Nargeleçekenler, 2010). In Table 6, Johansen co-integration test results of lnBIST and lnTLREF series are given. In the table, the fact that the critical values at the 5% error level are greater than the Trace and Maximum Eigenvalue (Max-Eigen) statistics (15.49471>4.74982,3.841466>0.647206,14.2646>4.102776 and 3.841466>0.647206) show that there is no co-integration between the series. As a result, according to Engle and Granger and Johansen co-integration tests, it was determined that there was no long-term relationship between the series.

Table 6. *Johansen Co-integration Test Results*

Null hypothesis (H_0)	***Trace Statistic***	***Critical Value***	***Prob.*****
There is no co-integration	*4.749982*	*15.49471*	*0.8348*
There is at most one co-integration	*0.647206*	*3.841466*	*0.4211*
Null hypothesis (H_0)	***Max-Eigen Statistic***	***Critical Value***	***Prob.*****
There is no co-integration	*4.102776*	*14.26460*	*0.8483*
There is at most one co-integration	*0.647206*	*3.841466*	*0.4211*

Notes: *Trace test indicates no co-integration at the 0.05 level. Max-eigenvalue test indicates no co-integration at the 0.05 level. **MacKinnon-Haug-Michelis (1999) p-values. With the VAR model, the optimal lag length was determined as 5.*

At this stage of the research, the hidden co-integration relationship between BIST-100 and TLREF is investigated. For this purpose, the series were separated into positive and negative components. Positive components of lnBIST+ and $lnTLREF^{+}$ series; $lnBIST^{-}$ and $lnTLREF^{-}$ represent the negative components of the series. The long-term relationships between these components were tested with the hidden co-integration tests of Granger-Yoon and Hatemi J-Irandoust. Before the hidden co-integration tests, unit root tests should be applied to the series that are decomposed into positive and negative components. ADF and PP unit root test results of $lnBIST^{+}$, $lnBIST^{-}$, $lnTLREF^{+}$ and $lnTLREF^{-}$ series are given in Table 7. It has been determined that the positive and negative components of the series contain unit roots at 1%, 5%, and 10% significance levels and become stationary when the first difference is taken. Since the series become stationary at the first difference (I(1)), hidden co-integration tests can be applied.

Table 7. *Unit Root Test Results of $lnBIST^{+}$, $lnBIST^{-}$, $lnTLREF^{+}$ and $lnTLREF^{-}$*

Series		ADF		PP	
		Constant	**Constant & Trend**	**Constant**	**Constant & Trend**
$lnBIST^{+}$	***At Level***	*3.6454 (1.0000)*	*1.6151 (1.0000)*	*3.5689 (1.0000)*	*1.6556 (1.0000)*
	At First Difference	*-31.0159 (0.0000)*	*-31.4094 (0.0000)*	*-31.2637 (0.0000)*	*-31.4298 (0.0000)*
$lnBIST^{-}$	***At Level***	*-0.1652 (0.9402)*	*-2.8467 (0.1809)*	*-0.3274 (0.9183)*	*-3.0083 (0.1304)*
	At First Difference	*-17.3817 (0.0000)*	*-17.3722 (0.0000)*	*-30.2220 (0.0000)*	*-30.2099 (0.0000)*
$lnTLREF^{+}$	***At Level***	*1.4221 (0.9991)*	*-0.9230 (0.9517)*	*1.3873 (0.9990)*	*-0.9472 (0.9488)*
	At First Difference	*-30.7957 (0.0000)*	*-30.8566 (0.0000)*	*-30.8197 (0.0000)*	*-30.8710 (0.0000)*
$lnTLREF^{-}$	***At Level***	*0.3753 (0.9819)*	*-0.6093 (0.9779)*	*0.2501 (0.9756)*	*-0.8156 (0.9627)*
	At First Difference	*-29.4337 (0.0000)*	*-29.4323 (0.0000)*	*-29.9671 (0.0000)*	*-29.9555 (0.0000)*

Notes: *Contents in parentheses ( ) indicate probabilities. In the ADF and PP unit root tests, the critical values were -3.4370 (1%), -2.8643 (5%), and -2.5683 (10%) for the fixed model; for the fixed and trend model, it is - 3.9677 (1%), -3.4145 (5%) and -3.1294 (10%). The optimal lag in all tests was decided by Schwarz Information Criterion (SIC). In addition, in the PP test, the Bartlett kernel is decided for the Spectral estimation method, while the Bandwith options are used for the Newey-West method.*

Granger and Yoon hidden co-integration test results of the series decomposed into positive and negative components are given in Table 8. This test is based on Engle and Granger co-integration test. In the related test, the null hypothesis of "the series are not cointegrated" is tested. The fact that tau and z statistical probability values are greater than 0.05 (p>0.05) in all models selected as dependent and independent variables causes the null hypothesis not to be rejected. Therefore, according to the Granger and Yoon test, it has been determined that there is no hidden co-integration relationship between the series.

Table 8. *Granger-Yoon Hidden Co-integration Test Results*

Null hypothesis H_0	*The series are not cointegrated.*				
Dependent Variable	***Independent Variable***	***tau − statistic***	**Prob.**	***z***	**Prob.**
$lnBIST^{+}$	*$lnTLREF^{+}$*	-0.706130	0.9434	-1.536905	0.9500
$lnBIST^{+}$	*$lnTLREF^{-}$*	-0.472062	0.9645	-0.804234	0.9723
$lnBIST^{-}$	*$lnTLREF^{+}$*	-1.657260	0.6977	-4.916352	0.7388
$lnBIST^{-}$	*$lnTLREF^{-}$*	-1.283335	0.8361	-3.420811	0.8506
$lnTLREF^{+}$	*$lnBIST^{+}$*	-0.824505	0.9290	-1.799487	0.9398
$lnTLREF^{+}$	*$lnBIST^{-}$*	-1.510858	0.7591	-4.482837	0.7729
$lnTLREF^{-}$	*$lnBIST^{+}$*	-0.774836	0.9354	-1.326001	0.9573
$lnTLREF^{-}$	*$lnBIST^{-}$*	-1.208357	0.8565	-3.220664	0.8638

Hatemi J and Irandoust hidden co-integration test is based on Johansen co-integration test to investigate the long-term relationship between positive and negative components of variables. First of all, the optimal lag lengths are determined between the series with the VAR model. It was seen that the VAR models met all the stability conditions at the determined optimal lag lengths. In

Table 9, the results of the hidden co-integration test of Hatemi J and Irandoust are given. By comparing the Trace and Max-Eigen statistics with the critical values, the hidden co-integration relationship was determined. The positive components of the lnBIST series and the positive components of the lnTLREF series; A hidden co-integration relationship was found between the positive components of the lnBIST series and the negative components of the lnTLREF series. In other words, it has been observed that the cumulative positive shocks of the lnBIST series and the positive and negative cumulative shocks of the lnTLREF series have a long-term relationship.

In the study, it is seen that the results of the co-integration tests of Granger and Yoon and Hatemi J and Irandoust are different. According to the Granger and Yoon test, there is no long-term relationship between the positive and negative components of the series. According to the Hatemi J and Irandoust test, a long-term relationship was determined. Şener et al. (2013) attribute the reason for this difference to the superiority of the Johansen co-integration test over the Engle and Granger test. It has been stated that relying on the Hatemi-J-Irandoust co-integration test results based on the Johansen co-integration test will enable more accurate decisions to be made.

Table 9. *Hatemi J-Irandoust Hidden Co-integration Test Results*

The Relationship Under Study	*Hypothesis*	*Max-Eigen Statistic*	*Prob.***	*Trace-Statistic*	*0.05 Critical Value*	*Prob.***
lnBIST⁺ lnTLREF⁺ (1)	*No co-integration**	23.45709	0.0014	24.52714	15.49471	0.0017
	There is co-integration	1.070050	0.3009	1.070050	3.841466	0.3009
lnBIST⁺ lnTLREF⁻ (1)	*No co-integration**	14.95860	0.0388	16.21089	15.49471	0.0390
	There is co-integration	1.252297	0.2631	1.252297	3.841466	0.2631
lnBIST⁻ lnTLREF⁺ (3)	*No co-integration**	5.105207	0.7285	5.588443	15.49471	0.7435
	There is co-integration	0.483236	0.4870	0.483236	3.841466	0.4870
lnBIST⁻ lnTLREF⁻ (5)	*No co-integration**	2.655926	0.9670	2.722597	15.49471	0.9780
	There is co-integration	0.066671	0.7962	0.066671	3.841466	0.7962

Notes: ** denotes rejection of the hypothesis at the 0.05 level. **MacKinnon-Haug-Michelis (1999) p-values. The ( ) notation indicates the optimal lag lengths from the VAR model. It has been tested that the stability conditions of the VAR model are met at optimal lag lengths.*

At the last stage of the research, causality relationships between positive and negative components of BIST-100 and TLREF series were tested with Hatemi J asymmetric causality test. Test results are shown in Table 10.

Table 10. *Hatemi - J Asymmetric Causality Test Results*

Model Number	*Null hypothesis (H_0)*	*Test Value*	*Bootstrap Critical Values*		
			%1	%5	%10
1	$lnBIST^+ \neq> lnTLREF^+$	*0.671*	1.7219	1.2086	0.9828
2	$lnBIST^+ \neq> lnTLREF^-$	*1.5033*	1.7503	1.1696	1.0168
3	$lnBIST^- \neq> lnTLREF^+$	*6.5365*	1.6306	1.2323	0.9744
4	$lnBIST^- \neq> lnTLREF^-$	*0.6661*	1.8303	1.2469	0.9953
5	$lnTLREF^+ \neq> lnBIST^+$	*1.3720*	1.7952	1.1930	0.9685
6	$lnTLREF^+ \neq> lnBIST^-$	*1.9105*	1.6841	1.2152	0.9806
7	$lnTLREF^- \neq> lnBIST^+$	*3.9891*	1.7164	1.2424	1.0291
8	$lnTLREF^- \neq> lnBIST^-$	*1.3688*	1.5087	1.1410	0.9533

Notes: *The notation "≠>" indicates the null hypothesis of no causality. While generating critical values, the number of bootstraps is taken as 10.000. The optimal lag length was determined based on the AIC and SIC information criteria in the VAR model.*

Model 1. The null hypothesis of no causality from the positive shocks of the BIST-100 index to the positive shocks of the TLREF ($lnBIST^+ \neq>$ lnTLREF^+) is tested. If the test value is less than the critical values at 1%, 5%, and 10% error levels, the null hypothesis is accepted. Therefore, the null hypothesis is accepted since "*Test Value* = 0.671 < *Bootstrap Critical Values* = 1%: 1.7219,5%: 1.2086,10%: 0.9828". It has been determined that there is no causality from the positive shocks of the BIST-100 index to the positive shocks of the TLREF.

Model 2. The null hypothesis of no causality from the positive shocks of the BIST-100 index to the negative shocks of the TLREF ($lnBIST^{+} \neq> lnTLREF^{-}$) is tested. While there is no causality at the 1% error level. Causality was detected between the series indicated at 5% and 10% error levels.

Model 3. The null hypothesis of no causality from negative shocks of BIST-100 index to positive shocks of TLREF ($lnBIST^{-} \neq> lnTLREF^{+}$) is tested. A causal relationship was determined between the series indicated at 1%, 5%, and 10% error levels.

Model 4. The null hypothesis ($lnBIST^{-} \neq> lnTLREF^{-}$) that there is no causality from the negative shocks of the BIST-100 index to the negative shocks of the TLREF is tested. A causal relationship could not be determined between the series specified at the error levels of 1%, 5%, and 10%.

Model 5. The null hypothesis that there is no causality from the positive shocks of TLREF to the positive shocks of the BIST-100 index ($lnTLREF^{+} \neq> lnBIST^{+}$) is tested. While there is no causality at the 1% error level. Causality was detected between the series indicated at 5% and 10% error levels.

Model 6. The null hypothesis of no causality from the positive shocks of TLREF to the negative shocks of the BIST-100 index ($lnTLREF^{+} \neq> lnBIST^{-}$) is tested. A causal relationship was determined between the series indicated at 1%, 5%, and 10% error levels.

Model 7. The null hypothesis of no causality from the negative shocks of TLREF to the positive shocks of the BIST-100 index ($lnTLREF^{-} \neq> lnBIST^{+}$) is tested. A causal relationship was determined between the series indicated at 1%, 5%, and 10% error levels.

Model 8. The null hypothesis that there is no causality from the negative shocks of TLREF to the negative shocks of the BIST-100 index ($lnTLREF^{-} \neq> lnBIST^{-}$) is tested. While there is no causality at the 1% error level. Causality was detected between the series indicated at 5% and 10% error levels.

5. Conclusions and Recommendations

In this research, an attempt has been made to elucidate the relationship between stock markets and interest rates, which is one of the most controversial issues both in theory and in practice. The study utilizes TLREF, which has a three-year calculation history, along with BIST-100. There are 946 observations in the study covering daily data between 28.12.2018 and 20.10.2022. The stationarity of variables has been tested using ADF, PP traditional unit root tests, and ZA structural break unit root tests. Traditional Engle and Granger as well as Johansen traditional co-integration tests are employed to determine long-term relationships in the analysis. Since a long-term relationship cannot be established using traditional co-integration tests, Granger-Yoon and Hatemi J-Irandoust hidden co-integration tests are applied. To apply the hidden co-integration tests, the series are decomposed into their positive and negative components. The Granger and Yoon test results did not reveal any hidden co-integration relationship between the series. A more robust test, the Hatemi J and Irandoust test, is then applied. In these test findings, it is observed that there is a long-term relationship between the cumulative positive shocks of the BIST-100 series and the positive and negative cumulative shocks of the TLREF series. The research findings underscore the importance of using series decomposed into cumulative shocks. Although it is seen that there is no long-term co-integration relationship between the series with traditional co-integration tests, it has been revealed that there may be hidden relationships between the series. What makes this research unique is the revelation of the co-integration relationship through hidden co-integration methods.

The research indicates that many financial variables exhibit asymmetric behavior. Hidden relationships that cannot be revealed by symmetric methods become possible through established asymmetric models. In this regard, causality relationships between variables were examined using Hatemi-J asymmetric causality analysis. In the results of asymmetric causality tests, no causality relationship was observed from the positive shocks of the BIST-100 index to the positive shocks of TLREF, nor from the negative shocks of the BIST-100 index to the negative shocks of TLREF. However, there exists a one-way causality relationship from the positive shocks of TLREF to the positive shocks of the BIST-100 index and from the negative shocks of TLREF to the negative shocks of the BIST-100 index. Additionally, a two-way causality was detected from the negative shocks of the BIST-100 index to the positive shocks of TLREF and from the positive shocks of the BIST-100 index to the negative shocks of TLREF. The research findings suggest a one-way causality relationship from both the positive and negative shocks of TLREF to the positive and negative shocks of the BIST-100 index, indicating that changes in interest rates result in changes in the stock index. The impact of changes in interest rates on stock markets is consistent with theory and empirically supported by previous studies such as Dritsaki-Borgiota and Dritsaki (2004), Mukit (2013), which found one-way Granger causality results from interest rates to stock exchanges. As indicated in the research findings, changes in interest rates have the capacity to influence stock markets. High interest rates often create selling pressure in stock markets as investors may shift towards other fixed-income investments. Furthermore, an increase in interest rates can raise borrowing costs for businesses, narrowing profit margins and potentially leading to declines in stock prices.

This underscores the importance of stock investors closely monitoring changes in interest rates and adjusting their investment strategies accordingly to these changing conditions.

The existence of a causality relationship from the positive shocks of the BIST-100 index to the negative shocks of TLREF, as indicated by another asymmetric causality test result, can be interpreted as suggesting that positive changes in the stock market lead to a decrease in interest rates. On the other hand, the one-way causality relationship from the negative shocks of the BIST-100 index to the positive shocks of TLREF also implies that negative changes in the stock index have a positive effect on interest rates. Positive developments in the stock market often reduce interest rates by diminishing investors' demand for alternative investment instruments. Consequently, increases in the stock market can lead to a decrease in interest rates. Conversely, fluctuations in the stock market can influence investors' risk perception. Stocks with high return potential may increase investors' sensitivity to interest rates. Particularly in the event of a negative trend observed in the stock market, investors may turn to fixed-income securities such as bonds or treasury bills, considered safer havens, thereby causing interest rates to rise. Due to the complexity of these factors, the impact of the stock market on interest rates generally occurs in a multifaceted and dynamic manner.

The relationship between interest rates and the stock market has been extensively examined in the literature. To contribute to the literature, this research aims to determine the asymmetric relationships between variables using both hidden co-integration and asymmetric causality tests, which will provide insights into investors' portfolio management. Additionally, it is believed that the study may offer a different perspective on the relationship between interest rates and investment in Turkey, thereby contributing to a better understanding of this dynamic.

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