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Nonlinear Relationships Between Inflation, Interest, and Exchange Rates in Türkiye: A Fourier-Based Approach

Cemal ÖZTÜRK[1]

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Abstract

This study examines the long-term relationships among Türkiye's inflation, interest, and exchange rates, using Fourier-based econometric techniques to account for structural breaks and non-linear trends. Traditional methods often fail to capture the complexities of emerging market economies with high volatility, such as Türkiye, where external shocks and structural shifts play a significant role. We apply the Fourier Augmented Dickey-Fuller and Johansen-Fourier cointegration tests to address these dynamics, enabling a nuanced analysis of Türkiye's economic variables. Our findings reveal a strong, positive long-term relationship between exchange rates and inflation, highlighting the critical impact of currency fluctuations on domestic price levels. In contrast, interest rates show a weaker direct influence on inflation, suggesting that while monetary policy adjustments are necessary, they may be insufficient to control inflation in Türkiye. Cointegration regression analyses using FMOLS, DOLS, and CCR methods further support these relationships, indicating the need for exchange rate stabilization policies to mitigate inflationary pressures. This study contributes to the literature by applying Fourier-based methods, which provide a more flexible and accurate model for understanding Türkiye's economic structure. The results offer valuable insights for policymakers in Türkiye and other emerging markets where external dependencies amplify inflation risks, underscoring the importance of integrated policy approaches for achieving long-term economic stability.

Keywords: *Inflation, interest rate, exchange rate, structural breaks, Fourier analysis, cointegration, nonlinear dynamics, Turkish economy*

JEL Code: *C22, C32, E31, F31*

1 Pamukkale Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, Ekonomi Bölümü, Arş.Gör.Dr., cemalo@pau.edu.tr, ORCID: 0000-0003-3850-7416

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Türkiye'de Enflasyon, Faiz ve Döviz Kurları Arasındaki Doğrusal Olmayan İlişkiler: Fourier Tabanlı Bir Yaklaşım

Öz

Bu çalışma, Türkiye'nin enflasyon, faiz oranı ve döviz kuru arasındaki uzun vadeli ilişkilerini, yapısal kırılmaları ve doğrusal olmayan eğilimleri dikkate alan Fourier tabanlı ekonometrik teknikler kullanarak incelemektedir. Geleneksel yöntemler, Türkiye gibi yüksek volatiliteye sahip gelişmekte olan ekonomilerin karmaşıklığını yakalamakta yetersiz kalmaktadır; bu ekonomilerde dış şoklar ve yapısal değişiklikler önemli bir rol oynamaktadır. Çalışmada, bu dinamikleri ele almak için Fourier Augmented Dickey-Fuller ve Fourier-Johansen eşbütünleşme testleri uygulanmıştır ve Türkiye'nin ekonomik değişkenlerinin daha ayrıntılı bir şekilde analizi sağlanmıştır. Bulgularımız, döviz kuru ile enflasyon arasında güçlü ve pozitif bir uzun vadeli ilişki olduğunu göstermekte ve döviz kuru dalgalanmalarının yurtiçi fiyat seviyeleri üzerindeki kritik etkisini vurgulamaktadır. Buna karşın, faiz oranlarının enflasyon üzerindeki doğrudan etkisi daha zayıf kalmakta, bu da para politikası ayarlamalarının gerekli olmakla birlikte enflasyonu kontrol etmekte tek başına yeterli olmayabileceğini göstermektedir. FMOLS, DOLS ve CCR yöntemleri kullanılarak yapılan eşbütünleşme regresyon analizleri, bu ilişkileri desteklemekte ve enflasyonist baskıları azaltmak için döviz kuru istikrarına yönelik politikaların önemini ortaya koymaktadır. Bu çalışma, Türkiye'nin ekonomik yapısını daha esnek ve doğru bir şekilde anlamayı sağlayan Fourier tabanlı yöntemlerin uygulanması yoluyla literatüre katkı sunmakta ve dış bağımlılıkların enflasyon risklerini artırdığı diğer gelişmekte olan ülkeler için de değerli politika içgörüleri sağlamaktadır.

Anahtar Kelimeler: *Enflasyon, faiz oranı, döviz kuru, yapısal kırılmalar, Fourier analizi, eşbütünleşme, doğrusal olmayan dinamikler, Türkiye ekonomisi.*

JEL Kodu: *C22, C32, E31, F31*

Introduction

In recent decades, Türkiye's economy has faced significant macroeconomic challenges characterized by high inflation, volatile interest rates, and frequent exchange rate fluctuations. These economic issues are closely interlinked, with exchange rate movements impacting inflation through import prices, while interest rates serve as a tool for monetary authorities to manage inflationary pressures. Understanding the relationships among these key macroeconomic variables is essential, particularly in economies like Türkiye that are vulnerable to external shocks and domestic policy shifts (Kara & Öğünç, 2008; Çatık & Karaalp, 2010; Ozdogan, 2022).

In emerging markets, the interconnectedness of inflation, interest, and exchange rates is often amplified by structural changes, policy interventions, and global economic cycles. Türkiye's dependence on imported intermediate goods and energy makes the exchange rate a particularly powerful transmission channel for inflationary dynamics. Several studies have documented that the exchange rate pass-through (ERPT) is notably high in Türkiye, particularly during episodes of currency depreciation and rising import costs (Sezgin, 2024; Bari, 2020). These effects have been further reinforced in recent years, where increased exchange rate volatility has significantly accelerated consumer price inflation (Ozdogan, 2022). Although this study does not include an explicit import variable, this well-documented pass-through mechanism provides a robust theoretical and empirical basis for analyzing how exchange rate fluctuations influence inflation in import-dependent economies like Türkiye.

In economic literature, the relationships among inflation, interest rates, and exchange rate changes are explained through various theoretical frameworks. These dynamics are particularly important in open economies, where fluctuations in exchange rates and interest rates can significantly impact inflation. Numerous studies have documented the relationship between inflation, interest rates, and exchange rate movements. For instance, Mishkin (1992) established that high inflation expectations often lead to elevated nominal interest rates, while Fama (1981) found that changes in exchange rates can directly affect inflation through import prices (Mishkin, 1992; Fama, 1981). Taylor (1995) also emphasized that exchange rates are integral to monetary policy settings, influencing inflation and interest rate decisions (Taylor, 1995).

In this study, we aim to derive a model that explains the domestic inflation rate as a function of the domestic interest rate and the rate of exchange rate changes. The primary theoretical assumptions underpinning our model are Interest Rate Parity (IRP), Purchasing Power Parity (PPP), the Fisher Hypothesis, and the Rational Expectations Hypothesis. Within this framework, we systematically investigate how fluctuations influence domestic inflation in exchange rates and interest rates.

Interest Rate Parity (IRP) posits that the expected rate of change in nominal exchange rates, denoted as $\dot{e_t}$ is equal to the difference between the domestic and foreign interest rates, formally expressed as:

$$\dot{e_t} = i_t - i_t^*,$$

where i_t and i_t^* represent domestic and foreign interest rates, respectively. IRP assumes that arbitrage will ensure no differential in returns between domestic and foreign assets in the presence of risk-neutral investors (Dornbusch, 1976).

Purchasing Power Parity (PPP) complements IRP by linking exchange rates to inflation differentials, such that:

$$e_t = \pi_t - \pi_t^*,$$

where π_t and π_t^* are the domestic and foreign inflation rates, respectively. PPP suggests that currency values adjust to equate price levels across countries, especially in the long term (Cassel, 1918).

The Fisher Hypothesis further supports the model by connecting nominal interest rates to expected inflation, positing that the nominal interest rate i_t is composed of the real interest rate r_t and expected inflation π_t, expressed as:

$$i_t = r_t + \beta\pi_t$$

where $\beta = 1$ represents a full pass-through of inflation expectations to interest rates (Fisher, 1930).

Finally, the Rational Expectations Hypothesis introduces the assumption that the expected change in nominal exchange rates $\dot{e_t}$ reflects all available information, including the observed exchange rate e_t and a random error term ε_t with $E(\varepsilon_t) = 0$:

$$\dot{e_t} = e_t + \varepsilon_t.$$

Using these theoretical foundations, we can derive a model that expresses the domestic inflation rate in terms of the domestic interest rate and the rate of the exchange rate change. First, using PPP, we know that $e_t = \pi_t - \pi_t^*$. Substituting this into the IRP equation, we express the exchange rate change rate in terms of interest rates and inflation rates:

$$\dot{e_t} = i_t - i_t^* = (\pi_t - \pi_t^*) + \varepsilon_t.$$

Assuming constant values for the foreign interest rate (i_t^*), foreign inflation rate (π_t^*), and real interest rate (r_t), adding the Fisher Hypothesis allows us to relate the nominal interest rate i_t to the inflation rate. Consequently, we arrive at the following final model, which represents domestic inflation as a function of interest rate and exchange rate change:

$$\pi_t = \alpha_0 + \alpha_1 i_t + \alpha_2 e_t + u_t,$$

where $\alpha_0 = r_t - \pi_t^*$, represents the constant term, α_1 and α_2 are coefficients to be estimated, capturing the effect of interest rates and exchange rates on inflation, and u_t is an error term accounting for unobserved factors. This specification provides a structured framework to empirically investigate the relationship between inflation, interest rates, and exchange rate dynamics, facilitating an analysis of inflationary behavior in response to monetary and exchange rate policies.

Despite the widely documented interrelationships among these macroeconomic variables, much of the existing literature relies on traditional econometric methods that assume stable and linear relationships over time. These methods may prove to be inadequate for the economy of Türkiye, where instances of structural change and nonlinear paths are evident. Standard unit root and cointegration tests often cannot capture these irregular patterns sufficiently, limiting their ability to fully capture dynamically the inter-relationships obtained among inflation, interest rates, and exchange rates in emerging markets.

This study addresses the existing gap by employing advanced econometric techniques, specifically the Fourier Augmented Dickey-Fuller (Fourier ADF) and Johansen-Fourier cointegration tests. These methods integrate Fourier components to account for both abrupt structural breaks and gradual trends, enabling a more comprehensive analysis of long-term equilibrium relationships in nonlinear dynamics. By capturing both sudden shifts and smooth transitions, this approach offers a more flexible and accurate framework for examining the interdependencies among Türkiye's macroeconomic indicators.

Literature Review

The relationship between inflation, interest rates, and exchange rates has been extensively studied, especially in emerging markets where these variables are more volatile and responsive to external shocks. Cabral et al. (2016) explore how inflation targeting influences exchange rate volatility in 24 emerging market economies, showing that while it stabilizes inflation, it also impacts exchange rate volatility, especially in response to crises. The study highlights the importance of tailored monetary policies to balance inflation control with currency stability in emerging markets.

The complex dynamics between exchange rates and interest rates are further examined by Capasso et al. (2019) in the Mexican economy, using a nonlinear autoregressive distributed lags (NARDL) model. They find a significant asymmetric long-term relationship between real interest rates and real exchange rates, suggesting that central banks in emerging markets often respond differently to exchange rate changes based on economic conditions.

Nazlıoğlu et al. (2018) analyze how oil prices impact inflation and monetary policy across major emerging economies, including Türkiye. Using a Toda-Yamamoto causality framework, they highlight how structural shifts in oil prices influence the interrelationship between interest rates and inflation, stressing the importance of energy prices in inflation management.

Asab et al. (2018) examine whether inflation targeting or fixed exchange rate regimes better support price stability in emerging markets. Using GARCH models, they conclude that while fixed exchange rates stabilize inflation, inflation-targeting regimes reduce inflation inertia and persistence, indicating that inflation-targeting regimes are more effective in emerging markets.

Ibrahim and Sukmana (2023) investigate Indonesia's exchange rate and monetary policy post-2009. Using VAR models, they reveal that monetary policy tightening results in a temporary appreciation of the rupiah, but exchange rates remain sensitive to external economic factors (Ibrahim and Sukmana, 2023).

Recent studies in the Turkish context have provided insights into how inflation, interest rates, and exchange rates interrelate. Sahin and Dereli (2019) analyzed these dynamics post-1980, highlighting how changes in Turkish monetary policy, especially after the 2008 global crisis, influenced the interplay among these macroeconomic factors. They observed a strengthened relationship between inflation and exchange rates following policy adjustments.

Şen et al. (2020) investigated these relationships in five emerging market economies, including Türkiye, Brazil, and South Africa. They identified long-term co-movement among inflation, interest, and exchange rates. They found that currency depreciation contributes to inflationary pressures across these economies, demonstrating the close interdependence of these macroeconomic indicators in emerging markets. Similarly, Kara and Dede (2023) emphasize the impact of exchange rate volatility on inflation in Türkiye, finding that exchange rate movements significantly contribute to inflation. Supporting these findings, recent empirical studies such as Sezgin (2024) and Bari (2020) confirm that Türkiye's strong import dependency amplifies the pass-through effect of exchange rates on domestic prices. Ozdogan (2022) further shows that this pass-through has increased in recent years, correlating with heightened currency volatility.

A growing number of Turkey-based studies examine the causality and cointegration among these variables using various econometric techniques. Konak and Peçe (2023) find bidirectional causality between exchange rates and inflation in the short term and unidirectional causality from inflation to exchange rate in the long term. Şanlı (2022) confirms that a 1% increase in the exchange rate leads to a 0.7% increase in wholesale prices, with significant long-run cointegration. Küçük and Dereli (2021) report short-run causality from exchange rates to interest rates and mutual causality based on VEC models.

Other notable studies such as Baktemur (2021), Yıldırım and Sarı (2020), İşcan and Durgun Kaygısız (2019), Yenice and Yenisu (2019), Akgül and Özdemir (2018), Karahan and Çolak (2017), and Doğan et al. (2016) further explore these interrelationships using nonlinear causality tests, ARDL, NARDL, and cointegration frameworks. Collectively, these works confirm that the transmission mechanisms between interest rates, exchange rates, and inflation are complex, regime-sensitive, and time-varying in the Turkish economy.

Although a growing number of studies examine the relationships among inflation, interest rates, and exchange rates in Türkiye, most of these works rely on linear models and do not fully capture the presence of multiple or gradual structural changes. Very few studies employ nonlinear methodologies that account for smooth shifts over time—an especially relevant feature given Türkiye's frequent policy changes and economic shocks. In this context, the present study contributes to the literature by applying Fourier-based econometric techniques specifically designed to detect nonlinear trends and smooth structural breaks. This paper addresses an important empirical gap by modeling inflation, interest rates, and exchange rates over a long horizon. It provides more nuanced insights into the evolving macroeconomic dynamics of the Turkish economy.

Data Description and Characteristics

Table 1 provides essential information on the data utilized in this study, covering Türkiye's interest rates, inflation rates, and exchange rates over an extended observation period (January 2006 – November 2024) with monthly frequency. The interest rate data represent Türkiye's 2-year government bond yields (Investing.com, 2024), the inflation rate data capture the annual percentage change in the Consumer Price Index (CPI), and the exchange rate data reflect the Turkish Lira/US Dollar nominal spot rate (Central Bank of the Republic of Türkiye, 2024). The choice of 2006 as the starting year is driven by its significance in Türkiye's macroeconomic policy history. Specifically, 2006 marks the official transition from an implicit inflation-targeting framework to a fully-fledged inflation-targeting regime, a milestone in the country's monetary policy evolution. This shift was a key outcome of the post-2001 crisis structural reforms, aiming to enhance central bank independence and monetary policy credibility. Additionally, adopting a floating exchange rate regime and deepening financial markets during this period significantly influenced the interactions among inflation, interest rates, and exchange rates. Since the study focuses on long-term macroeconomic relationships, selecting 2006 as the starting point ensures that the analysis aligns with a stable and policy-relevant economic framework.

Table 1

Summary of Data Variables and Sources For Economic Analysis

Variable	Description	Frequency	Period	Source
Interest Rate	Türkiye 2-Year Government Bond Yield	Monthly	January 2006 – November 2024	Investing.com
Inflation Rate	Annual percentage change of the Consumer Price Index (CPI)	Monthly	January 2006 – November 2024	Central Bank of the Republic of Türkiye
Exchange Rate	Nominal spot exchange rate (Turkish Lira/US Dollar)	Monthly	January 2006 – November 2024	Central Bank of the Republic of Türkiye

Figure 1 depicts the historical trends of three primary economic indicators in Türkiye — the exchange rate (USD/TRY), the interest rate (2-year government bond yield), and the inflation rate (annual CPI change) — from 2006 to 2024. The blue line represents the exchange rate, the green line denotes the interest rate, and the red line illustrates the inflation rate. Significant economic events are marked as shaded areas in the background, providing contextual insights into the fluctuations of these indicators over time.

Key economic events include the Global Financial Crisis (2008-2009), the Taper Tantrum (2013), the Coup Attempt in Türkiye (2016), the Currency Crisis in Türkiye (2018), the COVID-19 Pandemic (2020-2021), and the Recent Inflation Surge (2022 onwards). Each of these events corresponds to notable shifts in the economic indicators, reflecting Türkiye's sensitivity to global and domestic economic disruptions.

The nominal exchange rate between the Turkish Lira and the U.S. Dollar has generally shown an upward trend, with significant depreciation episodes during the 2018 currency crisis and the recent post-2021 inflation surge. These periods of rapid depreciation indicate heightened economic uncertainty and investor concerns regarding Türkiye's monetary stability.

The interest rate, as represented by the 2-year government bond yield, has demonstrated substantial volatility, particularly around periods of economic crises. Peaks in bond yields during the Global Financial Crisis, the currency crisis, and the recent inflation surge reflect heightened risk perceptions among investors and tighter monetary policies aimed at containing inflation.

Türkiye’s inflation rate remained relatively stable until the mid-2010s, after which it rose significantly, especially during and after the currency crisis in 2018. The inflation rate surged to unprecedented levels post-2021, reflecting a combination of factors, including currency depreciation, global inflationary pressures, and domestic policy responses.

This figure visually represents how major economic events impact multiple facets of the Turkish economy simultaneously, demonstrating the interconnected nature of exchange rates, interest rates, and inflation. Understanding these dynamics is critical for econometric analysis, especially for testing long-term equilibrium relationships and examining the stability of these indicators over time. The figure thus sets a foundation for econometric approaches such as Fourier unit root and cointegration tests, which can help assess the persistence and structural shifts in these variables.

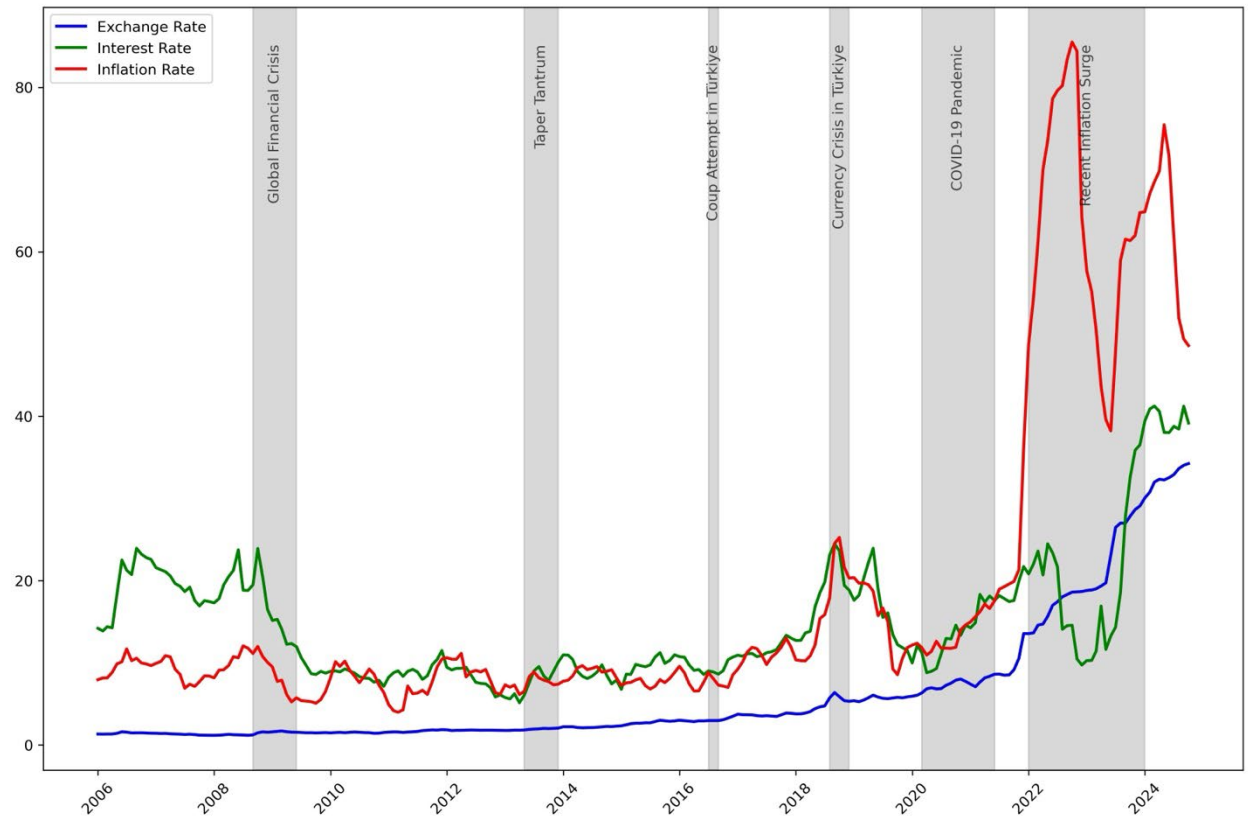

Figure 1. Historical trends in inflation, interest, and exchange rate with key economic events

Table 2 provides an overview of the inflation, interest, and exchange rates through key descriptive statistics and nonlinearity tests. The inflation rate shows substantial variability, with a high mean (18.22%) and significant dispersion, reflected in a large standard deviation and extreme values. The positive skewness and high kurtosis further indicate that inflation experiences occasional large spikes, deviating from normality, as confirmed by the Jarque-Bera test. Similarly, the interest and exchange rates exhibit notable volatility and skewness, indicating the presence of extreme values and asymmetry in their distributions. Both variables deviate from normality and exhibit nonlinearity, supported by the significant BDS and F_{trig} tests. These results suggest complex, non-linear dynamics across all three indicators, likely influenced by structural shifts, policy changes, and external shocks. Such findings validate the need for advanced econometric techniques, such as Fourier-based unit root and cointegration tests, to accurately capture these non-linearities and structural breaks in modeling the relationships among inflation, interest rates, and exchange rates in the Turkish economy.

Table 2

Descriptive Statistics and Nonlinearity Tests for Inflation, Interest, and Exchange Rate

	Inflation Rate	**Interest Rate**	**Exchange Rate**
Mean	18.22	14.78	6.26
Median	9.95	11.90	2.68
Maximum	85.51	41.23	34.23
Minimum	3.99	5.14	1.18
Std. Dev.	19.80	7.75	8.12
Skewness	2.05	1.64	2.14
Kurtosis	2.85	2.71	3.60
Jarque-Bera	234.91***	169.90***	294.51***
BDS	8.31***	5.31***	6.45***
F_{trig}	76.74***	101.48***	72.12***
k^*	1.0	1.0	1.0

Notes: SD denotes the standard deviation, S refers to skewness, K represents kurtosis, and JB indicates the Jarque-Bera normality statistic, as developed by Jarque and Bera (1987). The F_{trig} statistic evaluates the null hypothesis of no trigonometric components within the model, utilizing the F-test approach for validation. The selected Fourier frequency, k^*, is determined by minimizing the sum of squared residuals, ensuring optimal representation of structural breaks and nonlinear patterns. Additionally, the BDS statistic, introduced by Broock et al. (1996), is employed to detect nonlinearity in the time series data. Statistical significance is marked with *, **, and *** to indicate levels at 10%, 5%, and 1%, respectively.

In Figure 2, Fourier transformations are applied to three key economic indicators — the exchange, interest, and inflation rates — to capture periodic fluctuations and potential structural shifts over time. The Fourier analysis, represented by the orange dashed line, smooths the underlying trends in each variable, allowing us to identify cyclical patterns and long-term changes beyond short-term volatility.

Fourier transformations are useful for identifying non-linear patterns and structural breaks that traditional linear models might not capture. By applying Fourier transformations, we can better understand how each variable's long-term trends relate to one another, aiding in tests for cointegration and unit root processes within the Fourier-based framework. These insights are crucial for assessing the stability and equilibrium relationships between inflation, interest, and exchange rates. This study will test Fourier ADF and Fourier Johansen cointegration tests.

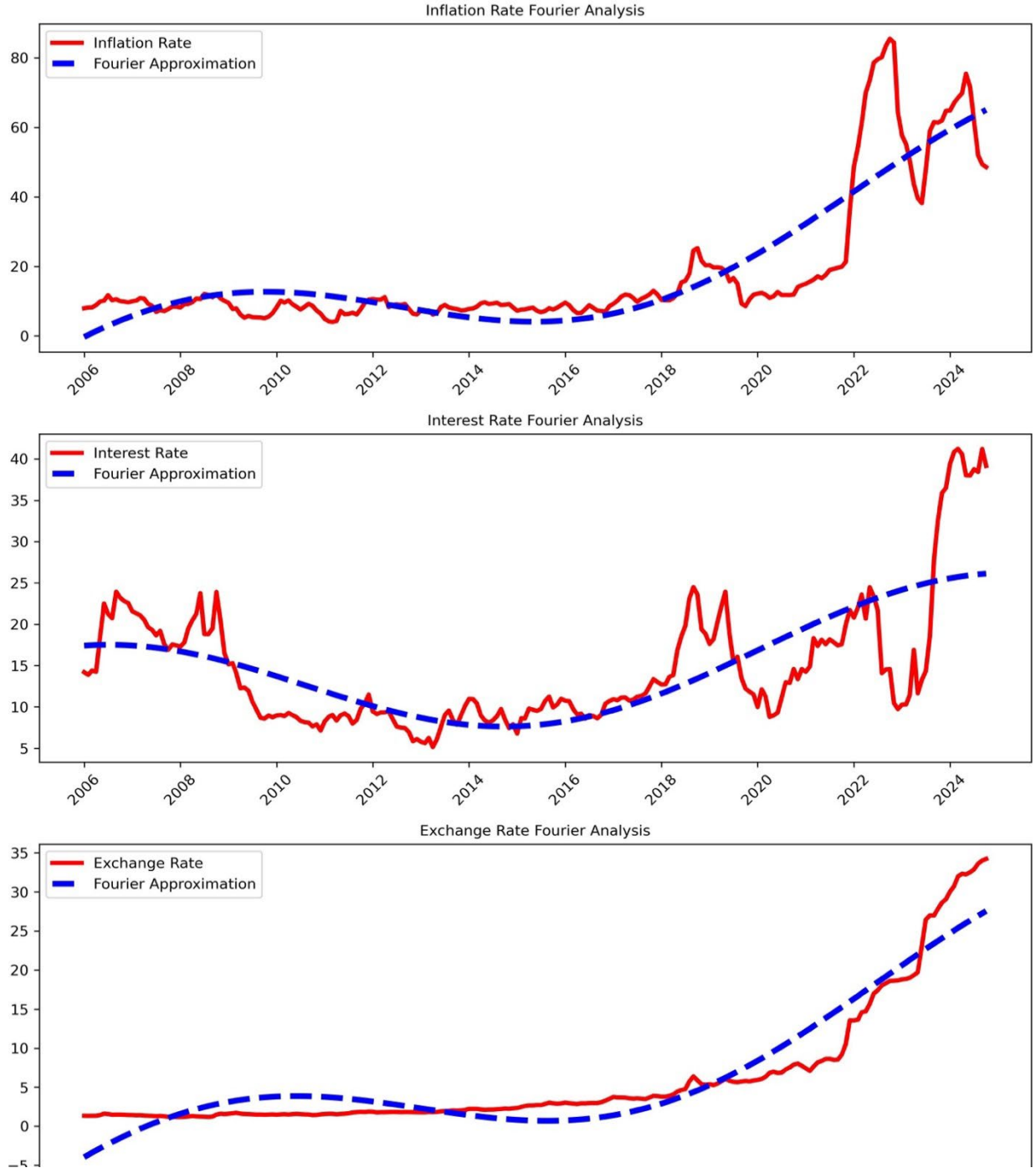

Figure 2. Fourier analysis of inflation, interest, and exchange rate

Figure 3 presents the correlation matrix for Türkiye's inflation, interest, and exchange rates over the entire period (2006-2024). This matrix reveals a strong positive correlation between inflation and the exchange rate, suggesting that fluctuations in the Turkish Lira significantly impact inflation, likely due to Türkiye's reliance on imported goods and raw materials. Additionally, a moderate positive correlation is observed between inflation and interest rates, indicating that interest rates tend to rise alongside inflationary pressures as part of monetary policy responses.

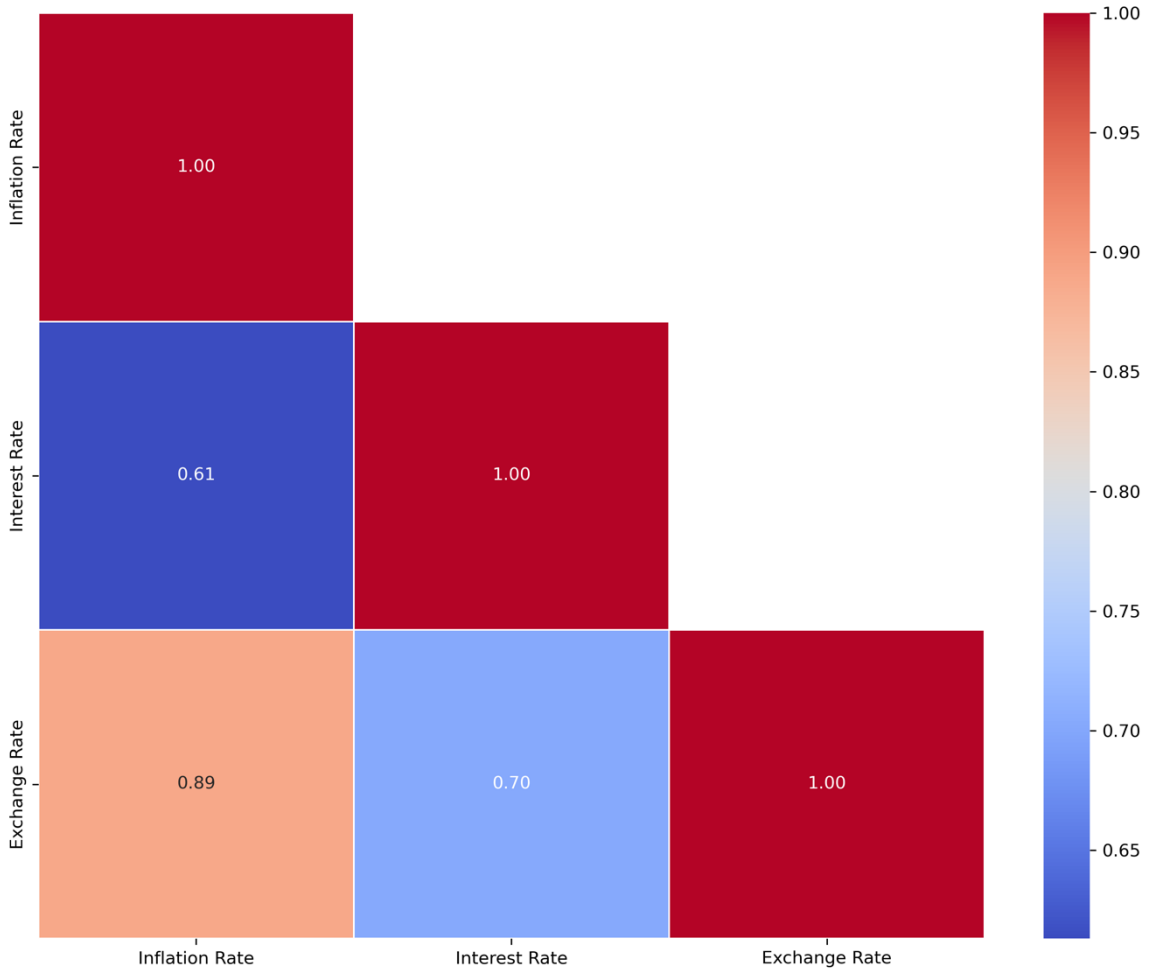

Figure 3. Correlation matrix

Table 3 extends this analysis by providing correlation measures across three distinct periods, allowing for a more granular examination of how these relationships have evolved. The motivation for breaking down the analysis into sub-periods lies in capturing the changing economic dynamics influenced by major events, such as the global financial crisis, domestic economic policies, and recent currency fluctuations. It is important to note that this table only illustrates the evolution of correlation structures over time. It highlights how different economic conditions and external shocks have shaped inflation, interest, and exchange rate relationships over these three sub-periods.

In the pre-2008 period, the correlation between inflation and the exchange rate is relatively low, reflecting a period of relative currency stability. Post-2008, the correlations fluctuate, particularly as Türkiye's economy adjusts due to global financial events and internal policy shifts. In the most recent period (2018-2024), a notable increase in the inflation-exchange rate correlation underscores how recent currency depreciation has intensified inflationary pressures. This pattern indicates that the exchange rate has become an increasingly critical factor in driving inflation, especially under recent economic challenges, emphasizing the need for policies that stabilize the currency to manage inflation effectively.

Table 3

Correlation Analysis of İnflation, İnterest, and Exchange Rate Across Different Periods

Inflation Rate	January 2004 - November 2008	December 2008 - December 2017	January 2018 - October 2024
Interest Rate	0.61	0.35	0.51
Exchange Rate	0.36	0.49	0.81

Methodology

In this study, we investigate the stationarity properties of key economic variables—namely, inflation, interest, and exchange rates—in Türkiye. These variables exhibit complex dynamics influenced by internal factors, such as monetary policy shifts, and external shocks, such as global financial crises. Understanding the statistical properties of these variables is crucial, as non-stationary time series can lead to spurious regression results, potentially misleading the interpretation of econometric models.

Descriptive analysis of these variables reveals notable features, including high variability and skewness, as well as significant deviations from normality. For instance, the inflation rate displays substantial volatility with periods of sharp increases, especially in recent years, indicating the likelihood of structural breaks. Similarly, the exchange rate has experienced pronounced shifts, reflecting periods of currency devaluation, while the interest rate has shown fluctuations linked to monetary policy adjustments. Standard unit root tests like the Augmented Dickey-Fuller (ADF) test may lack the power to detect stationarity effectively in the presence of these features, particularly when structural breaks or non-linearities are present.

To address these complexities, we apply the Augmented Dickey-Fuller (ADF), Zivot-Andrews (ZA), and Fourier Augmented Dickey-Fuller (Fourier ADF) tests. Each test has specific strengths that complement our analysis in light of the statistical characteristics of the variables. The ADF test, developed by Dickey and Fuller (1981), is foundational to determining whether a variable is non-stationary without structural breaks. However, given the high variability and potential regime shifts observed in our data, traditional unit root tests can sometimes lack the power to detect non-stationarity in the presence of structural breaks, which motivates the use of the ZA and Fourier ADF tests as complementary approaches.

The ADF test, developed by Dickey and Fuller (1979, 1981), extends the basic Dickey-Fuller test by including lagged differences of the dependent variable to account for autocorrelation. The model tested in the ADF framework is:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{j=1}^{p} \delta_j \Delta y_{t-j} + \varepsilon_t, \quad (7)$$

where Δy_t is the first difference of the series, t represents a deterministic trend, p is the lag length chosen to eliminate autocorrelation, and γ is the coefficient of interest. The ADF test statistic is computed as follows:

$$ADF = {\hat{\gamma}}/{se(\hat{\gamma})}, \quad (8)$$

where $\hat{\gamma}$ is the estimated coefficient, and $se(\hat{\gamma})$ is its standard error. The null hypothesis $H_0: \gamma = 0$ indicates a unit root (non-stationarity), while rejection of H_0 implies stationarity.

While the ADF test accounts for autocorrelation by adding lagged terms, it assumes homoscedasticity in the error term, which may not hold in practice. Phillips and Perron (1988) modifies the ADF framework by incorporating non-parametric corrections to the test statistic, specifically using the Newey-West heteroscedasticity and autocorrelation consistent (HAC) estimator. The model for the PP test is:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \varepsilon_t, \tag{9}$$

The PP test statistic is similar to the ADF test but includes adjustments:

$$PP = \frac{\hat{\gamma} - \frac{1}{2} T \hat{f}_0}{\sqrt{VAR(\hat{\gamma})}}, \tag{10}$$

where $\hat{f}_0$ is an estimate of the long-run variance of ε_t, and $VAR(\hat{\gamma})$ is the asymptotic variance of $\hat{\gamma}$. Like the ADF test, the PP test's null hypothesis is that the series has a unit root.

Economic time series are often subject to structural breaks due to events such as policy changes or economic shocks. The Zivot and Andrews (1992) test improves on traditional tests by allowing for a single, endogenously determined structural break in the series. This test is suitable for situations where a sudden change in the trend or level is expected. The ZA model is specified as:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 D_t^B + \delta_2 D_t^T + \sum_{j=1}^{p} \delta_j \Delta y_{t-j} + \varepsilon_t, \tag{11}$$

where D_t^B is a dummy variable for a structural break in the intercept, and D_t^T represents a dummy variable for a break in the trend. The null hypothesis is that the series has a unit root with no structural break, while the alternative hypothesis suggests stationarity with a break.

The test statistic for the null hypothesis of a unit root is given by the t-statistic of γ, denoted as $ADF(\lambda)$, where $\lambda = {}^{T_B}/_{T}$ represents the location of the break as a proportion of the sample size. The break location λ is chosen to minimize the $ADF(\lambda)$, statistic across all potential break points. Let λ_{inf} denote the value of λ that minimizes the test statistic. The unit root test statistic in Zivot and Andrews (1992) is therefore defined as:

$$ADF(\lambda_{inf}) = \inf_{\lambda} ADF(\lambda). \tag{12}$$

This approach enables the ZA test to endogenously select the optimal break point, enhancing its sensitivity to structural shifts in the data.

When data exhibit multiple or gradual structural breaks, traditional unit root tests may not fully capture these dynamics. The Fourier ADF test, developed by Enders and Lee (2012), addresses this by incorporating low-frequency trigonometric terms into the deterministic component of the model, allowing it to approximate smooth, gradual shifts in trend without requiring prior knowledge of the break dates.

It is important to note that the including Fourier terms captures nonlinear trends in the deterministic component. In other words, this approach does not test for nonlinear behavior like regime-switching or asymmetries found in models such as TAR frameworks. Rather, the Fourier ADF test is particularly suitable when structural changes are unknown and continuous, enabling more flexible modeling of the trend structure while remaining within a linear time series framework. The Fourier ADF test is specified as:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \sin\left(\frac{2\pi k t}{T}\right) + \delta_2 \cos\left(\frac{2\pi k t}{T}\right) + \sum_{j=1}^{p} \delta_j \Delta y_{t-j} + \varepsilon_t, \tag{13}$$

where $\sin\left(\frac{2\pi kt}{T}\right)$ and $\cos\left(\frac{2\pi kt}{T}\right)$ are Fourier terms that capture smooth structural shifts. For the Fourier ADF test, the test statistic for the null hypothesis of a unit root is given by the t-statistic of γ, denoted as $ADF(k)$, where k represents the Fourier frequency used in the model.

An advanced cointegration testing method is required to accurately capture the complex dynamics of macroeconomic variables influenced by structural shifts and gradual changes. The Johansen-Fourier cointegration approach builds on the traditional Johansen cointegration test (Johansen, 1991) by incorporating Fourier functions to account for structural breaks and non-linear trends. This methodology is particularly suitable when the timing and number of breaks in the data are unknown. The Fourier function helps approximate multiple smooth breaks without the need for abrupt dummy variables, thus enhancing the test's flexibility and performance in gradual shifts in economic relationships (Pascalau et al., 2022).

The cointegrated vector autoregressive (VAR) model with a Fourier function is expressed as:

$$\Delta X_t = \Pi X_{t-k} + \sum_{j=1}^{k-1} \Gamma_j \Delta X_{t-j} + \mu + f_t + e_t, \tag{14}$$

where X_t is a p-dimensional vector, $e_t \sim N_p(0, \Lambda)$ and f_t represents the Fourier function introduced to capture smooth, gradual breaks in the cointegrating vector. Cointegration exists if the matrix Π has reduced rank, $r < p$, allowing $\Pi = \alpha\beta'$, where α and β are $p \times r$ matrices of adjustment and cointegrating vectors, respectively.

The Fourier function f_t is modeled as:

$$f_t = \sum_{j=1}^{n} \left(A_j \cos\left(\frac{2\pi jt}{T}\right) + B_j \sin\left(\frac{2\pi jt}{T}\right) \right), \tag{15}$$

where n is the number of cumulative frequencies, A_j and B_j are parameters, and T is the sample size. By selecting appropriate low-frequency components, the Fourier function captures unknown non-linear breaks across time, reducing the need to specify exact breakpoints or the number of breaks.

The Fourier-Johansen test is based on maximizing the likelihood function while determining the cointegrating rank. Residuals are obtained from regressions of ΔX_t on lagged values and the Fourier terms. The eigenvalues from these residuals are used to compute two test statistics: the trace test and the maximum eigenvalue test, formulated as:

$$Trace\ Test: LR = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i), \tag{16}$$

$$Max\ Eigenvalue\ Test: \lambda_{max} = -T \ln(1 - \hat{\lambda}_{r+1}), \tag{17}$$

where $\hat{\lambda}_i$ are the eigenvalues from the system of residuals. These statistics allow testing the null hypothesis of at most r cointegrating relationships against the alternative of more cointegrating vectors.

The optimal frequency k^* is typically selected based on the minimization of the sum of squared residuals from the Ordinary Least Squares (OLS) estimation. In practice, low frequencies (e.g., $k \leq 3$) are preferred to capture economic trends without overfitting, as too many parameters may reduce the test's power.

This approach offers robustness in identifying cointegrating relationships in the presence of smooth, unknown structural changes. However, it is more suitable for smooth breaks and may lose power due to sharp, abrupt structural shifts. Therefore, when both smooth and sharp breaks are suspected, a combination of tests may provide a comprehensive analysis (Pascalau et al., 2022).

Empirical Results

This section applied various unit root tests to examine the stationarity properties of inflation, interest rate, and exchange rate series, incorporating both traditional and advanced methodologies. Tables 4, 5, and 6 present the results from the ADF, PP, Zivot-Andrews, and Fourier ADF tests, offering insights into the presence of unit roots and the impact of structural breaks and non-linear trends. The empirical analysis in this study was performed using GAUSS, utilizing TSPDLIB for time series methods as provided by Nazlıoğlu (2021).

Table 4 displays the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, conducted under two specifications: with a constant and with a constant and trend. Both tests consistently indicate non-stationarity at levels for all variables, as the test statistics for inflation, interest rate, and exchange rate fail to exceed the critical values at standard significance levels. This suggests that the series exhibits unit root behavior, reflecting a lack of mean reversion in levels when structural changes are not accounted for. However, when the variables are first-differenced, both the ADF and PP tests strongly reject the null hypothesis of a unit root at the 1% significance level in almost all cases. This confirms that the variables are integrated of order one, I(1), satisfying the necessary condition for applying cointegration analysis.

Table 4

Conventional Unit Root Test Results

	Constant			**Constant and trend**		
	ADF	**p**	**PP**	**ADF**	**p**	**PP**
Level						
Inflation Rate	0.509	12	-1.481	-0.955	12	-2.431
Interest Rate	-1.389	8	-0.997	-1.944	8	-1.440
Exchange Rate	3.635	10	6.026	2.569	10	2.918
First Difference						
Inflation Rate	-4.802***	12	-7.964***	-4.933***	12	-7.956***
Interest Rate	-5.653***	12	-12.529***	-6.133***	12	-12.576***
Exchange Rate	-1.963	12	-8.037***	-5.466***	4	-8.864***

Notes: The optimal lag length, p, for the ADF test was selected based on the t-statistic significance of the final lagged dependent variable at a 10% threshold, with a maximum lag length set at 12. For the PP test, the Quadratic Spectral kernel was applied along with the Newey–West automatic bandwidth selection method for spectral estimation. The critical values for the ADF test with a constant are -3.41 at the 1% level, -2.83 at the 5% level, and -2.53 at the 10% level, while for the model with both constant and trend, the critical values are -3.93 (1%), -3.37 (5%), and -3.08(10%). In the PP test, the critical values for a model with a constant are -3.46 (1%), -2.88 (5%), and -2.58 (10%), and for a model with constant and trend, they are -3.98 (1%), -3.42 (5%), and -3.13 (10%).

Table 5 presents the Zivot-Andrews (ZA) test results, which account for a single endogenous structural break in the series. At the level, the test identifies a significant break for the inflation rate in November 2021. ADF statistics exceed the 1% critical value across both Model A and Model B, indicating stationarity after accounting for the break. This suggests that inflation is strongly influenced by recent structural changes, likely related to Türkiye's policy and price shocks in that period. For the interest rate and exchange rate, although break dates are detected (e.g., September 2022 and October 2020, respectively), the ADF statistics at the level do not exceed critical thresholds, indicating that a single structural break may not be sufficient to account for their non-stationary behavior.

However, when the series is first-differenced, the ZA test strongly rejects the unit root null across all three variables at the 1% level in both model specifications. This confirms that the variables become stationary after first differencing, even when accounting for structural breaks, and are thus integrated of order one, I(1). These results reinforce the robustness of earlier unit root test findings and validate the use of cointegration analysis in the subsequent stages.

Table 5

Zivot-Andrews (ZA) Test With Structural Breaks Results

	Model A			Model B		
	ADF(λ_{inf})	**p**	**T_B**	**ADF(λ_{inf})**	**p**	**T_B**
Level						
Inflation Rate	-8.713***	12	November 2021	-6.363***	12	November 2021
Interest Rate	-3.561	7	Sebtember 2022	-4.096	7	October 2008
Exchange Rate	1.639	11	October 2021	-3.698	11	October 2020
First Difference						
Inflation Rate	-5.638***	12	November 2021	-12.906***	11	October 2021
Interest Rate	-6.947***	12	October 2022	-7.403***	12	April 2022
Exchange Rate	-7.875***	3	October 2020	-7.755***	3	November 2013

Notes: The optimal lag length, p, was identified based on the significance of the t-statistic for the last lagged dependent variable at the 10% level, with a maximum lag limit of 12. The break date, TB, is determined endogenously. The critical values for Model A are -5.34 (1%), -4.80 (5%), and -4.58 (10%), while for Model B, they are -5.57 (1%), -5.08 (5%), and -4.82 (10%). Statistical significance is indicated as *** for 1%, ** for 5%, and * for 10%.

One limitation of the ZA approach is its inability to model multiple or gradual breaks over time—especially in economies like Türkiye's, where structural changes are frequent and not necessarily abrupt. To address this issue, the analysis proceeds with the Fourier ADF test, which allows for smooth and unknown structural changes by incorporating low-frequency trigonometric terms into the deterministic trend. This method offers a more flexible alternative to capture non-linear and time-varying shifts in the data's underlying structure.

Table 6 presents the results of the Fourier Augmented Dickey-Fuller (ADF) test, which extends the conventional unit root framework by incorporating low-frequency trigonometric terms to account for smooth structural changes. The test was applied under two specifications: level shift and level-and-trend shift.

At the level, none of the variables reject the unit root null hypothesis across either specification, confirming the findings from the standard ADF and Zivot-Andrews tests. However, the F_{trig} statistics are highly significant for all three variables in both models, strongly indicating that Fourier terms significantly improve the model by capturing underlying non-linear trend behavior and smooth structural shifts.

When the series is first differenced, the ADF test statistics reject the null hypothesis of a unit root at the 1% level for inflation and interest rates under both specifications and for the exchange rate under the level-and-trend shift model. These results confirm that the variables are integrated of order one ($I(1)$), even when accounting for gradual structural changes. Additionally, the F_{trig} values remain statistically significant, especially for inflation, further validating the presence of smooth and evolving trends in Türkiye's macroeconomic data.

Table 6

Fourier ADF Test Results

	Level shift					**Level and trend shift**				
	$\boldsymbol{ADF\ (k^*)}$	$\boldsymbol{p}$	$\boldsymbol{k^*}$	$\boldsymbol{F_{trig}}$	$\boldsymbol{p-val.}$	$\boldsymbol{ADF\ (k^*)}$	$\boldsymbol{p}$	$\boldsymbol{k^*}$	$\boldsymbol{F_{trig}}$	$\boldsymbol{p-val.}$
Level										
Inflation Rate	1.089	12	4	74.03***	0.000	-0.864	12	4	143.89***	0.000
Interest Rate	-3.454	9	1	101.48***	0.000	-2.077	8	2	93.66***	0.000
Exchange Rate	4.324	11	4	72.12***	0.000	-0.274	10	1	338.12***	0.000
First Difference										
Inflation Rate	-5.175***	12	4	2.79*	0.0634	-5.508***	12	4	3.12**	0.0462
Interest Rate	-5.947***	12	2	3.2	0.1034	-6.352***	12	2	2.01	0.1368
Exchange Rate	-2.317	12	2	16.23***	0.0000	-5.704***	9	1	11.84***	0.0000

Notes: The optimal lag length, p, was chosen based on the significance of the t-statistic for the last lagged dependent variable at the 10% level, with a maximum lag limit of 12. The optimal Fourier frequency, k^*, was selected by minimizing the sum of squared residuals from the OLS estimation with k values ranging from 1 to 5. The Ftrig statistic is the standard F-statistic used to test the null hypothesis of no trigonometric terms ($\delta_1 = \delta_2 = 0$) in the model for level shifts and both level and trend shifts in equation (13), using $k = k^*$. The critical values for the Fourier ADF, ADF(k^*), test are provided in Enders and Lee (2012). Statistical significance is marked as *** at the 1% level, ** at the 5% level, and * at the 10% level.

Based on the previous unit root test results, all variables demonstrate non-stationarity, indicating the presence of unit roots across the inflation rate, interest rate, and exchange rate. This non-stationary nature suggests that these macroeconomic variables will likely exhibit persistent trends over time, making it essential to explore potential long-term equilibrium relationships among them. The Fourier unit root test is particularly well-suited here, as it accommodates the possibility of structural breaks and non-linear adjustments, which are common in economic series influenced by various policy changes and external shocks.

The standard Johansen cointegration test was first applied to examine long-term equilibrium relationships among inflation, interest rates, and exchange rates. The test results, presented in Table 7, indicate that at rank 1 and 2, both the Lambda and Trace statistics significantly exceed their 5% critical values, thereby confirming the existence of at least two cointegrating relationships under the conventional framework.

However, the standard Johansen cointegration test may be unreliable in the presence of structural breaks, as it assumes parameter stability throughout the sample. Several studies have noted that such breaks can lead to biased inference if not properly modeled (Trenkler, 2005; Gregory & Hansen, 1996). Trenkler (2005) provides simulation-based evidence showing that the standard Johansen procedure is prone to size distortions and misleading inference under such conditions. This limitation is particularly relevant for Türkiye, where the economy has undergone multiple regime changes, policy shifts, and external shocks over the study period.

The Fourier-Johansen cointegration test was also employed to address this issue, as it allows for smooth and gradual structural changes to be captured using low-frequency sine and cosine terms. Unlike conventional approaches, this method does not rely on pre-specified break dates or arbitrary dummies, offering a flexible and robust framework for testing cointegration in complex macroeconomic systems. Pascalau et al. (2022) further support this approach by showing that Fourier-based cointegration tests exhibit superior size and power properties under structural instability.

The analysis incorporated both single-frequency and cumulative-frequency specifications within the Fourier-Johansen framework to ensure robustness. As shown in Table 7, under the single-frequency approach, both the Lambda and Trace statistics at rank 1 and 2 exceed their respective critical values at the 5% level, indicating the existence of two cointegrating relationships.

In contrast, under the cumulative-frequency specification, although rank 1 still confirms at least one cointegrating vector, the test statistics at rank 2 fall below their critical thresholds, suggesting that the evidence for a second relationship weakens when multiple frequencies are aggregated.

This divergence highlights the sensitivity of the results to the chosen frequency specification and reinforces the need for robustness checks in Fourier-based analysis. Still, the consistency in identifying at least one long-term equilibrium relationship across all methods supports the validity of the findings.

In conclusion, the cointegration analysis confirms the presence of at least one stable long-term relationship among Türkiye's inflation, interest rates, and exchange rates across both standard and Fourier-based methodologies. These findings emphasize the necessity of accounting for structural shifts and nonlinear trend behavior when analyzing macroeconomic interactions in structurally evolving economies like Türkiye.

Table 7

Johansen-Fourier Cointegration Test Results for Long-Term Equilibrium Relationships

Rank	Lambda	Trace	cv (5%) Lambda	cv (5%) Trace
Johansen				
1.000	67.443**	83.764**	17.796	24.276
2.000	14.769**	16.321**	11.225	12.321
3.000	1.551	1.551	4.129	4.129
Fourier Johansen Single frequency				
1.000	37.342**	66.079**	29.614	46.791
2.000	27.822**	28.738**	22.179	28.560
3.000	0.915	0.915	14.214	14.214
Fourier Johansen Cumulative frequency				
1.000	47.334**	93.764**	45.626	89.826
2.000	30.449	46.430	38.466	58.419
3.000	15.980	15.980	30.288	30.288

Notes: The number of lags for the VAR model (k) is set to 2, and the Fourier frequency (f) is chosen as 3 to capture smooth breaks and cyclical components in the data optimally. These parameters were selected to minimize the sum of squared residuals and enhance model precision. Statistical significance is marked as *** at the 1% level, ** at the 5% level, and * at the 10% level.

Given the confirmed presence of cointegration through the Fourier Johansen cointegration test, we applied three cointegration regression methods—FMOLS, DOLS, and CCR—to estimate the long-term relationships between the variables of interest. These approaches are widely recognized in econometric literature for providing robust long-term parameter estimates in the presence of cointegrated variables (Phillips and Hansen, 1990; Park, 1992; Stock and Watson, 1993).

The long-term relationship was estimated by incorporating Fourier terms at optimal frequencies, as reported in Table 8, to capture the smooth, nonlinear long-run dynamics implied by the Fourier-based cointegration test. The FMOLS, DOLS, and CCR models include sine and cosine components to reflect periodic structural changes and nonlinear adjustment patterns.

The results show that both the exchange rate and interest rate have statistically significant effects on inflation, with the exchange rate having a notably stronger impact. This finding is consistent with earlier studies focusing on Türkiye, Kara and Öğünç (2008), Karaoğlu and Kılıçkaplan (2018), Türel and Orhan (2022), and Şen et al. (2020) highlight the strong pass-through effect of exchange rate changes on inflation in the Turkish economy.

This supports the exchange rate pass-through mechanism (ERPT), where currency depreciation increases the cost of imported goods and inputs, resulting in higher consumer prices—especially in import-dependent economies like Türkiye. The statistical significance of the interest rate variable also indicates the role of monetary transmission mechanisms, although with a weaker effect. This suggests that while interest rate changes influence inflation expectations, their long-term impact may be limited without accompanying structural reforms. Including Fourier components strengthens the model's ability to reflect cyclical inflation behavior and structural shifts, aligning it with the nonlinear characteristics of macroeconomic dynamics in emerging markets.

Table 8

Cointegration Regression Results Using FMOLS, DOLS, and CCR

Inflation Rate	**FMOLS**	**DOLS**	**CCR**
Constant	5.677***	4.850***	5.677***
Interest Rate	0.343**	0.450***	0.343**
Exchange Rate	1.196***	1.151***	1.196***
$\sin(2\pi t/T)$	-4.053***	-4.523***	-4.053***
$\sin(2\pi 2t/T)$	-6.484***	-7.336***	-6.484***
$\sin(2\pi 3t/T)$	-5.695***	-6.432***	-5.695***
$\cos(2\pi t/T)$	5.177***	5.232***	5.177***
$\cos(2\pi 2t/T)$	1.759**	2.009**	1.759**
$\cos(2\pi 3t/T)$	-1.105	-1.083	-1.105

Notes: Statistical significance is marked as *** at the 1% level, ** at the 5% level, and * at the 10% level.

Conclusion And Policy Implications

This study applied Fourier-based econometric techniques to explore the long-term interactions among Türkiye's inflation, interest rates, and exchange rates while accounting for structural breaks and nonlinear trends. The Johansen-Fourier cointegration tests confirmed the existence of at least one stable long-term equilibrium relationship, particularly highlighting the strong influence of exchange rate dynamics on inflation. Cointegration regression methods, including FMOLS, DOLS, and CCR, were estimated using Fourier terms to account for smooth structural changes in the long-term relationship. The results confirmed that both the exchange rate and interest rate have statistically significant effects on inflation, with the exchange rate exerting a notably stronger influence. The significance of the Fourier components indicates that nonlinear trend behavior and gradual structural shifts are present in Türkiye's inflation dynamics. These findings suggest that traditional monetary policy tools alone may not be sufficient to control inflation in Türkiye's context, especially without considering exchange rate movements and underlying structural changes.

The findings of this study suggest that a more integrated and comprehensive policy framework is required to achieve price stability in Türkiye. Policymakers should prioritize exchange rate stabilization policies, as exchange rate fluctuations significantly contribute to inflationary pressures. Strengthening foreign exchange reserves and implementing measures to reduce currency volatility can be critical. Additionally, structural reforms focusing on reducing import dependence, enhancing domestic production, and improving the resilience of financial markets should be considered. Since monetary policy alone may not be sufficient, a coordinated approach between fiscal and monetary policies would be more effective in maintaining long-term economic stability.

While this study provides important insights, it has certain limitations. The analysis is limited to three macroeconomic variables (inflation, interest rates, and exchange rates), excluding other potential determinants such as energy prices, fiscal policies, or global economic conditions. Future studies could expand the dataset to include additional macroeconomic indicators for a more comprehensive understanding. Additionally, the study is focused solely on Türkiye, and while the findings may provide relevant insights for other emerging economies, generalizability remains limited. Further research could apply Fourier-based techniques to different economies to compare structural shifts and nonlinearities across various economic environments.

This study underscores the importance of applying Fourier-based econometric methods to capture structural breaks and nonlinear trend patterns in macroeconomic analysis. By addressing these complexities, this approach accurately represents Türkiye's macroeconomic dynamics and offers valuable insights for policymakers in other emerging market economies facing similar structural challenges.

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Genişletilmiş Özet

Amaç

Bu çalışma, Türkiye ekonomisindeki enflasyon, faiz oranı ve döviz kuru arasındaki uzun vadeli ilişkileri, yapısal kırılmaları ve doğrusal olmayan eğilimleri dikkate alarak analiz etmeyi amaçlamaktadır. Türkiye gibi ithalat bağımlılığı yüksek olan ve sık sık dış şoklara maruz kalan ekonomilerde, bu değişkenler arasındaki etkileşimler, para politikalarının etkinliği açısından kritik öneme sahiptir. Geleneksel ekonometrik yöntemler bu karmaşık dinamikleri yeterince açıklamada yetersiz kalırken, Fourier tabanlı yöntemler, yapısal kırılmalar ve kademeli değişimlerin etkilerini modellemekte önemli avantajlar sunmaktadır. Bu bağlamda, çalışma, döviz kuru dalgalanmalarının enflasyon üzerindeki etkilerini ve faiz oranlarının enflasyon kontrolündeki etkinliğini değerlendirmeyi hedeflemektedir. Araştırmanın temel sorusu, Türkiye'deki bu makroekonomik değişkenlerin uzun vadeli ilişkilerinin politika yapıcılar için ne tür içgörüler sunduğudur. Bu çalışma, literatüre metodolojik ve uygulamalı katkılar sağlamayı amaçlamaktadır.

Tasarım ve yöntem

Bu çalışmada, Türkiye ekonomisindeki makroekonomik değişkenlerin uzun vadeli dinamiklerini incelemek için Fourier tabanlı ekonometrik yöntemler kullanılmıştır. Bu yöntemler, yapısal kırılmalar ve doğrusal olmayan eğilimleri modelleme konusundaki esneklikleri ile öne çıkmaktadır. Analizde ilk olarak, Fourier Augmented Dickey-Fuller (ADF) testi kullanılarak değişkenlerin birim kök özellikleri değerlendirilmiştir. Bu test, hem ani hem de kademeli yapısal değişimlerin etkisini dikkate alarak daha güvenilir sonuçlar sağlamaktadır. İkinci olarak, Fourier Johansen eşbütünleşme testi, değişkenler arasındaki uzun vadeli ilişkilerin varlığını ve bu ilişkilerin yapısal kırılmalar ışığında nasıl evrildiğini belirlemek için uygulanmıştır. Çalışmada, 2006-2024 yılları arasındaki dönemi kapsayan aylık veriler kullanılmıştır. Veriler, Türkiye Cumhuriyet Merkez Bankası ve uluslararası veri tabanlarından temin edilmiştir. İncelenen değişkenler arasında enflasyon oranı (TÜFE), 2 yıllık devlet tahvil faiz oranı ve nominal döviz kuru (TL/USD) bulunmaktadır. Bu veri seti, Türkiye'nin ekonomik istikrarını etkileyen temel unsurları kapsamlı bir şekilde değerlendirmek için seçilmiştir. Verilerin analizi GAUSS ve Python yazılımları aracılığıyla gerçekleştirilmiştir. Elde edilen sonuçların güvenilirliğini artırmak amacıyla, eşbütünleşme analizinden sonra FMOLS (Fully Modified Ordinary Least Squares), DOLS (Dynamic Ordinary Least Squares) ve CCR (Canonical Cointegration Regression) yöntemleri kullanılarak uzun vadeli ilişkilerin tahmini yapılmıştır. Bu yöntemler, otokorelasyon ve içsellik gibi ekonometrik sorunları minimize ederek değişkenler arasındaki ilişkinin daha net bir şekilde anlaşılmasını sağlamaktadır. Bu metodolojik yaklaşım, özellikle gelişmekte olan ekonomilerde karşılaşılan doğrusal olmayan eğilimleri ve ani yapısal kırılmaları modelleme açısından geleneksel yöntemlere göre üstünlük sunmaktadır. Bu sayede, Türkiye gibi yüksek volatiliteye sahip bir ekonomide, döviz kuru dalgalanmalarının enflasyon üzerindeki etkisi daha ayrıntılı bir şekilde incelenebilmiştir. Çalışma hem ekonomik teoriye katkı sunmakta hem de politika yapıcılar için uzun vadeli ve pratik içgörüler sağlamaktadır.

Bulgular

Çalışma sonuçları, döviz kuru ile enflasyon arasında güçlü ve pozitif bir uzun vadeli ilişki olduğunu ortaya koymaktadır. Fourier Johansen eşbütünleşme testi, bu iki değişkenin uzun vadede birlikte hareket ettiğini ve döviz kurundaki değişimlerin enflasyon üzerinde belirgin bir etkisi olduğunu göstermektedir. FMOLS, DOLS ve CCR yöntemleriyle yapılan tahminler, döviz kurundaki 1 birimlik artışın enflasyonda yaklaşık 2.2 birimlik bir artışa neden olduğunu ortaya koymuştur. Bu bulgu, döviz kuru dalgalanmalarının Türkiye'nin ithalat bağımlılığı nedeniyle iç fiyatlar üzerinde güçlü bir baskı oluşturduğunu ve fiyat istikrarının sağlanmasında döviz kuru yönetiminin kritik bir öneme sahip olduğunu vurgulamaktadır. Ayrıca, analiz sonuçları faiz oranlarının enflasyon üzerindeki etkisinin hem istatistiksel olarak zayıf hem de büyüklük açısından sınırlı olduğunu göstermektedir. Bu durum, faiz oranlarının uzun vadeli enflasyon kontrolünde tek başına etkili bir araç olmadığını ortaya koymaktadır. Faiz oranı ayarlamalarının enflasyon kontrolünde kısa vadeli etkileri olsa da, özellikle Türkiye gibi dış şoklara duyarlı ekonomilerde, bu etkilerin sınırlı kaldığı görülmüştür. Bu bağlamda, sonuçlar, döviz kuru istikrarını sağlamaya yönelik politikaların daha etkili olduğunu ortaya koymaktadır. Döviz kuru dalgalanmaları, ithalat maliyetlerini artırarak enflasyonu tetiklemekte ve bu da fiyat istikrarını sağlamak için uygulanan politikaların etkinliğini zorlaştırmaktadır. Özellikle, Türkiye gibi ithalat bağımlılığı yüksek ekonomilerde, döviz kuru dalgalanmalarının enflasyon üzerindeki etkisi daha da belirgin hale gelmektedir. Bu nedenle, döviz kuru istikrarını hedefleyen politikalar, enflasyon yönetiminde daha öncelikli bir alan olarak öne çıkmaktadır. Son olarak, Fourier tabanlı yöntemlerin kullanımı, yapısal kırılmalar ve doğrusal olmayan eğilimlerin etkisini modellemekte önemli avantajlar sağlamıştır. Geleneksel ekonometrik yöntemlerle analiz edilmesi güç olan bu tür etkiler, Fourier tabanlı analiz sayesinde daha net bir şekilde ortaya konulmuştur. Bu yöntem, özellikle Türkiye gibi gelişmekte olan ülkelerde makroekonomik istikrarın sağlanması için kapsamlı ve esnek politika önerileri geliştirilmesine olanak tanımaktadır.

Sınırlılıklar

Bu çalışmanın belirli sınırlılıkları bulunmaktadır. İlk olarak, analiz yalnızca Türkiye ekonomisine odaklanmakta olup, bulguların diğer gelişmekte olan ülkeler için genellenebilirliği sınırlı olabilir. Ayrıca, kullanılan veri seti, mevcut resmi istatistiklerle sınırlıdır ve bazı potansiyel yapısal kırılmaların tam olarak yakalanamaması olasılığı bulunmaktadır. Ek olarak, çalışmada sadece üç ana makroekonomik değişken (enflasyon, faiz oranı, döviz kuru) ele alınmış olup, diğer potansiyel etkileyici faktörler (örneğin, enerji fiyatları veya dış ticaret verileri) dahil edilmemiştir. Bununla birlikte, bu eksiklikler çalışmanın temel amacını ve bulgularının geçerliliğini olumsuz etkilememektedir. Gelecek araştırmalar, daha geniş bir değişken seti ve alternatif modeller kullanarak bu sınırlılıkları gidermeyi hedefleyebilir.

Öneriler

Bu çalışma, döviz kuru dalgalanmalarının enflasyon üzerindeki etkilerini ve faiz oranlarının sınırlı etkisini vurgulamaktadır. Bu bulgular, Türkiye'de fiyat istikrarının sağlanması için daha kapsamlı ve entegre bir politika yaklaşımının gerekli olduğunu göstermektedir. Döviz kuru istikrarını sağlamak için merkez bankasının döviz rezervlerini güçlendirmesi ve döviz piyasasındaki volatiliteyi azaltıcı politikalar uygulaması önerilmektedir. Ayrıca, ithalat bağımlılığını azaltmak için uzun vadeli yapısal reformlar uygulanmalıdır. Bu reformlar, enerji ve sanayi sektörlerinde yerli üretimi artırmayı ve dış ticaret açığını azaltmayı hedeflemelidir. Para politikasına yönelik olarak, faiz oranı ayarlamalarının tek başına yeterli olmadığı göz önüne alındığında, enflasyon hedeflemesine yönelik bütüncül yaklaşımlar benimsenmelidir. Maliye politikası ile para politikasının uyumlu bir şekilde kullanılması, enflasyonla mücadelede daha etkili sonuçlar sağlayabilir.

Özgün değer

Bu çalışma, Fourier tabanlı ekonometrik yöntemleri kullanarak Türkiye ekonomisindeki makroekonomik değişkenler arasındaki ilişkileri inceleyen ilk araştırmalardan biridir. Yapısal kırılmaların ve doğrusal olmayan eğilimlerin etkisini dikkate alan bu yöntemler, geleneksel analizlerin ötesine geçerek daha doğru ve güvenilir sonuçlar sunmaktadır. Çalışma, Türkiye ekonomisinde döviz kuru dalgalanmalarının enflasyon üzerindeki güçlü etkisini vurgulayarak, döviz kuru istikrarının makroekonomik politika açısından önemini ortaya koymaktadır. Ayrıca, faiz oranlarının enflasyon üzerindeki sınırlı etkisini tespit ederek, politika yapıcıların daha geniş bir araç seti kullanması gerektiğini göstermektedir. Bu yönüyle çalışma, sadece Türkiye için değil, benzer ekonomik koşullara sahip diğer gelişmekte olan ülkeler için de uygulanabilir içgörüler sunmaktadır. Fourier tabanlı analizlerin sunduğu metodolojik yenilik, literatürdeki mevcut boşluğu doldurarak makroekonomik ilişkilerin daha derinlemesine anlaşılmasına katkı sağlamaktadır.