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INTERACTION AND VOLATILITY SPILLOVER AMONG SELECTED FINANCIAL ASSETS IN TÜRKİYE

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Abstract

This study aims to examine the dynamic relationships and volatility propagation mechanisms among selected financial assets in Türkiye. By analyzing the interactions between the Borsa Istanbul 100 Index (XU100), interest rates, gold prices and the USD/TRY exchange rate, the study assesses how shocks between these assets propagate. Using a time-varying parameter vector autoregression (TVP-VAR) model, the analysis analyzes monthly data for the period 01:2002-10:2024. The findings of the study shed light on the complex and interconnected nature of financial markets. While the XU100 is most affected by its own past shocks, assets such as gold and exchange rates are more exposed to external shocks. Aggregate volatility dispersion analysis reveals that Borsa Istanbul and gold act as net shock emitters, while interest rates and exchange rates act as net shock receivers. These results have important implications for both policymakers and investors. Investors should optimize their portfolio management strategies in line with these dynamics, while policymakers should take measures to minimize economic uncertainties and the effects of external shocks. The study contributes to a more effective and sustainable analysis of Turkish financial markets.

Keywords: *Financial Markets, Volatility, Time-Varying Parameter Vector Autoregressive Models (TVP-VAR), Türkiye.*

JEL Codes: *D53, F65.*

Türkiye'de Seçilmiş Finansal Varlıklar Arasındaki Etkileşim ve Volatilite Yayılımı

Öz

Bu çalışma, Türkiye'de seçilmiş finansal varlıklar arasındaki dinamik ilişkileri ve volatilite yayılım mekanizmalarını incelemeyi amaçlamaktadır. Araştırma, Borsa İstanbul 100 Endeksi (XU100), faiz oranları, altın fiyatları ve USD/TRY döviz kuru arasındaki etkileşimleri analiz ederek, bu varlıklar arasındaki şokların nasıl yayıldığını değerlendirmektedir. Zamana göre değişen

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parametreli vektör otoregresyon (TVP-VAR) modeli kullanılarak gerçekleştirilen analizde, 01:2002-10:2024 dönemine ait aylık veriler incelenmiştir. Araştırmanın bulguları, finansal piyasaların karmaşık ve bağlantılı yapısına ışık tutmaktadır. XU100, kendi geçmiş şoklarından en fazla etkilenirken, altın ve döviz kurları gibi varlıkların daha yüksek oranda dış şoklara maruz kaldığı gözlemlenmiştir. Toplam volatilite yayılımı analizleri, Borsa İstanbul ve altının net şok yayıcı olarak, faiz oranları ve döviz kurunun ise net şok alıcı olarak davrandığını ortaya koymaktadır. Bu sonuçlar, hem politika yapıcılar hem de yatırımcılar için önemli çıkarımlar sunmaktadır. Yatırımcıların portföy yönetim stratejilerini bu dinamikler doğrultusunda optimize etmeleri, politika yapıcıların ise ekonomik belirsizlikleri ve dış şokların etkilerini minimize edecek önlemler almaları gerekliliğini vurgulamaktadır. Çalışma, Türkiye finansal piyasalarının daha etkin ve sürdürülebilir bir şekilde analiz edilmesine katkı sağlamaktadır.

Anahtar Kelimeler: *Finansal Piyasalar, Volatilite, Değişen Parametreli Vektör Otoregresif (TVP-VAR), Türkiye.*

JEL Kodu: *D53, F65.*

1. INTRODUCTION

Shocks in financial markets affect not only individual assets but also the interactions and volatility propagation processes among these assets. Understanding such interactions provides important insights into the overall functioning of the financial system and plays a critical role in the decision-making processes of market actors (Diebold and Yılmaz, 2012). In particular, external factors such as financial crises, economic uncertainties and geopolitical risks may accelerate the spread of shocks in financial markets, which may directly affect investors' risk perception and strategies (Baur and McDermott, 2010). In this context, analyzing interactions between assets and volatility spillovers is of great importance from both theoretical and practical perspectives.

In emerging markets, especially in countries like Türkiye, the dynamic relationships among financial assets are subject to greater uncertainty and volatility. Türkiye's financial markets have been shaped by factors such as various economic crises, high inflation rates, exchange rate fluctuations and changes in interest rate policies in the past years. These variables have profoundly influenced the conduct of market participants and market dynamics (Özcan and Turhan, 2015). The Turkish economy, where interest rates and exchange rate policies played an important role especially after the 2001 crisis, faced high volatility and uncertainties again after the currency crisis in

2018. In this period, investors turned to assets such as gold and foreign exchange as hedging instruments, while factors such as the depreciation of the Turkish lira and global trade wars led to increased interactions and volatility in financial markets (Balcilar and Zeydan, 2020).

This study aims to analyse the interconnections and volatility spillovers among specific financial assets in Türkiye. The study analyses in detail the interactions between Türkiye 's largest stock market index, the BIST 100 (XU100), interest rates, gold prices and the USD/TRY exchange rate. These assets have undergone significant fluctuations in light of Türkiye 's economic and political events and have been in strong relationships with each other. In particular, gold and the exchange rate stand out as safe havens during periods of economic uncertainty, while the relationship between the BIST 100 Index and interest rates has fluctuated under the influence of Türkiye 's domestic and foreign economic policies (Yeldan and Yüceer, 2018).

In order to understand the time-varying nature of these interactions, the Time-Varying Parameterized Vector Autoregression (TVP-VAR) model is used in this study. TVP-VAR is a powerful tool for understanding how the dynamic relationships between financial assets evolve over time and the effects of exogenous shocks on these relationships (Primiceri, 2005). The use of this model provides a great advantage for analyzing time-varying macroeconomic conditions and market shocks. Moreover, this study on how financial markets transmit volatility spillovers and shocks aims to provide a Türkiye - specific perspective compared to other studies in the existing literature.

The study aims to make an important contribution to better understand the dynamic nature of interactions and volatility spillovers in Türkiye's financial markets and provide guidance to market actors and policy makers. In contrast to similar studies in the literature, this study analyses the dynamics of the Turkish economic and financial system in a specific way and provides an in-depth analysis of how the interactions between assets are shaped.

In the second section of the study, both national and international studies investigating the volatility spillover effect among financial assets using the Diebold and Yilmaz approach are presented, while the data set and methodology are presented in the third section. The fourth section presents the empirical findings and the fifth section presents the results and discussions.

2. LITERATURE

The interaction between investment instruments and the volatility spillovers between markets has been a topic of interest for many researchers. With the Diebold and Yılmaz (2012) article, the methodology used to reveal the spillover effect between different financial assets was introduced to the literature. With this study, it is observed that studies using the methodology of Diebold and Yılmaz (2012) have started to be included in the literature. Both national and international studies investigating the volatility spillover effect among financial assets using the Diebold and Yılmaz approach are presented.

Roy and Roy (2017) analysed the commodity market, bond index, gold and equity markets and exchange rate variables in India for the period 2006-2016 with daily data using the DCCMGARCH model and Diebold and Yilmaz (2012) diffusion index model. Volatility spillovers across markets are detected. While commodity and equity markets transmit volatility to other markets, bond, exchange rate and gold markets are volatility receiver markets. Volatility is transmitted to the commodity market only from the equity market. Volatility spillovers are found to vary across time periods, being higher in 2013-2014, the years of the global financial crisis and the depreciation of the rupee.

He et al. (2018) investigated the correlation between the real estate market and bank loans in China from 2005 to 2017. The study's results reveal a dynamic link between house prices and bank loans, with changes observable in both demand and supply aspects. The influence of property values on bank loans is considerably greater.

Liu et al. (2019) analysed the volatility of the Chinese stock market in relation to 28 distinct stock markets, including the IBEX35 (Spain), Hang Seng (Hong Kong), FTSE100 (UK), Bell20 Index (Belgium), Dow Jones Industrial Average (USA), DAX (Germany), CAC40 (France), Bovespa (Brazil), All Ordinaries (Australia), AEX (Netherlands) and Shanghai Composite Index (China). The study's findings demonstrate that TVP models produce more accurate results than other models in evaluating the interaction among stock markets, with the Chinese stock market exerting a more significant influence on other markets.

Karabıyık (2020) analysed the US dollar exchange rate, BIST 100 index, commodity index and bond interest rate variables in Türkiye for the period 2014-2019 using daily data and the Diebold and Yılmaz (2012) diffusion index approach. It was found that 4.4% of the volatility observed in the four markets analysed was caused by volatility spillovers. The bond market was found to have the largest impact on other markets with a value of 5.2 per cent.

Dahir et al. (2020) examined the volatility between Bitcoin and the stock market in BRICS countries (Brazil, Russia, India, China, and South Africa) from 2012 to 2018. The study's findings indicate that Bitcoin does not substantially influence the stock markets of BRICS nations; however, these stock markets propagate volatility to Bitcoin.

Adekoya and Oliyide (2021) analysed the influence of the COVID-19 pandemic on the correlation between financial markets and commodities. Gold, stock market indices, USDEUR exchange rates, Bitcoin, and oil prices were employed as variables for this purpose. The study's results demonstrate that gold and the dollar are net recipients of shocks, whereas the stock market, Bitcoin, and oil act as net shock transmitters. The COVID-19 epidemic was primarily responsible for the transmission of risk between financial markets and commodities.

Şenol and Koç (2022) analyse the MSCI world index, bond yields, US dollar, gold, oil and Bitcoin variables in twenty-three developed countries for the period 2015-2021 using daily data and the Diebold and Yılmaz (2012) diffusion index approach.

There is volatility spillovers across major markets at the global level. It is concluded that MSCI world index and interest rate are volatility spreaders while dollar index, gold, oil and bitcoin are volatility receivers. Interest rate is found to be the most volatility-emitting asset, while gold and MSCI world index are found to be the most volatility-receiving financial assets. Volatility spreads were observed to increase during the COVID-19 pandemic.

Cao and Xie (2022) conducted a study to assess the dynamic interrelations between the cryptocurrency market and the financial market. In this context, Bitcoin, Ethereum, and Ripple, which are cryptocurrencies, were picked as variables alongside China's foreign exchange, commodities, and foreign exchange markets. The study's results indicate a negative volatility correlation between assets overall, with cryptocurrencies exerting a similar influence on Chinese markets, despite exerting a more significant influence on commodity and exchange rate markets. Additionally, Bitcoin and Ripple exhibit a positive volatility spread, but Ethereum demonstrates a negative volatility spread.

Akyıldırım et al. (2022) performed a study to examine the dynamic interrelationships among assets in Turkish financial markets. The study period spans from 2008 to 2021, utilising variables such as CDS premium, commodity, bond, USDTRY exchange rate, BIST100 index and deposit rate. The study's results indicate that the degree of dynamic interconnection across assets escalates during moments of stress throughout the examined timeframe. Furthermore, CDS premium and the exchange rate function as shock propagators, whilst the bond, deposit rate and commodities markets serve as shock absorbers. The BIST100 index exhibits features of both a shock absorber and a shock propagator over time.

Chatziantoniou et al. (2022) investigated the volatility linkages between crude oil prices and the stock markets of G7 countries over the period from 2007 to 2021. The study analyzed major indices, including the American S&P 500, Canadian S&P/TSX, British FTSE 100, German DAX 30, French CAC 40, Italian FTSE MIB, and Japanese Nikkei 225. The results revealed that crude oil acted as a net transmitter of

shocks during the 2014 price collapse but shifted to functioning as a net absorber of shocks by around 2018. During the Brexit period, the UK stock market emerged as a net shock transmitter, while the German, Italian, and Japanese stock markets played the role of net shock absorbers.

Şak and Öcal Özkaya (2022) analyzed the dollar, euro, gold, and BIST 100 index variables in Türkiye between 2000 and 2022 using daily data. The study employed the diffusion index methodology developed by Diebold and Yılmaz (2012) and determined the volatility diffusion index among these variables to be 46.9%. During the post-2000 period analyzed, the lowest volatility spread was observed in 2012, followed by a sharp increase in 2013, with a consistent upward trend in volatility spread beginning in 2017. The pandemic period led to a continued rise in volatility spread until 2020. The findings indicate that the Euro and Dollar act as volatility spreaders, while Gold and the BIST 100 index function as volatility receivers.

Akkuş and Doğan (2023) conducted a study to explore the dynamic interactions between cryptocurrencies, NFTs (Non-Fungible Tokens), and DeFi (Decentralized Finance). The study focused on Bitcoin and Ethereum as representatives of cryptocurrencies, Tezos and Sandbox for NFTs, and Chainlink and Uniswap for DeFi assets. The results revealed that Ethereum and Chainlink act as volatility spreaders, while the other variables function as volatility absorbers. Additionally, NFT assets were found to have lower volatility levels compared to cryptocurrencies.

Gökgöz and Kayahan (2023) conducted a study to explore the volatility relationship between Bitcoin cryptocurrency and financial markets. The study analyzed data from 2017 to 2022, using Bitcoin, the MSCI US index, the MSCI Europe index, and the MSCI Emerging Markets index as key variables. The findings indicated that Bitcoin absorbs volatility from the MSCI US and MSCI Europe indices, while it generates volatility in relation to the MSCI Emerging Markets index. The analysis also revealed a weak correlation between Bitcoin and the financial markets.

Huang et al. (2023) studied the volatility dynamics between energy assets and financial markets from 2018 to 2022. The analysis included variables such as WTI (West Texas Intermediate), the natural gas market (NGS), gold, the S&P 500, US bonds, the US dollar, and Bitcoin. The findings concluded that the S&P 500 index acts as a net shock propagator, followed by NGS, gold, and the USD. In contrast, Bitcoin cryptocurrency was identified as a net shock absorber.

Höl (2023) conducted a study to evaluate the volatility of financial assets in Turkey during the COVID-19 period. The analysis focused on variables such as gold, Bitcoin, the BIST100 index, the dollar exchange rate, and the WTI (West Texas Intermediate) index, covering the years 2020 to 2022. The findings revealed that Bitcoin and gold are sources of volatility, while the BIST100 index, dollar exchange rate, and WTI crude oil prices act as recipients of volatility. The BIST100 index was found to be the most volatile variable, influenced by gold, Bitcoin, and the dollar exchange rate.

Doğan et al. (2023) explored the dynamic relationship between the BIST Sustainability Index, BIST100 Index, S&P Global Clean Energy Index (S&P GCEI), and S&P GSCI Carbon Emission Permits from 2014 to 2022. The study found that the carbon emission variable contributes to volatility in the S&P GCEI, BIST 100, and BIST Sustainability indices; however, this volatility significantly decreased during the COVID-19 period. Additionally, a weak volatility transmission was observed from the S&P GCEI index to both the BIST Sustainability Index and the BIST 100 index.

Medetoğlu (2024) aimed to examine the volatility spillovers and interconnections among nations. The study utilized data from January 1, 2015, to October 31, 2023, focusing on the benchmark stock markets of the CIVETS group, which includes Colombia, Indonesia, Vietnam, Egypt, Turkey, and South Africa. The findings indicated that the benchmark stock markets of Colombia, Indonesia, and Vietnam are volatility emitters, while those of Egypt, Turkey, and South Africa are classified as volatility receivers.

Sevillano et al. (2024) examined the relationship between oil price shocks and US sector returns, focusing on dynamic returns and volatility from October 2001 to January 2022. The study employed time series decomposition across various time scales using a wavelet methodology, combined with the TVP-VAR model introduced by Antonakakis et al. (2020). The findings revealed significant dynamic connectivity between markets, allowing for the identification of the contributions of all sector indices (except Communication Services, Utilities, and Real Estate) and risk shocks as net contributors to system shocks. In contrast, demand and supply shocks were found to act as net recipients of these spillovers.

3. DATA AND METHOD

3.1. Data Set

This study seeks to elucidate the dynamic interrelationship among the BIST 100 index, interest rates, gold prices, and exchange rates using monthly data from January 2002 to October 2024, comprising 264 observations. The variables used for this purpose are presented in Table 1.

Table 1. Variables Used in the Study

Code	Veriable	Explanation	Period	Observations	Source
LNXU100	BIST 100 Index	XU100 Closing Price	01:2002 - 10:2024	274	https://evds2.tcmb.gov.tr/
LNINTEREST	Interest Rates	Weighted Average Interest Rate on Deposits			
LNGOLD	Gold Price	Gram Gold Price (TL)			
LNUSD/TRY	Dollar Rate	US DolLar-TCMB Foreign Exchange Buying Rate			

The time series of the variables in the study were obtained from the TCMB Electronic Data Distribution System (TCMB,

2024). BIST 100 index is obtained with the criterion of January 1986=0.01 according to XU100 closing prices. Interest rates are obtained from the weighted average interest rates of deposits opened by banks over TRY with a maturity of up to 1 year. Deposit interest rates emerge as a more suitable indicator for measuring the dynamic relationships among financial assets. The primary reasons for this include their rapid adjustment to market conditions, their ability to better reflect risk perception and investor behavior, their strong interaction with assets such as exchange rates and gold, and their lower susceptibility to regulatory interventions compared to loan interest rates. Therefore, the preference for deposit interest rates over loan interest rates in this study enables a more accurate and objective analysis of the interconnectedness among financial markets. Gold prices are obtained by converting AUX/USD dollar-based ounce values into grams according to the Troy weight system and then converting the ounce value into Turkish Lira using the CBRT foreign exchange buying rate at the relevant time. Dollar exchange rates were obtained by using the foreign exchange buying rates and added to the study. After the relevant transformations of all variables, all variables are used in natural logarithmic form. The variable data sets were converted into return series using the formula $\ln(P_t/P_{t-1})*100$, and subsequently, the volatility series were derived by squaring the return series.

3.2. Method

This study used the time-varying parameter vector autoregressive (TVP-VAR) method to examine the interrelationship among the four financial assets. Antonakakis and Gabauer (2017) along with Diebold and Yilmaz (2009, 2012, 2014) enhanced the connectivity metrics utilising the fixed-parameter sliding window VAR methodology. The authors concurrently proposed dynamic metrics of connectivity utilising the TVP-VAR methodology with a time-varying covariance structure. The TVP-VAR model is preferred because it is sensitive to outliers, avoids the problem of randomisation of the moving window length and allows for smaller data sets

(Akyıldırım at al., 2022:352). The implementation of the TVP-VAR model is as follows (Antonakakis and Gabauer, 2017):

$$Y_t = \beta_t Y_{t-1} + \epsilon_t \qquad \epsilon_t | F_{t-1} \sim N(0, S_t) \tag{1}$$

$$\beta_t = \beta_{t-1} + v_t \qquad v_t | F_{t-1} \sim N(0, R_t) \tag{2}$$

Time-varying coefficients and error covariances are employed to estimate a generalised connectedness procedure grounded in the generalised impulse-response functions of Diebold and Yilmaz (2014) and the generalised forecast error variance decompositions established by Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998). The aggregate connectivity index is computed as follows (Antonakakis and Gabauer, 2017):

$$C_t^g(J) = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\phi}_{ij,t}^g(J)}{\sum_{i,i=1}^{N} \tilde{\phi}_{ii.t}^g(J)} * 100 \tag{3}$$

$$= \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\phi}_{ij,t}^g(J)}{N} * 100 \tag{4}$$

The concept of 'complete directional connectivity to others', in which variable i conveys its shock to all other j variables, is outlined as follows;

$$C_{i\rightarrow j,t}^g(J) = \frac{\sum_{j=1, i\neq j}^{N} \tilde{\phi}_{ji,t}^g(J)}{\sum_{i=1}^{N} \tilde{\phi}_{ii.t}^g(J)} * 100 \tag{5}$$

The condition called 'total directional connectedness from others' that variable i receives from other j variables is as follows;

$$C_{i\leftarrow j,t}^g(J) = \frac{\sum_{j=1, i\neq j}^{N} \tilde{\phi}_{ij,t}^g(J)}{\sum_{i=1}^{N} \tilde{\phi}_{ii.t}^g(J)} * 100 \tag{6}$$

'Net total directional connectedness, representing the "influence" of variable i on the network of all variables, is calculated by deducting total directional connectivity to others from total directional connectedness from others:

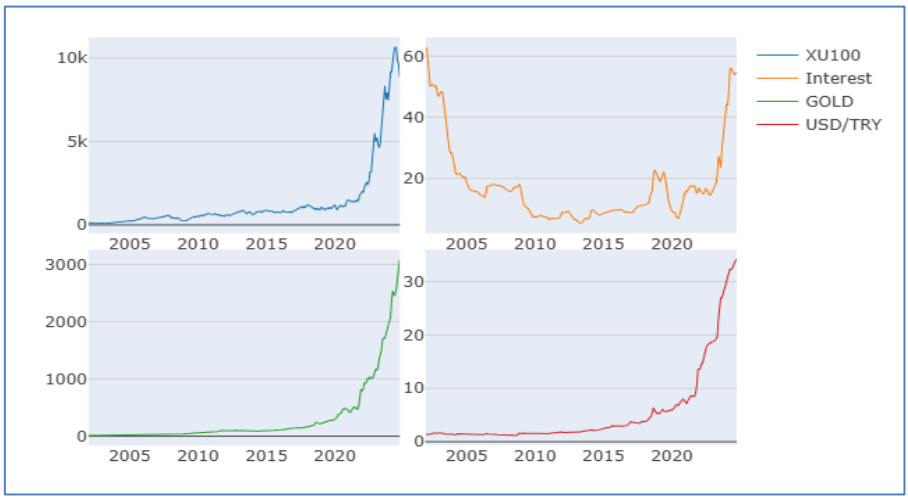
$$C_{i,t}^g = C_{i\rightarrow j,t}^g(J) - C_{i\leftarrow j,t}^g(J) \tag{7}$$

4. EMPIRICAL FINDINGS

This section analyses the dynamic interrelationship among the BIST 100 Index, interest rates, gold prices, and dollar

exchange rates employed in the study, utilising the TVP-VAR model. Figure 1 illustrates the graphs of the variable series.

Figure 1. Time Series Indicators of Variables



When the time series graphs of the variables in Figure 1 are analysed, it is seen that the XU100 followed an upward trend with a low slope until 2020, but the slope has increased since 2020 and made a leap. The XU100, which closed 2020 at 1,400 levels, exceeded the level of 10,000 in 04:2024, but started to decline as of 08:2024. It is seen that the interest rate, which was around 60% at the beginning of the 2000s, entered a downward trend and fell to single digits in 2009, and followed a horizontal trend by not fluctuating excessively until 2017. Although the interest rate increased between 2017-2019, it decreased to single digits again in 2020. Since then, it has followed a fluctuating trend, making a leap and reaching 50% in 2024. It is seen that gold prices did not show excessive fluctuations for many years until 2018 and followed a rising trend with a low slope. Since 2018, the slope has increased and the trend has jumped, and gold prices have increased twenty times on average, exceeding the TL 3,000 level from TL 150 levels. It is seen that the exchange rate did not fluctuate excessively until 2016 and followed a rising trend with a low slope for many years. Since 2016, it is seen that the slope has

increased and has exceeded 30 TRY by making a leap since 2020.

In order to determine the dynamic interconnectedness between the BIST 100 Index, interest rate, gold price and dollar exchange rate, the volatilities of the variables were calculated and the graphs of the volatility series are presented in Figure 2.

Figure 2. Volatility Series of Variables

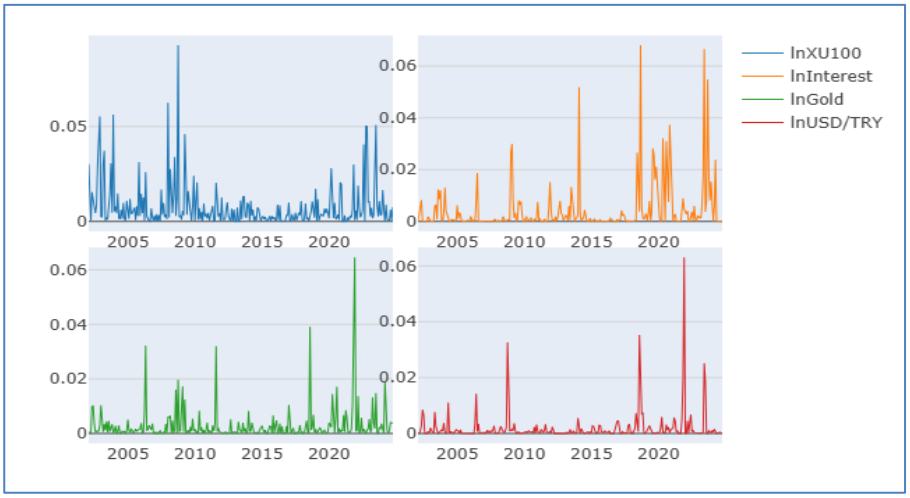


Figure 2 shows the volatility series graphs of the variables. When the logarithmic volatility series are analysed, it is seen that the XU100 index return has followed a fluctuating course, although it has increased since 2001, 2009 and the end of 2021. When the volatility series of the interest rate is analysed, it is seen that the volatility increased during the 2001 crisis and the 2008 crisis, and there was an excessive fluctuation in 2018 and 2023. When the volatility series of gold prices are analysed, it is observed that the volatility increased in 2006, 2009, 2018 and 2023, while the volatility was low in other years. When the volatility series of USD/TRY is analysed, it is observed that volatility increased in 2009, 2018, 2021 and 2023. Especially after 2020, it is observed that the volatility of interest rate, gold price and USD/TRY price is higher than the XU100.

Logarithmic returns of the series of variables were calculated and analysed. Descriptive statistics of the logarithmic return series are presented in Table 2.

Table 2. Descriptive Statistics of Variables

	lnXU100	**lnInterest**	**lnGold**	**lnUSD.TRY**
Mean	0.008	0.004	0.003	0.002
Variance	0	0	0	0
Skewness	3.277***	4.149***	5.399***	7.303***
	(0.000)	(0.000)	(0.000)	(0.000)
Ex.Kurtosis	13.596***	20.425***	37.809***	66.212***
	(0.000)	(0.000)	(0.000)	(0.000)
JB	2591.18***	5528.37***	17587.04***	52294.04***
	(0.000)	(0.000)	(0.000)	(0.000)
ERS	-1.831*	-4.867***	-6.071***	-6.305***
	(0.068)	(0.000)	(0.000)	(0.000)
Q(10)	24.999***	49.566***	14.049***	20.795***
	(0.000)	(0.000)	(0.009)	(0.000)
Q²(10)	11.714**	18.132***	15.793***	2.346
	(0.031)	(0.001)	(0.004)	(0.903)

(*) denotes significance at 10%; (**) denotes significance at 5%; (***) denotes significance at 1%.

The analysis reveals that the assets yielding the highest returns over the examined period are XU100, interest rates, gold, and USD/TRY, in that order; all return series of these assets exhibit left skewness, indicating a notable skewness in the returns of financial assets. The JB test statistic values indicate that the series do not conform to a normal distribution at the 1% significance level, however the ERS unit root test findings demonstrate that the interest rate, gold price, and USD/TRY series are stationary, while the XU100 series is non-stationary. Finally, among the Q(10) and Q2(10) test statistics expressing the error and error squares, only the Q2(10) statistic shows that the USD/TRY series does not contain autocorrelation.

In order to determine how many lags a past shock explains today's price, the appropriate lag length should be determined. In the analysis, the appropriate lag length was determined as 2 according to the Schwarz Information Criterion and the analysis was carried out by constructing the TVP-VAR (2) model. The

findings regarding the average dynamic interconnectedness between the variables are presented in Table 3.

Table 3. Average Dynamic Connectivity

	lnXU100	lnInterest	lnGold	lnUSD/TRY	FROM
lnXU100	70.69	2.28	15.40	11.63	29.31
lnInterest	6.58	75.38	9.99	8.05	24.62
lnGold	21.13	3.24	56.55	19.08	43.45
lnUSD/TRY	13.08	3.75	24.85	58.32	41.68
TO	40.78	9.27	50.25	38.76	139.06
Inc.Own	111.47	84.65	106.80	97.08	cTCI/TCI
NET	11.47	-15.35	6.80	-2.92	46.35/34.77
NPT	3.00	0.00	2.00	1.00	

Average dynamic interconnectedness shows the percentage of a change in the return of each variable during the period analysed, which is caused by itself and which is caused by other variables.

When the first row is analysed, 70.69% of a shock to the XU100 index is caused by its own past shocks, while the remaining 29.31% is caused by external shocks in the other three financial asset markets. Of the change in the variance of the XU100 index, 15.40% is explained by the gold price, 11.63% by the USD/TRY exchange rate and 2.28% by the interest rate shocks. However, when the XU100 column is analysed, it is seen that 6.58% of the shock spillovers from the XU100 index to other financial assets are towards interest rate, 21.13% towards gold price and 13.08% towards USD/TRY exchange rate asset markets. These findings indicate that XU100 has a strong interaction with the gold and foreign exchange markets, while its connection with interest rates remains relatively weak. This can be attributed to investors' risk perception, their search for safe-haven assets, and sensitivity to macroeconomic conditions. Particularly in periods of uncertainty, investors' tendency to shift towards safe-haven assets such as gold and foreign exchange may contribute to strengthening the relationship between the XU100 index and these markets.

When the second row is analysed, 75.38% of a shock in interest rates is caused by its own past shocks, while the remaining 24.62% is caused by external shocks in the other three financial asset markets. Of the change in the variance of

interest rates, 9.99% is explained by the gold price, 8.05% by the USD/TRY exchange rate and 6.58% by shocks to the XU100 index. However, when the interest rates column is analysed, it is seen that 3.75% of the shock spillovers from interest rates to other financial assets are towards USD/TRY market, 3.24% towards gold price and 2.28% towards XU100 index asset markets.

When the third row is analysed, 56.55% of a shock in gold prices is caused by its own past shocks, while the remaining 43.45% is caused by external shocks in the other three financial asset markets. Of the change in the variance of gold prices, 21.13% is explained by the XU100 index, 19.08% by the USD/TRY exchange rate and 3.24% by shocks to interest rates. However, when the gold prices column is analysed, it is seen that 15.40% of the shock spillovers from gold prices to other financial assets are towards the XU100 index, 9.99% towards the interest rate and 24.5% towards the USD/TRY asset markets.

When the fourth row is analysed, 58.32% of a shock to the USD/TRY exchange rate is caused by its own past shocks, while the remaining 41.68% is caused by external shocks in the other three financial asset markets. Of the change in the variance of the USD/TRY exchange rate, 13.08% is explained by the XU100 index, 3.75% by interest rates and 24.85% by gold price shocks. However, when the USD/TRY column is analysed, 11.63% of the shock spillovers from USD/TRY exchange rate to other financial assets are towards XU100 index, 8.05% towards interest rates and 19.08% towards USD/TRY gold markets.

When the diagonal values in the table are analysed, it is seen that the assets that are least affected by self-induced shocks are gold with 56.55%, USD/TRY with 58.32%, XU100 index with 70.69% and interest rate with 75.38%, respectively. The findings reveal that the assets with the highest shock spillovers are between gold and USD/TRY exchange rate markets. The impact of a shock in the gold market on the USD/TRY exchange rate is 24.85%, while the impact of a shock in the USD/TRY exchange rate on the gold market is 19.08%.

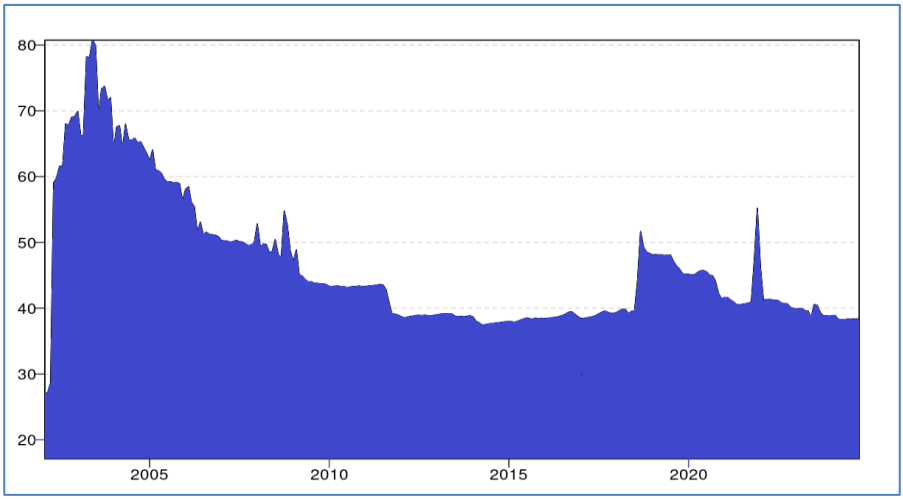
The values in the To Others (TO) row represent the sum of the percentage of shock spillovers from the variable in that column to other variables. The markets with the highest shock spillovers to other markets are gold with 50.25 per cent, XU100 with 40.78 per cent and USD/TRY exchange rate with 38.76 per cent. The shock effect of the interest rate on other financial asset markets is more limited with 9.27%.

The values in the From Others (FROM) column represent the total percentage shock spreads of a variable from other variables. Among financial assets, gold is the asset that is most affected by shocks in other markets with 43.45%, followed by USD/TRY exchange rate with 41.68% and XU100 index with 29.31%. The asset that receives the least shock propagation from other assets is interest rates with 24.62%.

In the table, each row is evaluated within itself; for a variable, the net shock propagation is calculated by subtracting the sum from others (FROM) from the sum to others (TO). If the value obtained is negative, it is concluded that the variable is a net shock receiver, and if it is positive, it is concluded that it is a net shock propagator. Since the difference between the 9.27% shock from the interest rate to other financial asset markets and the 24.62% shock to the interest rate is -15.35%, it is determined that the interest rate is a net shock receiver. However, the USD/TRY exchange rate (-2.92%) is a net shock absorber. The most dominant shock emitters on financial assets are the XU100 index with 11.47% and the gold price with 6.80%. This shows that the interest rate and USD/TRY exchange rate are vulnerable to external shocks originating from other financial assets.

According to the volatility spread table, the volatility spread index is calculated as 46.35%. This value indicates that 46.35% of the total spread is among these financial assets. While the average interconnectedness between variables is given with a single value in Table 3, the Total Interconnectedness Index shown in Figure 3 reveals the dynamic structure of the time-varying total interconnectedness between variables over the period analysed.

Figure 3. Total Connectivity Relationship



The graph 3 illustrates the evolution of total connectedness among financial assets over time. The findings indicate significant variations in financial linkages across different periods, suggesting that economic and financial conditions play a crucial role in shaping the interconnectedness of asset markets.

2002-2005 Period: The total connectedness level is notably high, fluctuating between 70% and 80%. This suggests a strong interdependence among financial assets, potentially driven by structural transformations in Türkiye's financial system and external market influences.

2005-2015 Period: A gradual decline in total connectedness is observed, stabilizing around 40%. While the 2008 Global Financial Crisis causes minor fluctuations, the overall downward trend continues, indicating a weakening interaction among financial assets.

2016-2020 Period: A sharp increase in financial connectedness is evident around 2018. This period coincides with significant currency shocks and economic uncertainties in Turkey, leading to heightened spillovers among financial markets.

Post-2020 Period: A distinct peak is noticeable around 2020, likely reflecting the impact of the COVID-19 pandemic. Increased market volatility and central bank interventions might have intensified financial interconnectedness. However, after the initial surge, total connectedness gradually stabilizes.

The graph suggests that financial connectedness has generally declined over time, implying a shift towards more independent asset movements. However, during periods of economic turbulence—such as the 2018 exchange rate shock and the 2020 pandemic—interdependencies among financial assets tend to strengthen temporarily. This indicates that macroeconomic shocks and uncertainty periods play a crucial role in shaping market dynamics and volatility spillovers.

Figure 4. Net Volatility Indexes

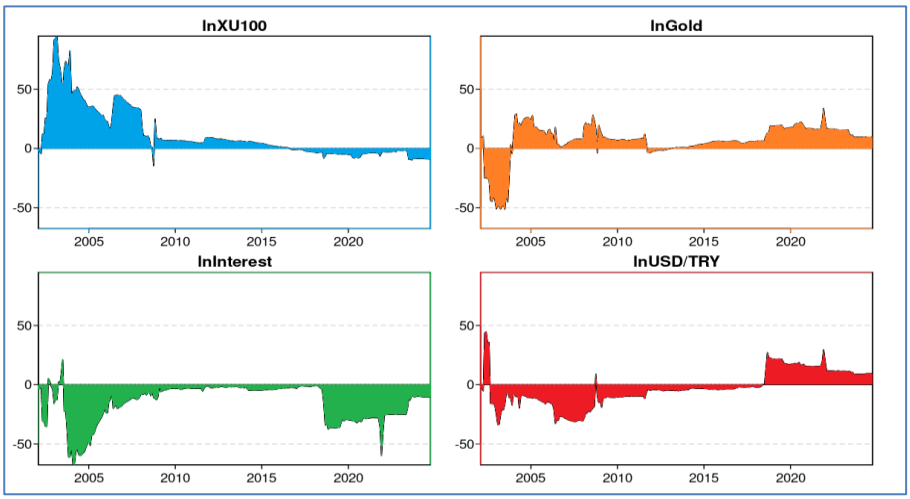
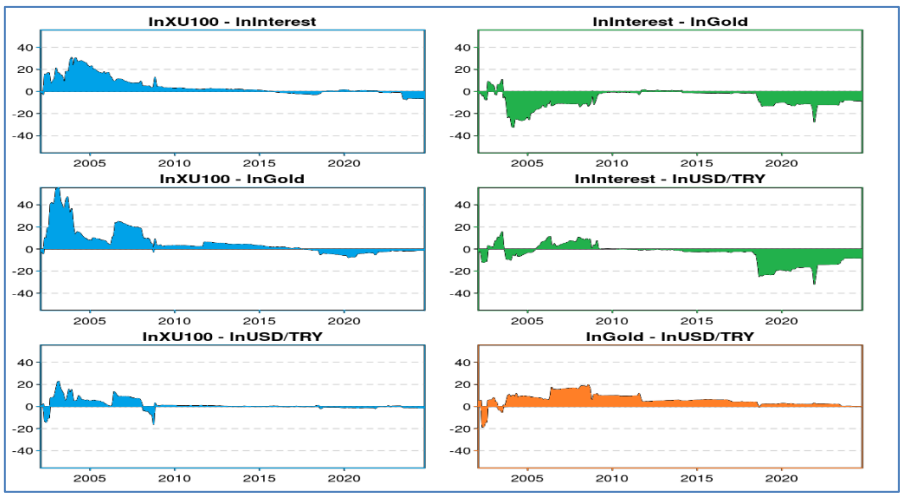


Figure 4 illustrates the results of net total directional connectedness. The shaded regions below the zero threshold indicate periods of volatility absorption, whereas the shaded regions above zero represent periods of volatility spillover. According to the findings, the XU100 index acted as a volatility transmitter until 2016 but has functioned as a volatility receiver since the last quarter of that year. The interest rate variable has consistently remained a volatility absorber across all periods. While gold prices exhibited volatility absorption until the end of 2013, they have transmitted volatility since 2014. Similarly, the

USD/TRY exchange rate absorbed volatility until mid-2018, after which it became a volatility transmitter. Furthermore, among the analyzed financial assets, the XU100 index emerges as the most significant volatility transmitter, whereas the interest rate variable represents the most substantial volatility absorber.

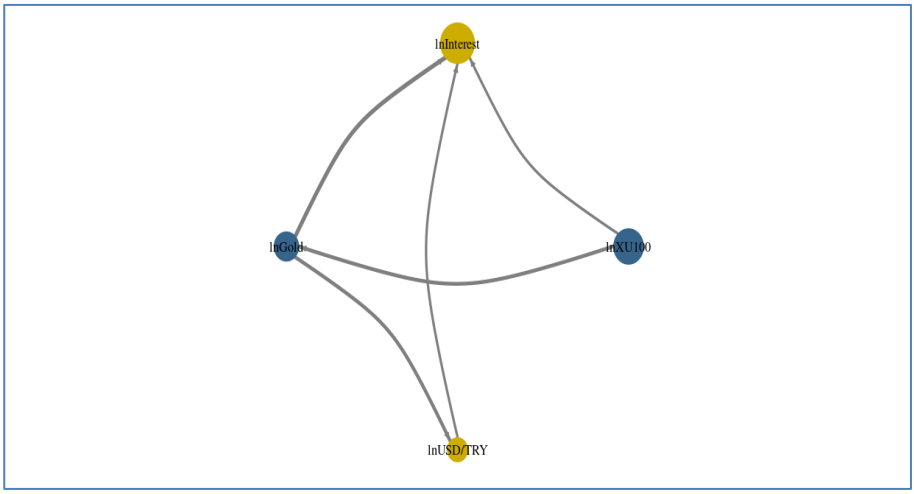
Figure 5. Net Binary Propagation Indices



The bilateral relationships between financial assets are shown in Figure 5. Changes in the relationship between variables on certain dates may be caused by the global financial crisis in 2008, the economic slowdown in China in 2015 and the US central bank's interest rate hike, political uncertainties and geopolitical risks in Turkey in 2016, sharp declines in stock markets due to Covid19, record high gold prices and the rapid rise in USD/TRY exchange rate. The coloured areas above the zero value represent the volatility spread of the first variable to the second variable in the corresponding date or period, while the coloured areas below the zero point represent the volatility spread of the second variable to the first variable in the corresponding date or period. When the spread between the XU100 index and the interest rate is analysed, the volatility of the XU100 index affected the volatility spread of the interest rate until the end of 2015. In the 2016-2018 period, the interest rate volatility affected the XU100 index, while in the 2019-2021 period, the XU100 index volatility affected the volatility spread

of the interest rate. In the 2022-2024 period, the XU100 index is affected by the interest rate volatility spread and is a volatility buyer. When the volatility spread between the XU100 index and gold is analysed, the volatility of the XU100 index affected the volatility spread of gold prices until mid-2017. Since then, the XU100 index has been affected by the volatility spread of gold prices and has been a volatility buyer. When the volatility spread between the XU100 index and USD/TRY prices is analysed, the volatility of the XU100 index affected the volatility spread of USD/TRY prices from late 2002 until the first quarter of 2008. Until the end of 2008, the volatility spread of USD/TRY prices affected the volatility spread of the XU100 index. In the 2009-2017 period, the XU100 index was a volatility emitter and the USD/TRY price was a volatility receiver. Since 2018, XU100 index has been a volatility receiver and USD/TRY price has been a volatility spreader. When the volatility spread between interest rates and gold is analysed, the volatility of interest rates affected the volatility spread of gold price in the 2012-2013 period. In periods other than this period, it is observed that the volatility spread in gold price is generally effective on the volatility spread of interest rates. When the volatility spillovers between interest rates and USD/TRY exchange rate are analysed, interest rate volatility affected the volatility of USD/TRY exchange rate in the 2002-2003 and 2005-2010 periods. After 2004 and 2010, on the other hand, interest rate volatility was affected by the USD/TRY exchange rate volatility and became a volatility receiver. When the volatility spread graph between gold and USD/TRY exchange rate is analysed, it is observed that gold affects the volatility spread of USD/TRY exchange rate in general except for 2002. According to the bilateral volatility spillovers table, interest rate and gold affect the XU100 index spillovers. In addition, gold and USD/TRY exchange rate spreads affect interest rate spreads. As a result, it can be stated that the volatility of BIST 100 has the lowest effect on the volatility interactions of financial assets, especially in recent years. The network analysis showing the direction and strength of shock propagation among financial assets is shown in Figure 6.

Figure 6. Network Analysis of Volatility Spillovers



In the network analysis that reveals the net shock spillover relationship between variables in a more understandable way, the circles in blue indicate that the variables are net shock emitters and the circles in yellow indicate that the variables are net shock receivers. In addition, the size of each circle indicates the size of the net spillover that spreads from and affects itself, while the thickness and direction of the arrow indicate the strength and direction of the net shock propagation between the two variables. As seen in Figure 6, in terms of the magnitude of net shock propagation, the XU100 index and gold prices are net shock propagators, while the interest rate and the USD/TRY exchange rate are net shock receivers, respectively. When the findings are analysed for the interest rate, it is observed that gold is the most important financial asset affecting interest rate volatility, followed by the USD/TRY exchange rate and the XU100 index, respectively. An analysis of the USD/TRY exchange rate reveals that gold is the most important financial asset affecting the USD/TRY exchange rate volatility, followed by the interest rate.

5. CONCLUSİON AND DISCUSSION

Understanding the dynamic relationships and shock propagation mechanisms among assets in financial markets is of critical importance for both investors and policymakers. In

this study, the interactions between the BIST 100 Index (XU100), interest rates, gold prices and the USD/TRY exchange rate and the propagation of shocks among these assets are analysed with the TVP-VAR model. The findings provide important clues about the interconnected nature of financial markets.

As a first step, the movements of the variables over time are analysed. The BIST 100 index, the interest rate, gold prices and the USD/TRY exchange rate have shown significant fluctuations due to major events in Türkiye 's economic and political history. XU100 has exhibited an upward trend in the long run. However, the pace and trend of this increase accelerated especially after 2020. The COVID-19 pandemic, the global low interest rate environment and the monetary easing policies in Türkiye increased the demand for equities. The decline in the second half of 2024 indicates that sharp increases in interest rates accelerated the outflow from risky assets. Interest rates rose as high as 60% during the 2001 economic crisis, but fell to single-digit levels thanks to economic reforms that lasted until 2009. The economic fluctuations in 2018 and the subsequent policy changes in the 2021-2024 period raised interest rates again. Gold is generally preferred as a safe haven in times of uncertainty. Since 2018, both global trade wars and currency crises in Türkiye have increased the demand for gold. The rise in gold prices is not only due to economic uncertainties, but also to the depreciation of the Turkish Lira. In the post-2016 period, Türkiye's geopolitical risks, economic imbalances and tensions in relations with the US led to an accelerating uptrend in the exchange rate 2020.

Volatility is an important indicator that measures the level of risk in the markets. The volatility levels of all assets analysed in the study increased significantly during the global and local economic crisis periods. The 2001 economic crisis, the 2008 global financial crisis, the 2018 currency crisis and the 2023 high inflation period were the periods when volatility peaked. In particular, gold prices and the USD/TRY exchange rate have attracted attention with their high volatility levels in the post-2018 period. This shows that investors tend to use these assets as a hedging instrument.

The data used in the study were analysed by transforming them into logarithmic returns. Descriptive statistics revealed the following findings: XU100 provided a higher average return compared to other assets, but these returns came with a higher risk (volatility). The JB test results showed that all series are far from normally distributed and have an asymmetric structure. The ERS unit root test revealed that the interest rate, gold prices and USD/TRY exchange rate are stationary, but the XU100 is non-stationary in the long run.

Aggregate volatility spillovers show that market interconnectedness is strong and shocks in one market can affect other markets. XU100 and Gold: Behaved as net shock propagators. This suggests that they have the potential to create uncertainty in other markets. Interest Rate and USD/TRY: As net shock absorbers, they are more exposed to fluctuations in external markets.

Karabıyık (2020), Şak and Öcal Özkaya (2022) examined volatility spillovers across different assets and markets and found that volatility increases especially in periods such as economic crisis, pandemic and war. The fact that our study shows that volatility spillovers increase during stress periods is consistent with these studies in the literature. For example, Karabıyık (2020) finds that the bond market is the largest impact spreader, while Şak and Öcal Özkaya (2022) find that the Euro and the Dollar are volatility spreaders. Parallels with these results can be evaluated. Studies such as Roy and Roy (2017), Adekoya and Oliyide (2021), Şenol and Koç (2022) have shown that certain markets assume shock-spreading or shock-receiving roles. Especially in emerging markets, exchange rates and commodity markets have been found to be effective in propagation dynamics. The finding in your study that variables such as the exchange rate or the BIST100 can play both shock-spreading and shock-receiving roles is consistent with the findings of Roy and Roy (2017) and Akyıldırım et al. (2022) that the exchange rate and CDS premium are shock-spreading variables. The COVID-19 pandemic has strengthened the linkages between financial markets and increased volatility spillovers. Adekoya and Oliyide (2021), Şenol and Koç (2022), Höl (2023), Doğan et al. (2023) emphasise the increase in

volatility and risk transmission during this period. The fact that our study shows that volatility increased and the links between markets intensified during the COVID-19 period seems to be directly consistent with these findings in the literature. Studies such as the impact of the Chinese stock market on global markets (Liu et al., 2019), the relationship between stock markets and Bitcoin in BRICS countries (Dahir et al., 2020), volatility spillovers in CIVETS countries (Medetoğlu (2024)) have analysed the dynamics of different market groups in a regional and global context. The findings of our study may parallel regional studies such as Medetoğlu (2024) and Liu et al. (2019) in terms of Türkiye's role in volatility spillovers or its level of influence from other markets.

This study aligns with existing literature that highlights the increase in volatility spillovers during stress periods such as economic crises, pandemics, and wars. Karabıyık (2020) identifies the bond market as the largest volatility spreader, while Şak and Öcal Özkaya (2022) find the Euro and Dollar as dominant spreaders. Similarly, Roy and Roy (2017), Adekoya and Oliyide (2021), and Şenol and Koç (2022) show that certain markets act as shock-spreaders or receivers, particularly exchange rates and commodity markets in emerging economies. Consistent with these findings, this study demonstrates that variables like the exchange rate and BIST 100 can function as both shock-spreaders and receivers. The intensified linkages between financial markets and increased volatility spillovers during the COVID-19 pandemic, emphasized by Adekoya and Oliyide (2021), Şenol and Koç (2022), and others, are also supported by this study. Regional and global analyses, such as Liu et al. (2019) on the Chinese stock market, Dahir et al. (2020) on BRICS stock markets and Bitcoin, and Medetoğlu (2024) on CIVETS countries, further contextualize the dynamics of volatility spillovers. This study’s findings parallel these works by highlighting Türkiye’s role in regional and global market volatility.

The findings of the study have important implications for the dynamic structure of financial markets. Portfolio Management: Investors should build a more balanced portfolio, taking into account the dynamic relationships between assets.

Policymakers: The vulnerability of interest rates and exchange rates to external shocks suggests that economic policies should be conducted in a more careful and predictable manner. Global Risk Perception: The finding that gold and USD/TRY are more sensitive to global risk perception requires close monitoring of external developments. These analyses provide valuable information for economic policy design as well as investment decisions.

Etik Beyanı: *Bu çalışmanın tüm hazırlanma süreçlerinde etik kurallara uyulduğunu yazar beyan eder. Aksi bir durumun tespiti halinde Akademik İzdüşüm Dergisinin hiçbir sorumluluğu olmayıp, tüm sorumluluk çalışmanın yazarlarına aittir.*

Destek ve Teşekkür: *Bu araştırmanın hazırlanmasında herhangi bir kurumdan destek alınmamıştır.*

Katkı Oranı Beyanı: *Araştırmanın tüm süreci makalenin beyan edilen tek yazarı tarafından gerçekleştirilmiştir.*

Çatışma Beyanı: *Araştırmanın yazarları olarak herhangi bir çıkar çatışma beyanımız bulunmamaktadır.*

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INTERACTION AND VOLATILITY SPILLOVER AMONG SELECTED FINANCIAL ASSETS IN TÜRKİYE

Extended Summary

Aim:

The aim of this study is to analyse the interactions and volatility spillovers among selected financial assets in Türkiye. The study analyses in detail the interactions between Türkiye's largest stock market index, the BIST 100 (XU100), interest rates, gold prices and the USD/TRY exchange rate. These assets have undergone significant fluctuations in light of Türkiye's economic and political events and have been strongly correlated with each other.

Method(s):

The relationship between the 5 stock market indices used in this study and the uncertainty and geopolitical risk index is tested with the time-varying parameter vector autoregressive (TVP-VAR) method. Antonakakis and Gabauer (2017) and Diebold and Yilmaz (2009, 2012, 2014) developed measures of connectedness based on the fixed-parameter sliding window VAR approach. In parallel, the authors proposed dynamic connectedness measures based on the TVP-VAR approach with time-varying covariance structure. The TVP-VAR model is preferred because it is sensitive to outliers, eliminates the problem of randomisation of the moving window length and allows working with smaller data sets (Akyıldırım at al., 2022:352).

Findings:

Since the difference between the 9.27% shock from the interest rate to other financial asset markets and the 24.62% shock to the interest rate is -15.35%, it is determined that the interest rate is a net shock receiver. However, the USD/TRY exchange rate (-2.92%) is a net shock absorber. The most dominant shock emitters on financial assets are the XU100 index with 11.47% and the gold price with 6.80%. This shows that the interest rate and USD/TRY exchange rate are vulnerable to external shocks

originating from other financial assets. According to the volatility spread table, the volatility spread index is calculated as 46.35%. This value indicates that 46.35% of the total spread is among these financial assets. According to the results, while the XU100 index emitted volatility until 2016, it has been receiving volatility since the last quarter of 2016. Interest rate is volatile in all periods. While gold prices were volatile until the end of 2013, they have been volatile since 2004. USD/TRY exchange rate was volatile until mid-2018, but has been volatile since then. In addition, the XU100 index is the financial asset that emits the highest volatility, while the interest rate variable is the financial asset that receives the highest volatility.

Conclusion and Discussion:

Volatility is an important indicator that measures the level of risk in the markets. The volatility levels of all assets analysed in the study increased significantly during the global and local economic crisis periods. The 2001 economic crisis, the 2008 global financial crisis, the 2018 currency crisis and the 2023 high inflation period were the periods when volatility peaked. In particular, gold prices and the USD/TRY exchange rate have attracted attention with their high volatility levels in the post-2018 period. This shows that investors tend to use these assets as a hedging instrument.

The findings of the study provide important implications for the dynamic structure of financial markets. Portfolio Management: Investors should construct a more balanced portfolio by taking into account the dynamic relationships between assets. Policymakers: The vulnerability of interest rates and exchange rates to external shocks suggests that economic policies should be conducted in a more careful and predictable manner. Global Risk Perception: The finding that gold and USD/TRY are more sensitive to global risk perception requires close monitoring of external developments. These analyses provide valuable information for economic policy design as well as investment decisions.