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Causality Relationship Between BIST 100 Index, Euro, and Gold Returns During the COVID-19 Pandemic

Covid 19 Salgını Döneminde BIST 100 endeksi, Euro ve Altın Getirileri Arasındaki Nedensellik İlişkisi

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Abstract

This study was conducted to determine the relationships between financial assets and the differences between these relationships in the pre- and post-COVID-19 periods. The study aims to reveal whether the movements of financial assets have changed during the pandemic. In the study, date ranges were determined separately for the period before and after COVID-19. The dates March 09, 2016–March 09, 2020 were determined as the pre-COVID-19 period, and the dates March 09, 2020–March 09, 2024 were determined as the post-COVID-19 period. The study obtained daily logarithmic returns of BIST 100, euro, and gold assets, and applied Correlation Analysis and Granger Causality Test. As a result of the study, the correlation levels of the variables and causality relationships are reported in the pre- and post-COVID-19 periods. When the findings obtained were evaluated, as a result of the correlation analysis, it was determined that the correlation levels decreased in the post-Covid period. In terms of causality relations, it was observed that the relationship levels increased in the post-COVID-19 period. In addition, it is another result that there are differentiations in the relevant periods. When the findings are evaluated together, determining the causality relationship between the substitution power of assets and returns is important for portfolio construction, asset investment, and risk-taking levels. The study is intended to guide individual investors, decision-makers, and the industry.

Keywords: BIST 100 index, COVID-19, euro, gold, Granger causality test

Öz

Bu çalışma, Covid 19 öncesi ve sonrası dönemde, finansal varlıklar arasındaki ilişkileri ve ilişkiler arasındaki farklılıkları tespit etmek amacıyla gerçekleştirilmiştir. Çalışmanın amacı, finansal varlıkların hareketlerinin salgın hastalık döneminde değişip değişmediğini ortaya çıkarmaktır. Çalışmada Covid 19 öncesi ve sonrası dönem için tarih aralıkları ayrı ayrı belirlenmiştir. 09.03.2016–09.03.2020 tarihleri Covid 19 öncesi dönem, 09.03.2020–09.03.2024 tarihleri de Covid 19 sonrası dönem olarak belirlenmiştir. Çalışmada BIST 100, euro ve altın varlıklarının logaritmik getirileri günlük olarak elde edilerek, Korelasyon Analizi ve Granger Nedensellik Testi uygulanmıştır. Çalışma sonucunda değişkenlerin korelasyon düzeyleri ve nedensellik ilişkileri Covid 19 öncesi ve sonrası dönem olarak raporlanmıştır. Elde edilen bulgular değerlendirildiğinde, korelasyon analizi sonucunda Covid sonrası dönemde ilişki düzeylerinin azaldığı tespit edilmiştir. Nedensellik ilişkileri açısından ise Covid 19 sonrası dönemde ilişki düzeylerinin arttığı gözlemlenmiştir. Ayrıca ilgili dönemlerde farklılaşmaların olduğu da elde edilen bir diğer sonuçtur. Bulgular birlikte değerlendirildiğinde, varlıkların ikame gücü ile getiriler arasındaki nedensellik ilişkisinin tespitinin; portföy oluşturma, varlıklara yatırım yapma ve risk alma düzeyi konularında önem arz ettiği ifade edilebilmektedir. Çalışmanın bireysel yatırımcılara, karar vericilere ve sektöre yol gösterici olması hedeflenmektedir.

Anahtar Kelimeler: BIST 100 Endeksi, Covid 19, Euro, Altın, Granger Nedensellik Testi

What is already known on this topic?

- *Relationship detection performed with past data*
- *Relationships between assets in routine periods*
- *Analysis performed with some assets*

What this study adds on this topic?

- *Relationship detection performed with current data*
- *Change in relationship between entities during the pandemic*
- *Causality analysis performed with multiple entities*

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Introduction

The financial system is a mechanism that includes individuals supplying and demanding funds, financial assets, intermediaries, institutions, and legal regulations. The system faces many systematic and non-systematic risk factors. Effective management of risks ensures the smooth functioning of the system (Altay, 2015: 1–4). Case such as epidemics, natural disasters, and global crises are among the factors affecting the system. The pandemic process announced in March 2020 continued its effects, and countries tried to manage the process by taking measures against the epidemic. The COVID-19 outbreak caused a global crisis that affected all countries. Countries have taken social, economic, and health measures, and developed strategies to combat the disease. The respiratory transmission of the disease affected the labor force, and measures such as closures were taken. Governments provided subsidies to compensate for grievances, and significant investments were made in the health field. Financially, different strategies and behaviors were followed in savings and investments made during this period. The process has been effective in many areas, and individual and institutional changes have been experienced financially. Decreases in the income level of individuals, financing needs, and financial process management have also changed during COVID-19.

The finance function is the process of directing the amount remaining after meeting the expenses with the revenues obtained to investment opportunities through saving or providing financing with the best opportunities in cases where revenues cannot meet the expenses. Converting the amounts remaining after subtracting expenses from revenues into investment opportunities provides a return opportunity. Investment opportunity is an important function for individuals and the national economy since it also protects against inflation (Pamukçu, 1999: 2–6). Investment means postponing consumption by allocating resources today. Investment, realized by channeling savings, also meets the financing needs that will arise for individuals, institutions, and governments.

Investment decisions are made in line with expected return and risk. The expected returns of investors affect these decisions as an important function in their decisions. Another function that is effective in investors' decisions is the concept of risk. Risk is defined as a concept that leads to possible negative results in case of realization. The concept of risk is divided into systematic and unsystematic, according to the nature of prevention. While it is impossible to prevent systematic risk, unsystematic risk is preventable (Altay, 2015: 4). The concept of risk became measurable in Markowitz's article "Portfolio Selection" (1952). Markowitz states that risk can be reduced by diversification in portfolios. Including risk-free assets in investment opportunities increases the probability of obtaining returns by reducing portfolio risk.

The process realized by units with surplus funds through the demand for financial assets is known as investment. Investment decisions of individuals, institutions, or states are made in financial markets. Markets involving buyers, sellers, assets, funds, and legal regulations are classified according to various criteria. Markets that enable the transfer process include money, capital, gold, foreign exchange, and derivatives. According to their maturity, financial markets are divided into money and capital markets. Short or long-term investment decisions increase the demand for different markets (Ceylan and Korkmaz, 2017: 442). The Efficient Markets Hypothesis proposed by Fama (1970) explains the efficiency of markets. The efficiency of the markets is also determined by the investors' ability to earn abnormal returns in the market. Markets in which all information is reflected in asset prices are considered efficient, and abnormal returns are impossible.

Financial assets in financial markets, subject to investment decisions, are products that investors trade to obtain returns. Financial assets have the potential to provide a return in exchange for funds. Financial assets can be categorized as money and capital market products with maturities of less than 1 year and more than 1 year. Instruments traded in the money market are classified as treasury bills, certificates of deposit, repurchase agreements, and interbank funds. Capital market instruments are classified as stocks, bonds, real estate certificates, warrants, lease certificates, income partnership certificates, and derivative instruments (Korkmaz and Ceylan, 2017). Individuals' risk perception is important when making investment decisions. Investors' degree of risk aversion is one of the determinants of their preference for financial assets. While risk-averse investors tend to invest in assets with fixed returns, risk-loving investors prefer investing in high-return assets. When forming a portfolio, adding risk-free and risky assets reduces the portfolio risk. With the perception of expected return and risk, investors tend to create portfolios and generate returns.

The original aspect of the study is the analysis based on the impact of the COVID outbreak, the changes in the returns of three financial assets taken as a sample since 2020, the increase and decrease in the number of investors in the stock market, and the periods in which price and volume changes occur. In addition, the study tries to ensure that the results obtained are guiding for investors with current data. The primary motivation of this study is to determine how the COVID-19 process affects financial assets. The main question of the research is whether there is a difference in the relationships between the related assets before and after the process. The study aims to identify the situation and the differences between the two periods. By obtaining observations with a similar duration before and after the pandemic process, the related purpose was tried to be realized. The study's design consists of an introduction followed by a literature review, the study's methodology, analysis, findings, and a conclusion and evaluation. The introduction section includes the conceptual framework for the COVID-19 process, investment, financial markets, financial assets, and portfolio diversification. The

literature review section lists the purpose, methodology, and results of the studies on financial assets and the Granger Causality Test. The data are analyzed and reported in the method, analysis, and findings section of the study. In the conclusion and evaluation section, the findings are interpreted, and evaluations are made.

Literature Review

Determining the relationships between financial assets is a guiding factor in making investments. While conducting the literature review, studies dealing with stocks, foreign exchange, and precious metals, and mainly using causality analysis as a method, are analyzed. Related studies are listed below in terms of purpose, method, and findings.

Aktaş and Akdağ (2013) conducted a study to determine the relationship between economic variables and stock prices in Türkiye. In the study, analyses were performed using the multiple regression method and the Granger causality test. Within the scope of the study, the BIST-100 index and various macroeconomic indicators for 2008–2012 were used as variables. As a result of the study, evaluations were made, and suggestions were presented.

Doğru and Uysal (2015) conducted a study to test the relationship between gold and equities. Data for the period 2000–2012 were used, and analyses were conducted using Johansen cointegration and Granger causality tests. As a result of the study, it was found that relationships differed before and after the 2008 financial crisis.

Poyraz and Tepeli (2015) studied the relationship between stock prices and selected economic indicators. In the study, multiple regression, correlation analysis, and the Granger causality test were performed using data from various variables between 1995 and 2011. In conclusion, treasury bill interest rates and exchange rates were found to be the most important variables affecting stock prices. Additionally, a positive correlation was found between the money supply and the Industrial Production Index and the BIST index, while it was found that the CPI does not affect the BIST index.

Tunalı and Çam (2016) conducted a study to determine the relationship between gold prices, stocks, and deposit interest rates. In the study, various statistical analyses were performed using data between 2004 and 2010. As a result of the regression analysis, a negative relationship was found between gold prices and deposit interest rates; no long-run relationship was detected as a result of cointegration tests, and a short-term relationship was detected between the variables as a result of the Granger causality test.

Sandal et al. (2017) conducted a study to determine the causality relationship between BIST 100 and gold and crude oil prices. Using data between 2005 and 2015, various analyses were performed with the Extended Dickey-Fuller unit root test, Engle-Granger co-integration test, Johansen cointegration test, and Granger causality test. The study found unidirectional causality from gold to stocks, and no causality was detected for other variables.

Doğanalp et al. (2016) conducted a study to determine the determinants of gold prices in Türkiye. The study conducted analyses using various variables and gold price data for 1996–2015. As a result of the study, it was found that there is a causality between the exchange rate, interest rate, and BIST 100 index and gold prices and that the exchange rate, interest rate, and BIST 100 index affect gold prices.

Güney and Ilgın (2019) conducted a study examining alternative investment instruments' effect on current share prices in BIST 100. The study used gold prices, exchange rates, and interest rate variables. The study concluded that a bidirectional causality relationship was detected between gold and BIST 100 and interest and BIST 100, and a unidirectional causality relationship was detected between foreign exchange and BIST 100 and gold and interest.

Torun and Demireli (2019) studied the connection between the BIST 100 index and various assets. The study analyzed BIST 100, dollar, euro, and gold returns for 2008–2018 with the Granger causality test based on the continuous wavelet transform. The study found a negative and bidirectional causality between the BIST 100 index and the dollar, and between the BIST 100 index and the euro. In addition, no causality was found between the BIST 100 index and gold returns.

Gülhan (2020) conducted a study to determine the causality relationship between gold prices and oil prices, BIST 100 Index, exchange rate (Dollar) and VIX Index. Granger causality test was used with data between 2015 and 2019. As a result of the study, a causality relationship was found between gold and BIST 100, oil prices, and exchange rate.

Kılıç and Uçaktürk (2020) conducted a study to determine the effect of investment instruments on Borsa Istanbul. In the study, various analyses were carried out with Johansen Cointegration and Toda-Yamamoto tests using BIST 100, gold, interest rate, and dollar variables between 2009 and 2018. As a result of the study, unidirectional causality was found between BIST 100 and the dollar and interest rates, while no causality relationship was found between gold and BIST 100.

Şanlı et al. (2021) carried out a study to find out the relationship between BIST 100 and various variables. The study used data between 2000 and 2021 to analyze and compare it with the COVID-19 pandemic period. As a result of the study, short- and long-term relationships were determined, and a comparison was made with the COVID-19 period. It was stated that there were differences in this period compared to the short-term relationships in the general period.

Özmerdivanlı (2021) conducted a study to determine the impact of the COVID-19 pandemic on various financial assets and to determine the relationships between financial ratios. The study performed cointegration and causality test analyses using data between March 11, 2020 and July 31, 2021. As a result of the cointegration analysis, it was determined that the variables moved together in the long term. Short- and long-term causality analyses were performed, and as a result of the causality analysis, it was stated that there was a bidirectional causality between BIST and the Dollar.

Demirdöğen and Emeç (2022) carried out a study to find out the relationship between gold and BIST 100 index prices during the COVID-19 pandemic. The study carried out various statistical tests using Causality Analysis of Variance with data for the period March 01, 2020–September 23, 2022. As a result of the study, it was determined that there is a bidirectional relationship between gold prices and BIST 100 index prices.

Büyükakın and Demir (2022) conducted a study to determine the effects of the COVID-19 pandemic on Türkiye's financial system. In the study, Toda-Yamamoto causality analysis was applied to the data on the number of COVID-19 patients and deaths, as well as gold prices, US dollars, Euro, and the BIST 100 index between the periods of April 06, 2020, and July 02, 2021. As a result of the study, it was stated that there was a causal relationship between the number of COVID-19 patients and deaths and the gram gold, Dollar, and Euro.

Pehlivan et al. (2022) carried out a study to determine the effects of the number of cases during the COVID-19 period on financial assets. The study carried out various statistical tests with daily data for the period March 11, 2020–December 22, 2021. As a result of the study, it was found that there was a relationship between the total number of cases and the BIST 100, and in another causality test, there was a two-way causality between the BIST 100 and the total number of cases, and a one-way causality from the total number of cases to the exchange rate and gram gold.

Yıldız and Aydın (2022) conducted a study to measure the impact of the COVID-19 pandemic on financial assets. In the study, the analysis was carried out using the EGARCH model with data between January 02, 2020 and July 30, 2021. As a result of the study, the relationships were interpreted, and it was concluded that, depending on the COVID-19 process, the number of cases has an increasing effect on stock, gold, and interest rate volatility and has no significant effect on the dollar and bitcoin.

Güneş (2022) conducted a study to determine the causality relations between financial assets in Türkiye before COVID-19 and during COVID-19. Two separate samples were formed in the study, and analyses were performed with the Toda-Yamamoto causality test. In conclusion, it was found that causality relations differed during the COVID-19 period.

When the studies in the literature are analyzed, it is observed that variables such as BIST 100, foreign exchange, interest rates, macroeconomic factors, precious metals, and oil prices are used as data. It is determined that analyses such as regression, Granger causality, cointegration, correlation, and volatility are applied to the data obtained. The results obtained in the studies differ from each other, and this situation is due to differences in the periods used. In particular, it has been stated in a significant part of the studies that the COVID epidemic, crisis periods, and extraordinary situations also cause differences.

Methodology, Analysis, and Findings

The study was conducted to determine the causality relationships between the returns of the BIST 100 index, euro, and gold assets in the pre- and post-COVID-19 periods. Within the scope of the study, the effect was tried to be measured by choosing the euro instead of the dollar as the foreign exchange variable. The reason for this choice is that the dollar variable is constantly used in the literature; the aim is to contribute different results since the euro unit is an investment tool frequently used by investors. Correlation Analysis and the Granger Causality Test were used as methods. Another objective is to determine whether there is a difference between the pre- and post-COVID period relationships. The data obtained in the study were calculated by taking the logarithmic returns of daily prices. Within the scope of the study, gold is taken in grams. The data used in the study were obtained from Investing.com. The study obtained financial asset data between March 09, 2016 and March 09, 2020 as the pre-COVID period and March 09, 2020–March 09, 2024 as the post-COVID period. In the study, there are 1000 observations in the pre-COVID period and 1002 observations in the post-COVID period. While obtaining BIST 100, euro, and gold prices, the data set was created based on the dates common to all variables. Analyses were performed using Eviews 12 software. The companies included in the BIST 100 index analyzed with euro and gold variables in the study are available in Table 1.

The variables included in the study are BIST 100, euro, and gold. While obtaining the data, the data set was created by calculating the logarithmic returns of daily prices. Descriptive statistics of the variables included in the study and used in the analysis are shown in Table 2 as pre and post-COVID period.

Table 2 presents the descriptive statistics of the variables. When Table 2 is examined, it is seen that the observation numbers are very similar. In particular, the effect was tried to be measured by taking the same periods. It is seen that the averages are lower in the pre-COVID-19 period. It is observed that the lowest values are in the post-COVID-19 period. Except for the BIST 100 variable, the highest values are in

Table 1.
BIST 100 Index

AGHOL	ARCLK	CCOLA	ENJSA	SAHOL	KCHOL	ODAS	SMRTG	TMSN	SISE
AGROT	ARDYZ	CWENE	ENERY	HEKTS	CONTR	OTKAR	SKBNK	TUPRS	VAKBN
AKBNK	ASELS	CANTE	ENKAI	ISGYO	KONYA	OYAKC	SOKM	THYAO	ULKER
AKFGY	ASTOR	CIMSA	EREGL	ISMEN	KOZAL	PGSUS	TABGD	TTKOM	VESBE
AKFYE	BTCIM	DOHOL	EUREN	IZENR	KOZAA	PEKGY	TAVHL	TTRAK	VESTL
AKSA	BERA	DOAS	EUPWR	KLSER	LMKDC	PETKM	TKFEN	GARAN	YKBNK
AKSEN	BIMAS	ECZYT	FROTO	KRDMD	BLUE	QUAGR	TKNSA	HALKB	YYLGD
ALARK	BRSAN	EGEEN	GESAN	KTLEV	MIATK	REEDR	TOASO	ISCTR	YEOTK
ALFAS	BRYAT	ECILC	GOLTS	KAYSE	MGROS	SASA	TUKAS	TSKB	ZOREN
AEFES	BFREN	EKGYO	GUBRF	KCAER	OBAMS	SDTTR	TCELL	TURSG	BINHO

Source: Public Disclosure Platform, 2024.

the pre-COVID-19 period. In terms of standard deviation, it is observed that the post-COVID-19 period values are higher. The study's data set consists of logarithmic returns obtained from the daily BIST 100, euro, and gold prices between March 09, 2016–March 09, 2020 and March 09, 2020–March 09, 2024. Correlation analysis was performed to test the variables used within the scope of the study as alternatives to each other. The results of the correlation analysis are presented in Table 3.

Table 2.
Descriptive Statistics

	BIST 100	EURO	GOLD
Pre-COVID-19 Period			
Average	0.000271	0.000735	0.000753
Median	0.000529	0.000493	0.000483
Maximum	0.044310	0.137450	0.144380
Minimum	-0.073470	-0.085687	0.085548
Standard deviation	0.012942	0.011076	0.012511
Total	0.271075	0.735488	0.753351
Total standard deviation	0.167321	0.122550	0.156360
Number of observations	1000	1000	1000
Post-COVID-19 Period			
Average	0.002169	0.001599	0.001649
Median	0.002941	0.001022	0.001691
Maximum	0.094219	0.120242	0.106602
Minimum	-0.103068	-0.191757	-0.210325
Standard deviation	0.018793	0.013628	0.015167
Total	2.173077	1.602493	1.651881
Total standard deviation	0.353513	0.185920	0.230264
Number of observations	1002	1002	1002

Correlation analysis determines the direction and severity of the relationship between variables. As a result of correlation analysis, the sign gives information about the direction of the relationship, and the coefficient gives information about the severity of the relationship. The correlation coefficient equals 1 or −1 indicates a complete relationship (Tabachnick and Fidell, 2015: 56). When the correlation analysis results Table 3 are analyzed, it is seen that there is a weak and negative correlation between BIST 100 and the euro and gold and a strong and positive correlation between the euro and gold in the pre-COVID period. In the post-COVID period, only a strong and positive correlation between gold and the euro was found to be significant. When correlation relationships are evaluated in general, it is stated that the relationship and significance decreased in the post-COVID period. Correlation analysis provides important information for portfolio construction. The related analysis determines the substitutability of assets.

Table 3.
Correlation Analysis

	BIST 100	EURO	GOLD
Pre-COVID-19 Period	1		
	-0.27*	1	
	-0.22*	0.80*	1
Post-COVID-19 Period	1		
	-0.02	1	
	0.01	0.75*	1

Note: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

In the rest of the study, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests are applied to determine whether the series contains unit roots, as reported in Table 4. There are two hypotheses established as a result of the ADF

Table 4.
Unit Root Test Results

			ADF		PP	
			t-Statistic	Probability	t-Statistic	Probability
Pre-COVID-19 Period	Fixed	BIST 100	-15.1047	0.0000*	-30.0907	0.0000*
		GOLD	-21.7710	0.0000*	-30.9571	0.0000*
		EURO	-8.4509	0.0000*	-28.0503	0.0000*
	Constant and trend	BIST 100	-15.1040	0.0000*	-30.0811	0.0000*
		GOLD	-21.7609	0.0000*	-30.9451	0.0000*
		EURO	-8.4482	0.0000*	-28.0343	0.0000*
Post-COVID-19 Period	Fixed	BIST 100	-14.1242	0.0000*	-32.2844	0.0000*
		GOLD	-28.4166	0.0000*	-28.2618	0.0000*
		EURO	-7.1815	0.0000*	-29.1540	0.0000*
	Constant and trend	BIST 100	-14.1369	0.0000*	-32.2974	0.0000*
		GOLD	-28.4145	0.0000*	-28.2584	0.0000*
		EURO	-7.1827	0.0000*	-29.1394	0.0000*

Note: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

and PP unit root tests. The null hypothesis defends that there is at least one unit root and there is no stationarity. The alternative hypothesis defends that there is no unit root and there is stationarity. The ADF unit root test is calculated by equations 1, 2, and 3.

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i+1} + \varepsilon_t \quad (1)$$

$$\Delta Y_t = \alpha_0 + \delta Y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i+1} + \varepsilon_t \quad (2)$$

Table 5.
Appropriate Lag Length Results

Pre-COVID-19 Period	**Delay**	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
	1	9469.289	32.22898	1.05e-12	-19.06712	-19.00784	-19.04458
	2	9482.730	26.69139	1.04e-12	-19.07607	-18.97234	-19.03663
	3	9506.391	46.84609	1.01e-12	-19.10563	-18.95745	-19.04929*
	4	**9519.937**	**26.73555***	**1.00e-12***	**-19.11479***	**-18.92216**	**-19.04155**
	5	9524.910	9.785803	1.01e-12	-19.10667	-18.86959	-19.01653
	6	9527.989	6.039654	1.02e-12	-19.09474	-18.81320	-18.98769
	7	9533.884	11.52908	1.03e-12	-19.08848	-18.76249	-18.96453
	8	9537.375	6.806756	1.04e-12	-19.07737	-18.70693	-18.93652
Post-COVID-19 Period	**Delay**	**LR**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
	1	**8635.618**	**55.27637**	**5.85e-12***	**-17.35134***	**-17.29217**	**-17.32885***
	2	8641.222	11.12893	5.89e-12	-17.34451	-17.24095	-17.30514
	3	8645.142	7.761362	5.95e-12	-17.33429	-17.18635	-17.27805
	4	8654.256	17.98927	5.95e-12	-17.33452	-17.14220	-17.26140
	5	8671.039	33.02433*	5.85e-12	-17.35018	-17.11347	-17.26019
	6	8677.392	12.46318	5.89e-12	-17.34485	-17.06377	-17.23799
	7	8679.055	3.253203	5.97e-12	-17.33009	-17.00462	-17.20635
	8	8684.580	10.77273	6.02e-12	-17.32310	-16.95325	-17.18249

$$\Delta Y_t = \alpha_0 + \alpha_2 t + \delta Y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-i+1} + \varepsilon_t \quad (3)$$

The Phillips-Perron test (Phillips and Perron, 1988) is another method for determining whether the series contains unit roots. Equations 4 and 5 calculate the PP unit root test.

$$Y_t = \breve{\mu} + \breve{\alpha} Y_{t-1} + \tilde{u}_t \quad (4)$$

$$Y_t = \breve{\mu} + \tilde{\beta}\left(t - \frac{1}{2}\lambda\right) + \tilde{\alpha} Y_{t-1} + \tilde{u}_t \quad (5)$$

The fact that the test statistics calculated for the ADF and PP tests are greater than the critical values or the probability values are significant indicates the rejection of the null hypothesis that the series are non-stationary and means that there is no unit root in the series. The unit root test results for the period before and after COVID-19 are presented in Table 4.

Table 4 shows the t statistics and probability values of the ADF and PP unit root tests for the periods before and after COVID-19, calculated as constant, constant, and trend. When the table is evaluated, it is understood that the series' constant, constant, and trend values do not contain unit roots according to ADF and PP statistics and are stationary at level I (0). Following the unit root test results, the lag length of the series opened with the VAR model should be determined. The results of the lag length of the periods are presented in Table 5.

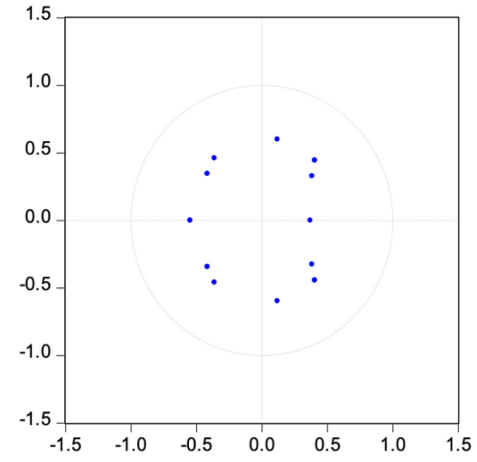
The Granger Causality Test is sensitive to the lag length used. The criteria in the table are used to select the lag length (Özsoy Çalış et al., 2022). Table 5 shows the lag length results according to various criteria. When the table is analyzed, it can be concluded that the lag length for the pre-COVID period is four, based on LR, FPE, and AIC criteria, and the lag length for the post-COVID period is one, based on FPE, AIC, and HQ criteria. The autocorrelation test, one of the assumptions of the Granger Causality test, was also carried out separately. Since the probability values are greater than 0.05, the data show no autocorrelation problem, as reported in Table 6.

Another assumption of the Granger Causality Test, that the AR polynomial roots are smaller than 1 is analyzed separately for the pre- and post-COVID period, as shown in Figures 1 and 2.

Table 6.
Autocorrelation Test

Pre-COVID-19 Period	**Delay**	**Statistic Value**	**Probability**
	1	10.54685	0.3081
	2	11.83950	0.2225
	3	6.929107	0.6445
	4	**12.59951**	**0.1816**
Post-COVID-19 Period	**Delay**	**LR**	**LR**
	1	**12.55249**	**0.1839**

Figure 1.
Inverse Roots of the Pre-Covid AR Characteristic.



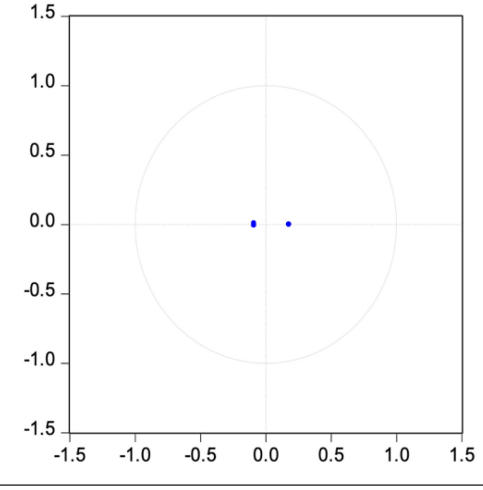
When the Figures 1 and 2 are analyzed, all roots lie between 1 and -1. The fact that the inverse roots lie within the unit circle proves the model is stable.

The Granger Causality Test, developed by Granger (1969), is applied to determine causality in stationary time series. The Granger Causality Test is used to determine the existence and direction of the relationship between two series. The Granger Causality Test is calculated with the help of equations 6 and 7.

$$Y_t = \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{j=1}^{n} \beta_j Y_{t-j} + \upsilon_{1t} \quad (6)$$

$$X_t = \sum_{i=1}^{n} \lambda_i X_{t-i} + \sum_{j=1}^{n} \delta_j Y_{t-j} + \upsilon_{2t} \quad (7)$$

Figure 2.
Inverse Roots of the Post-Covid AR Polynomial. Characteristic Polynomial.



In the Granger Causality Test, hypotheses are formed as to whether Granger is the cause or not. In this study, six common hypotheses were established and tested for both the pre-COVID and post-COVID periods. The hypotheses established in this context are given below.

H_1 = *Euro variable is the Granger cause of BIST 100 variable.*

H_2 = *Gold variable is the Granger cause of BIST 100 variable*.

H_3 = *BIST 100 variable is the Granger cause of the Euro variable*.

H_4 = *Gold variable is the Granger cause of the Euro variable*.

H_5 = *BIST 100 variable is the Granger cause of the Gold variable*.

H_6 = *Euro variable is the Granger cause of the Gold variable*.

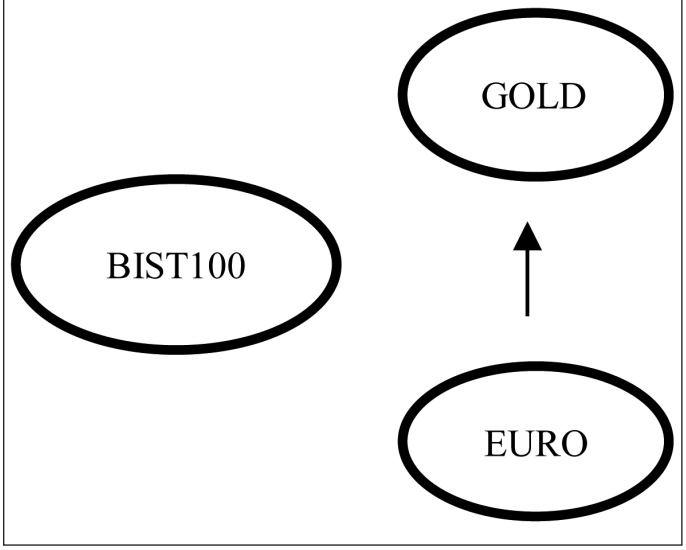
The results of the Granger Causality Test conducted with BIST 100, euro, and gold data for the pre- and post-COVID periods are presented in Table 7.

Table 7 presents the results of the Granger Causality Test. The table shows the chi-square statistics, probability values, and causality of BIST 100, euro, and gold. When the results of the analysis are analyzed, it is determined that there is only causality between the euro and gold in the pre-COVID period. In this case, one of the tested hypotheses H_6 is accepted, and other hypotheses are rejected. In the post-COVID period, causality relationships between assets differ. *H3*, *H4*, and *H5* were accepted among the tested hypotheses, and others were rejected. Causality was found between BIST100 and the euro, between gold and the euro, and between BIST100 and gold. All of the causality relations obtained are unidirectional, and it was determined that causality relations increased after COVID-19. When the results are evaluated, it is determined that while more independent movements were observed in the pre-COVID period, causality relations increased after COVID-19. Causality relations are expressed in Figures 3 and 4.

Table 7.
Granger Causality Test Results

Direction of Causality	Chi-Square Statistics	Probability Value	Status
Pre-COVID-19 Period			
Euro → BIST 100	7.321766	0.1198	Not a Granger cause
Gold → BIST 100	4.799725	0.3085	Not a Granger cause
BIST 100 → Euro	1.993283	0.7370	Not a Granger cause
Gold → Euro	5.387559	0.2498	Not a Granger cause
BIST 100 → Gold	1.168869	0.8832	Not a Granger cause
Euro→ Gold	20.95407	0.0003	Granger cause.
Pre-COVID-19 Period			
Euro → BIST 100	1.071761	0.3005	Not a Granger cause
Gold → BIST 100	0.279450	0.5971	Not a Granger cause
BIST 100 → Euro	19.08810	0.0000	Granger cause
Gold → Euro	9.728349	0.0018	Granger cause
BIST 100 → Gold	24.59943	0.0000	Granger cause
Euro→ Gold	2.642217	0.1041	Not a Granger cause

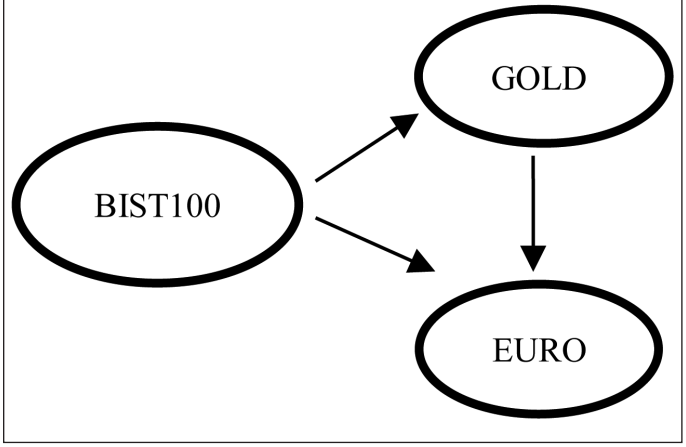
Figure 3.
Pre-COVID-19 Period.



Conclusion and Evaluation

Finance is the branch of science enabling income, expenditure, savings, financing, and investment decisions for individuals,

Figure 4.
Post-COVID-19 Period.



institutions, and states. Individuals directing the remaining amounts to investment opportunities by saving after allocating resources for their expenses provide the assurance function by meeting the financing needs that will arise in the future. Investment is a function realized from different perspectives and provides the process of allocating resources from today to be used in the future. In the system where the transfer mechanism is realized, funds and financial assets are exchanged between individuals who supply and demand funds. Portfolios created with financial assets represent the values owned by investors in order to provide returns. The total risk of the portfolio assets formed by individuals constitutes the portfolio risk. At the same time, the probability of return increases in portfolios formed with risk-free assets; an increase in risk reduces the probability of return. Existing risk can be reduced through portfolio diversification. Portfolio diversification means that investors invest in assets with multiple and different risk levels. Knowing the characteristics of financial assets well enables effective portfolio construction.

This study was carried out to determine the causality and correlation relationships between the selected index and financial assets. Knowing the causality relationship between the BIST 100 index, euro, and gold returns is important in understanding asset preferences and characteristics. In the study, March 09, 2016–March 09, 2020 is considered the pre-COVID-19 period, and March 09, 2020–March 09, 2024 is the post-COVID-19 period. In the relevant periods, prices were obtained daily, logarithmic returns were taken, and the sample was formed based on common dates. When the number of observations was analyzed, 1000 data were obtained in the pre-COVID-19 period, and 1002 data points were obtained in the post-COVID-19 period. Correlation Analysis and the Granger Causality Test were used in the study. Both analyses were applied separately for the pre and post-Covid periods. While Correlation Analysis provides information about the direction and severity of the relationship between variables, the Granger Causality Test is performed to determine the causality output of the relationships between stationary time series. The current analysis and tests in the study were carried out in the Eviews 12 software.

As a result of the correlation analysis conducted for the pre-COVID period, it was found that there was a weak and negative relationship between BIST 100 and other variables and a strong and positive relationship between gold and the euro. In the post-COVID-19 period, the relationships changed, and the level of correlation between assets decreased. As a result of the Granger Causality Test, only a unidirectional causality relationship was found between the euro and gold in the pre-COVID-19 period. In the post-COVID-19 period, an increase in causality relations was observed, and it was found that BIST 100 was the Granger cause of gold and euro, and gold was the Granger cause of the euro. For both periods, causality relations were found to be unidirectional.

Although a complete comparison cannot be made with existing studies in the literature in terms of the methods, variables, and periods used in the study, Doğru and Uysal (2015) found differences in financial asset movements in the pre-and post-crisis period Torun and Demireli (2019), especially for the post-Covid period in terms of a certain part of the direction of causality relations, Yıldız and Aydın (2022) in terms of uncertainties affecting financial assets, and changing relations, and Güneş (2022), where it is stated that the Covid epidemic affected assets and relations before and after the epidemic changed.

According to the findings, the relationships between financial assets have changed in the post-COVID period. Compared to the pre-COVID period, the ability of assets to influence each other has increased. It is inferred that the behavior of investors has also changed during the COVID-19 period. The COVID-19 pandemic has affected the financial markets of all countries in the world, as well as the Turkish financial markets. It is stated in the literature that pandemics, crisis periods, wars, and similar situations affect asset prices and returns. This study, which was conducted to test this situation, confirms the relevant situation. In this context, a situational analysis was carried out by making a comparison before and after the pandemic period. When the study is evaluated from the perspective of investors, it is important to know that the relationships have changed in terms of frequently used assets and to determine the movement of these relationships. Portfolio diversification is also important against situations that cause deviations in the movements of assets and changes in relationships. Quantitative analyses are guiding in the stage of obtaining the expected return and managing risk in converting savings into investment. In future studies, analyses of different financial assets and comparisons with the findings obtained from this study will be offered as suggestions to valuable researchers.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

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