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Multi-Horizon Causality Dynamics Among Gold, Currency, and Equity Markets: Evidence from Türkiye

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ABSTRACT

Purpose – This study examines the dynamic linkages among global gold prices (XAUUSD), the Turkish lira-U.S. dollar exchange rate (USDTRY), and the Borsa İstanbul 100 index (XU100) over the period 2015-2025, providing a comprehensive understanding of their interconnected behaviors across different time horizons.

Design/methodology/approach – Daily data from January 2015 to July 2025 are analyzed using a multi-method framework: Toda-Yamamoto causality for level relationships, Granger causality for return-based short-term dynamics, and Breitung-Candelon frequency-domain causality to capture horizon-specific effects. This integrated approach identifies both short- and long-run interactions among the three markets.

Findings – The study reveals a clear hierarchy of causality. Global gold prices strongly and persistently precede exchange rate movements across all horizons, a pattern consistent with gold reflecting global risk and liquidity conditions relevant for Türkiye. Equity shocks influence the exchange rate at short horizons, whereas the reverse channel from the currency to equities is limited to weak evidence at the very shortest cycles. Feedback from the currency to gold is weaker than the dominant gold-to-currency channel but is present at medium and long horizons. The equity-gold link is weak, appearing only as temporary, short-term portfolio adjustments.

Discussion – Monitoring equity volatility and global gold movements can signal near-term FX pressures, while the limited feedback from the currency to equities underscores how strongly external forces, rather than domestic feedback loops, shape Türkiye's financial system.

1. INTRODUCTION

There has been a significant increase in the interconnectedness of financial markets globally over the last few decades, creating complex relationships among different asset classes. Due to the significant interactions between precious metals, foreign exchange markets, and stock indices, these asset classes have gained increasing significance regarding portfolio diversification, risk management, and economic policy for developed and emerging markets. The current paper rigorously examines the causal relationships between gold prices (XAUUSD), the USD/TRY exchange rate, and stock market indices (XU100) in this age of interconnection and economic complexity. This study is distinguished by its focus on the causal linkages between asset classes rather than purely looking into traditional studies, which have focused primarily on volatility spillovers, hedging, or safe haven characteristics as contributions to the literature. The relationship between stock prices and exchange rates has been widely researched and debated by both researchers and policymakers, remaining a significant aspect of financial economics literature (Nusair & Olson, 2022).

Gold is commonly recognized as a commodity and monetary asset, a store of wealth, a unit of value, and a medium of exchange (Goodman, 1956). Additionally, gold is regarded as a form of currency and a commodity, with high liquidity compared to other asset classes, and a safe haven in unstable financial circumstances (Bhunia & Mukhuti, 2013). Beyond its historical significance, gold remains a highly liquid investment and a critical component of portfolio allocation, particularly during economic instability (Gokmenoglu & Fazlollahi,

ETHICAL APPROVAL: This study uses publicly available secondary financial market data and does not involve human participants; therefore, ethics committee approval was not required.

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2015). Central banks and other institutions hold substantial reserves of gold for diversification and economic security (Kaufmann & Winters, 1989). Markowitz's modern portfolio theory explains the connection between gold and stocks. The theory states that mixing risky assets (like equities) and safe assets (like gold) creates optimal returns for a given level of risk (Markowitz, 1952).

Stock markets have an integral role in economic development by mobilizing capital for investment and reflecting the economy's overall health. Stock markets channel funds from surplus to deficit units and are widely read as indicators of economic conditions, which has made their interaction with alternative assets such as gold a standing empirical question (Patel, 2013). Stock markets not only provide returns for investors but also serve as indicators of economic confidence and stability. In the Turkish context, literature indicates a strong nexus between the Borsa İstanbul 100 index (XU100) and currency dynamics, with evidence of time-varying and bidirectional causality between the stock market and exchange rates (Zeren & Koç, 2016; Yıldırım & Adalı, 2018; Kassouri & Altıntaş, 2020).

The co-movement of these instruments has been widely noted in the literature. Investors regularly include both gold and equities in their portfolios to lower systematic risk, viewing gold as a store of value and equities as sources of return (Bhunia & Mukhuti, 2013). This interaction makes gold and stocks economic substitutes, where volatility in one market can trigger reallocations toward the other market. Extremely turbulent or uncertain market conditions create a more robust relationship (Bhuyan & Dash, 2018). Furthermore, the interconnectedness of financial markets has strengthened these relations, where abrupt price movements in one market drive similar movements in other markets (Reboredo et al., 2021). In Türkiye, empirical studies have shown significant causal relationships between gold and equity markets, indicating that a change in one market quickly transfers to the other (Ocaklı, 2020; Doğru & Uysal, 2015).

Exchange rates are important players in the movements of these financial markets. In an open economy, movement in exchange rates receives attention because exchange rate fluctuation impacts the cost of imports and exports, overall competitiveness, and investor sentiment (Bubák et al., 2011; Kumar et al., 2023). A weakened domestic currency often drives investors toward gold as an inflation hedge, while an appreciated currency may bolster investor confidence in equities (Jain & Biswal, 2016). In Türkiye, empirical evidence indicates movement in the USD/TRY exchange rate is also associated with movement in other financial markets, highlighting the interconnected nature of currency, gold, and equity dynamics (Baktemur, 2024; Cingöz & Kendirli, 2019).

There is a large body of research documenting interdependencies within financial markets, including the interdependencies between gold prices, exchange rates, and stock market indices. However, this body of literature has significant gaps regarding causal relationships between gold prices, exchange rates, and stock market behavior in an emerging market context, such as Türkiye. Most existing studies have either focused on bivariate linkages or relied upon single-method approaches, such as standard Granger causality or cointegration tests, which may fail to capture the interdependencies between these variables over time fully. Only a few studies examine these three variables concurrently within a single framework, and most of the existing research findings on linkages between gold prices, exchange rates, and stock market indices have produced inconsistent or contradictory evidence regarding the directions and strengths of causal linkages. Additionally, with emerging markets increasingly attracting global investment flows, understanding these relationships is critical for portfolio construction and risk management. These inconsistencies underscore the need for multi-method studies based on emergent trends or a longer period of time that can produce more reliable and rich insights into dynamic interdependencies among these three key variables.

In aiming to address these gaps, this study explores the causal interactions among USDTRY, XU100, and XAUUSD using three complementary frameworks: Toda–Yamamoto (TY) level-based causality, return-based Granger causality, and Breitung–Candelon (BC) frequency-domain causality. The strength of utilizing these frameworks lies in capturing both the short- and long-term dynamics, as well as variations across different frequencies, providing a more robust and comprehensive understanding of interdependencies.

The current study adds to the literature in three ways. First, the combination of methods allows it to serve as a means of identification for the conflicting evidence that is discussed below. If causal relationships vary by time horizon, then single-method studies should have some degree of disagreement simply due to their methods, and decomposing causality based upon frequency can indicate where prior studies based in Türkiye diverged from each other. Second, horizon-dependent causality has a direct interpretation in terms of the economic differences among participants in financial markets. In addition, high-frequency relationships may represent active trading, while lower frequency relationships would represent longer-term influences such as inflation pass-through, trade pricing, and changes to the balance sheets of market participants (Müller et al., 1997). Lastly, to date, there appears to be no study utilizing Türkiye data that incorporates level-based, return-based, and frequency-domain causality tests to assess the causal relationships among gold, currency, and equity markets. Therefore, the paper presents the first horizon-by-horizon map of the causal relationships of these markets in an economy with significant levels of both dollarization and household demand for gold.

The rest of this article is structured as follows: Section 2 reviews the theoretical and empirical literature on the relationships between gold, exchange rates, and equity markets. Section 3 describes the data sources and variable definitions. Section 4 outlines the econometric methodology applied. Section 5 presents and discusses the empirical results. Finally, Section 6 concludes with a summary of key findings, practical implications, and suggestions for future research.

2. LITERATURE REVIEW

The relationship between exchange rates and stock markets has been widely investigated in the literature, especially in emerging markets. Zeren and Koç (2016) showed that the causality between stock indices and exchange rates is time-varying and often stronger during financial distress. Yıldırım and Adalı (2018) and Kassouri and Altıntaş (2020) reported significant relationships between the BIST100 index and the Turkish lira, with evidence of causal relationships. Baktemur (2024) also noted important relationships between the BIST100 index and exchange rates, reinforcing that shocks in one market can spill over to the other. The evidence from the studies described above is consistent with the broader international evidence. Śmiech and Papież (2013) found bidirectional causality between stock indices, exchange rates, and fuel prices in European markets, and Piccillo (2008) documented two-way causality between stock prices and exchange rates in Japan, the UK, and Germany. Like the findings above, Köseoğlu and Çevik (2013) found that stock markets in Central and Eastern European countries (including Türkiye) Granger-cause their foreign exchange markets in mean and variance, and Köse, Doğanay, and Karabacak (2010) provided evidence of unidirectional causality from stock prices to exchange rates in the Turkish market. These studies demonstrate that the stock market–exchange rate linkage is time-varying and multi-dimensional, stemming from changes in time and market conditions.

The relationship between gold and exchange rates has also been studied rigorously. Güriş and Kıran (2014) found evidence of threshold cointegration between gold prices and the USD/TRY rate, suggesting significant, though non-linear, interdependencies between these two variables. Beckmann, Czudaj, and Pilbeam (2015) and Pukthuanthong and Roll (2011) found that currency depreciations tend to be followed by increases in gold prices in various economies, suggesting that the movement of a currency is often related to the price of gold. Pata et al. (2024) further indicated that the connection between gold and currency markets may become more apparent in periods of greater uncertainty. In terms of the Turkish setting, Cingöz and Kendirli (2019) established that fluctuations in exchange rates impact gold prices in the long-run, while Şanlı, Konak, and Özmen (2021) showed periods where movements in stock prices influenced gold prices. In addition, Tanin, Sarker, and Brooks (2021) stated that during the COVID-19 crisis, the exchange rate changes caused increases in gold prices, mostly in the short-run, regardless of the degree or direction. These studies suggest that the changes in currency values related to exchange rates and gold prices are dynamic and time-sensitive.

The linkage between gold and equity markets has been studied in various settings. Ocaklı (2020) provided evidence of unidirectional causality from the BIST100 index to gold, indicating that equity markets can influence movements in gold. On the other hand, Tursoy and Faisal (2018) found unidirectional causality from gold prices to stock prices in the short and long-run, while İlarslan (2017) found bidirectional causality between gold and stock prices, implying feedback between the two markets. In support of this, Açıkalın and Başcı (2016) found a long-term equilibrium relationship between the BIST and BIST Gold indices and described unidirectional causality running from equities to gold. Also, Doğru and Uysal (2015) found a long-term relationship between equity indices and gold prices before and after the global financial crisis, although the direction of the causal relationship changed over time. Sandal, Çemrek, and Yıldız (2017) also found unidirectional causality from gold prices to the BIST100 index. Outside of Türkiye, Raza et al. (2016) found that gold prices positively influence stock prices across emerging markets, again highlighting the global relevance of these interactions. Collectively, these studies demonstrate that interactions between gold and equities are complex, time-varying, and influenced by market conditions and structural changes.

Although these asset classes exist simultaneously, they are conflicting. Regarding the equity and gold pair, the literature shows equity in the lead (Ocaklı, 2020; Açıkalın and Başcı, 2016), but also shows an opposite effect (Tursoy and Faisal, 2018; Sandal, Çemrek and Yıldız, 2017), and even feedback in both directions (İlarslan, 2017). Likewise, on the currency-gold pair, Cingöz and Kendirli (2019) have also documented an effect flowing from exchange rates to gold prices; whereas Beckmann, Czudaj and Pilbeam (2015) and Pukthuanthong and Roll (2011) treated the two as jointly determined. As such, differences in the sample periods, frequencies, and policy regimes explain some of the discrepancies in findings (Zeren & Koç, 2016). More fundamentally, however, there is a methodological explanation: except for Kassouri and Altıntaş (2020), who examine only the stock and currency pair, all of these studies use only a single time-domain test for assessing their causal hypotheses. This test provides one answer for those relationships that may hold at some horizons and not at others. A finding of causality by means of a monthly frequency, but no evidence of causality at a daily frequency, can both be correct. This paper tests both directions at five different frequencies, along with level-based and return-based tests, allowing us to consider this heterogeneity within the data as our focus for analysis, rather than background "noise".

Only a limited number of studies have jointly examined the interactions among exchange rates, gold prices, and equity markets in Türkiye, such as Baktemur (2024), Cingöz and Kendirli (2019), and Şanlı, Konak, and Özmen (2021). These studies provide valuable insights by characterizing interconnected behaviours of these variables, yet they remain limited in scope and methodology. This limitation highlights the need for additional perspectives that can involve combinations of level-based, return-based, and frequency-domain analyses to understand better the evolving components of these connected markets, which this study will examine.

3. DATA AND VARIABLES

This study investigates the dynamic causal relationships between the USD/TRY exchange rate (USDTRY), the BIST100 stock market index (XU100), and the gold price in USD (XAUUSD). The data, compiled for each variable from January 2, 2015, to July 30, 2025 (2,556 data points for each series), were chosen to represent relatively contemporary dynamics relevant to the market. This timeframe included cases of extreme volatility, including, but not limited to, the COVID-19 pandemic and the significant monetary and financial activity in Türkiye.

The variables are defined as follows:

- USDTRY: The daily closing price of the U.S. dollar against the Turkish lira.
- XU100: The daily closing level of the Borsa İstanbul 100 index (BIST100), which represents the aggregate performance of the largest and most liquid companies traded in Türkiye.
- XAUUSD: The daily global spot price of one ounce of gold in U.S. dollars.

Restricting attention to only these three series is a methodological decision. A bivariate (see Section 4.4) method is used in the frequency domain for testing; selecting a parsimonious set keeps the three methods on the same footing. In addition, they represent an economic unit: households have historically allocated their portfolio assets among currency, gold, and equities; and the price movements of each of these assets reflect a large portion of the influences of interest rates, sovereign risk, oil, and global risk appetite that affect investor decisions, and those are reflected directly within the price data being examined here. The cost of this decision is that it is not possible to estimate the separate effects of channels through omitted variables, a point explored in detail in Section 6.

All data series were sourced from Yahoo Finance, ensuring consistency across series. The data series were first transformed to natural logarithms before conducting empirical analysis, and the log-transformed data help stabilize the variance and make the analysis easier to interpret. The log-level data were used in the TY and BC frequency-domain causality tests, with the BC statistics computed from a lag-augmented levels VAR to ensure valid inference with integrated series (Section 4.4). The log-return series were used in the Granger causality framework to identify short-run dynamic interactions.

Table 1. Descriptive Statistics

Series	count	mean	std	min	max	skew	kurtosis
USDTRY	2556	12.33	11.36	2.28	40.57	1.1114	-0.2189
XU100	2556	2998.40	3257.18	685.67	11172.74	1.3203	0.0928
XAUUSD	2556	1682.33	513.52	1050.80	3439.19	1.2810	1.5156

Table 1 presents the descriptive statistics of the raw (level) data; after computing the descriptive statistics, all series were transformed to natural logarithms for the analyses. The USD/TRY exchange rate (USDTRY) has a mean of 12.33 and a relatively high standard deviation (11.36), indicating considerable volatility over the sample period. The skewness value (1.1114) indicates a right-tailed distribution, which aligns with occasional instances of significant currency depreciation, and the slightly negative (-0.2189) kurtosis indicates a flatter distribution than a normal distribution. The BIST100 (XU100) index had an average value of 2,998.40, with a standard deviation of 3,257.18; this indicates significant variability in the levels observed in the equity markets. The positive skewness (1.3203) suggests extreme upward movements were more frequent than declines, and the near-zero kurtosis (0.0928) indicates that the distribution is nearly normal. The gold price in USD (XAUUSD) has an average of 1,682.33 with relatively moderate variability (standard deviation of 513.52); the skewness (1.2810) suggests occasional sharp increases in gold prices, and the positive kurtosis (1.5156) indicates heavier tails than a normal distribution, with more extreme events. Overall, these statistics highlight the volatility that is inherent in Turkish financial markets, with the exchange and stock markets exhibiting more dispersion and asymmetry compared to the gold price, which is relatively more stable but still demonstrates significant tail risk.

4. METHODOLOGY

This section outlines the methodological framework for examining the causal relationships among gold prices (XAUUSD), the USD/TRY exchange rate, and the BIST100 index (XU100). The analysis combines level-based, return-based, and frequency-domain approaches to capture both short and long-term dynamics.

4.1. Common setup and notation

Let $yt = (g_t, e_t, s_t)'$ denote the $k = 3$ vector observed on day t, where g_t is the (log) gold price (XAUUSD), e_t is the (log) USD/TRY exchange rate, and s_t is the (log) BIST100 index (XU100). For lag order p, the VAR(p) is

$$yt = c + \sum \mathrm{l} = 1^p A\mathrm{l}\ y_{t-1} + u_t, \qquad ut \sim \mathrm{WN}(0, \Sigma),\ \ A\mathrm{l} \in R^{k\times k}$$

where WN denotes white noise with zero mean and positive-definite covariance Σ.

- **Data treatment.** Log-level data are used for the TY and BC tests, with the BC statistics computed from a lag-augmented VAR, while stationary log returns are used for the classical Granger tests to capture short-run dynamics
- **Lag selection.** The optimal lag length (p) is selected using a trivariate VAR including USDTRY, XU100, and XAUUSD, based on AIC and BIC criteria; d_{max} is inferred from ADF and PP tests.
- **Causality tests.** All causality analyses (TY, Granger, and BC) are implemented in a bivariate (pairwise) design. For each ordered pair (cause, effect), we estimate a two-variable VAR using the transformation appropriate to each test (log levels for TY and BC, log returns for Granger) and test whether the lags of the cause jointly matter in the effect equation.

The use of a pairwise design also warrants comment. The lag order used to determine causation comes from a trivariate VAR, but the statistical tests are bivariate. The BC test was developed for two-variable systems, and its conditional extensions complicate the restrictions that define the null hypothesis, especially at low frequencies. Running TY and Granger tests on the same bivariate systems keeps all three methods directly comparable, so that any differences in results will be due to the horizon dimension rather than the size of the conditioning set. The common lag order, obtained from the trivariate VAR, applies the full dynamics of the system to all pairs. There is a cost, however. Bivariate tests cannot reveal whether causality exists directly between two variables or indirectly by passing through some other omitted market. Section 5.5 interprets the gold and equity results with just this in mind, and conditional frequency-domain extensions are left until Section 6.

4.2. Classical Granger causality

Granger (1969) asks whether past values of x_j help predict x_i conditional on the other variable included in the **bivariate** system. In the i-th equation:

$$x_{i,t} = c_i + \sum_{l=1}^{p} a_{ii,l}\ x_{i,t-l} + \sum_{l=1}^{p} a_{ij,l}\ x_{j,t-l} + u_{i,t}.$$

The null of no Granger causality $j \rightarrow i$ is

$$H_0:\ \beta_{ij} = 0, \qquad \beta_{ij} = \left(a_{ij,1}, \dots, a_{ij,p}\right)'$$

To test for joint significance, an F-test is applied to log returns. Since the lag order for each pair is set to $p = 4$ (the AIC-selected order of the trivariate VAR presented in Table 3), the Granger, TY, and BC tests use the same dynamic specification, and no lag-searching is performed. All test statistics for $p = 1, \dots, 5$ are reported in Appendix Table A1. While the results for the strong and silent channels do not change based on p, the two weak channels pass into or out of conventional threshold values.

4.3. TY causality

TY (Toda & Yamamoto, 1995) provides valid level-causality irrespective of integration/cointegration by augmenting the VAR with d_{max} extra lags:

$$yt = c + \sum l = 1^{p+d_{max}} A_l\ yt - l + ut$$

Causality $j \rightarrow i$ is tested by restricting only the first p lags of x_j in the i-th equation:

$$H_0:\ aij,1 = aij,2 = \cdots = a_{ij,p} = 0$$

We use the modified Wald statistic with White-robust covariance; under $H_0, W \rightarrow d\chi^2_p$.

TY is applied pairwise on log-level series (two-variable VARs). The baseline lag length (p) is selected using trivariate AIC/BIC, and d_{max} is inferred from ADF/PP tests across series.

4.4. BC frequency-domain causality

BC (Breitung & Candelon, 2006) tests for no causality $j \rightarrow i$ at frequency $\omega \in (0, \pi)$ in a stationary VAR(p). For $p \geq 2$, the null is equivalent to two linear restrictions on $\beta_{ij} = \left(a_{ij,1}, \dots, a_{ij,p}\right)'$:

$$\sum_{l=1}^{p} a_{ij,l} \cos(l\omega) = 0$$

$$\sum_{l=1}^{p} a_{ij,l} \sin(l\omega) = 0$$

i.e. $H_0:\ R(\omega)\ \beta_{ij} = 0$ with

$$R(\omega) = \begin{bmatrix} cos\ \omega & cos\ 2\omega, \dots cos\ p\omega \\ sin\ \omega & sin\ 2\omega, \dots sin\ p\omega \end{bmatrix} \in R^{2\times p}$$

The Wald statistic:

$$W_{\mathrm{BC}}(\omega) = \left(R(\omega)\hat{\beta}ij\right)' \left[R(\omega)\ \widehat{\mathrm{Var}}\left(\hat{\beta}ij\right) R(\omega)'\right]^{-1} \left(R(\omega)\hat{\beta}ij\right) \rightarrow \mathrm{d}\ \chi^2 2$$

is computed on a grid of \omega and specifically at $\{\pi/2, \pi/6, \pi/12, \pi/36, \pi/60\}$, which correspond to cycles of approximately 4, 12, 24, 72, and 120 trading days. For clarity, these horizons are classified as short (4–12 days), medium (24 days), and long (72–120 days), and this convention is used in the interpretation of the BC results.

Since all three series are I(1) (see Table 2), the VAR used to compute the BC statistic is augmented by one additional lag. In the spirit of Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996), the augmented VAR has p + 1 = 5 lags. However, the frequency restrictions are applied only to the first p = 4 lags of the causal variable. This preserves the information regarding long-run behavior in the levels of the variables while ensuring that the Wald statistic is chi-squared at each frequency.

The grid represents some familiar horizons: a frequency ω implies a cycle of $2\pi/\omega$ trading days. As such, the five points represent approximately one week, half a month, a month, a quarter, and half a trading year (120 days vs. about 126 in six calendar months). The lower bound lies at $\pi/60$ as the sine row of $R(\omega)$ degenerates as ω approaches zero, leaving the semi-annual cycle as the longest horizon at which the two restrictions are still reasonably well conditioned. The points are simply markers on a continuum: Figures 2 through 7 display the complete Wald curve and thus the significance regions are unaffected at nearby frequencies like $\pi/48$ or $\pi/72$.

5. FINDINGS

This study employs three complementary causality testing frameworks to capture both persistent and horizon-specific dynamics across markets:

- TY causality tests are applied to the level data to detect persistent and long-run causal relationships while maintaining valid inference even with integrated series.
- Classical Granger causality tests are performed on log-return data to identify short-run predictive linkages and high-frequency information flows.
- BC frequency-domain causality tests are implemented on the log-level series using a lag-augmented VAR, revealing horizon-specific relationships while preserving valid inference with integrated series.

This multi-method design emphasizes both the long-term structural relationships and the short-run and horizon-dependent dynamics among USDTRY, XU100, and XAUUSD, thus providing a more in-depth interpretation of the relationships between the three markets.

5.1 Integration, lag selection, stability, and diagnostics

Table 2. Unit Root Test Results (ADF and PP, Level and First Difference)

Series	Level (Const)	Level (Const + Trend)	1st Diff (Const)	1st Diff (Const + Trend)
USDTRY	ADF: 0.538 (0.986) PP: 0.523 (0.986)	ADF: -2.031 (0.585) PP: -1.932 (0.638)	ADF: -10.483 (0.000) PP: -46.486 (0.000)	ADF: -10.528 (0.000) PP: -46.485 (0.000)
XU100	ADF: 1.204 (0.996) PP: 1.040 (0.995)	ADF: -1.594 (0.795) PP: -1.633 (0.779)	ADF: -20.745 (0.000) PP: -49.859 (0.000)	ADF: -20.860 (0.000) PP: -49.855 (0.000)
XAUUSD	ADF: 0.757 (0.991) PP: 0.948 (0.994)	ADF: -1.883 (0.663) PP: -1.629 (0.781)	ADF: -51.923 (0.000) PP: -52.227 (0.000)	ADF: -51.959 (0.000) PP: -52.370 (0.000)

As shown in Table 2, the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests indicate that all three series (USDTRY, XU100, and XAUUSD) are non-stationary in their levels. In both the constant and constant-plus-trend specifications, the p-values exceed the 5% significance threshold, indicating that the null hypothesis of a unit root cannot be rejected. This result confirms that the price series exhibit unit root behavior and are integrated of order one, I(1).

When the tests are applied to the first differences, both ADF and PP statistics yield very low p-values, strongly rejecting the null of a unit root and confirming that the differenced series are stationary. The similar result from the two tests confirms that all three variables are I(1) processes, confirming the assessment of integration order consistency.

The results support the case for specifying dmax = 1 in the TY causality mechanism, where the augmented VAR(p+dmax) model accounts for the maximum integration order across the series. In parallel, the classical Granger causality tests, used as robustness checks, are applied to the log-return series, which satisfy the stationarity requirement. This dual-modeling approach minimizes the risk of spurious inference while preserving both the analysis's short- and long-term dynamics.

Table 3. Optimal Lag Length Selection Based on Information Criteria

Lag	AIC	BIC	FPE	HQIC
1	-26.4310	-26.4035	3.320e-12	-26.4210
2	-26.4543	-26.4063	3.244e-12	-26.4369
3	-26.4563	-26.3876	3.237e-12	-26.4314
4	-26.4582*	-26.3689	3.231e-12	-26.4258
5	-26.4563	-26.3463	3.237e-12	-26.4164
6	-26.4500	-26.3194	3.258e-12	-26.4026
7	-26.4539	-26.3026	3.245e-12	-26.3990
8	-26.4465	-26.2745	3.269e-12	-26.3841
9	-26.4421	-26.2494	3.284e-12	-26.3722
10	-26.4411	-26.2276	3.287e-12	-26.3636
11	-26.4366	-26.2024	3.302e-12	-26.3517
12	-26.4344	-26.1796	3.309e-12	-26.3420

Table 3 outlines the optimal lag order for the VAR model based on Information Criteria, including AIC, BIC, FPE, and HQIC. The AIC criterion suggests a lag order of 4, and the BIC criterion suggests a lag order of 2. Considering the characteristics of financial time series where complex dynamic interactions and delayed effects are common, the AIC-based lag (p=4) was selected for the main analysis. This choice aligns with the approach in the existing literature because AIC captures richer dynamics and provides more reliable results in causality testing. For robustness checks, results based on the BIC-selected lag length are also examined to ensure that the findings are not overly sensitive to the choice of criterion.

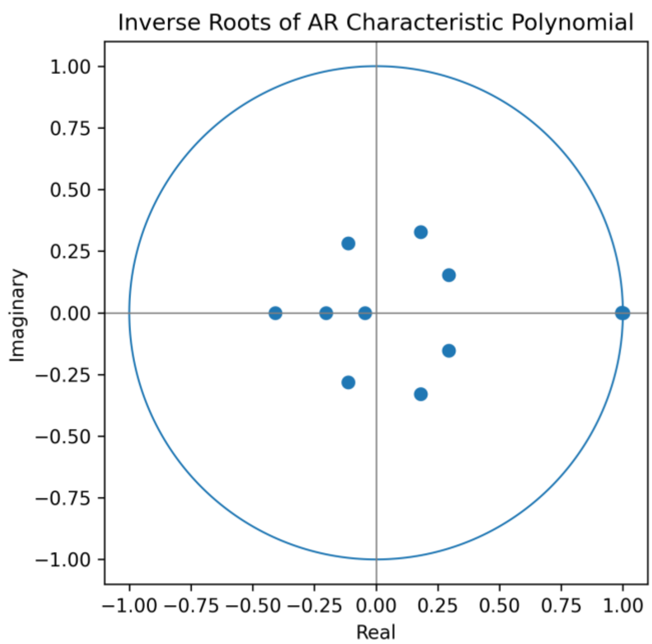

Figure 1. Inverse Roots of the AR Characteristic Polynomial

Figure 1 shows that all but one inverse root of the AR characteristic polynomial lie inside the unit circle, with a single root exactly on the unit circle. This indicates the presence of a unit root in the level VAR, consistent with the unit root tests in Table 2. However, the TY framework accounts for this by augmenting the VAR with d_{max} lags, ensuring valid Wald asymptotics.

Table 4. Autocorrelation, Heteroskedasticity, and Normality Test Results

White Heteroskedasticity Test		
Equation	**Test Statistic**	**p-value**
USDTRY	948.189	0.000
XU100	391.608	0.000
XAUUSD	264.992	0.000
Lagrange Multiplier (LM) Autocorrelation Test		
	Test Statistic	**p-value**
	102.609	0.010
Normality Test (Jarque–Bera)		
	Test Statistic	**p-value**
	938331.010	0.000

Table 4 reports that the VAR residuals deviate from certain Gauss–Markov assumptions, a common characteristic of financial time series. For all three equations (USDTRY, XU100, and XAUUSD; $p < 0.001$), White heteroskedasticity test rejects the null of constant variance, indicating that residuals have time-varying volatility. The LM autocorrelation test has also rejected the null of no residual autocorrelation (nlags=12, p=0.010). Furthermore, the Jarque–Bera test strongly rejects the null hypothesis of normality (p=0.000), highlighting heavy tails and asymmetry in the distribution of residuals. Accordingly, the TY Wald tests are reported with White-robust covariance, the Granger tests are performed on stationary log returns, and the BC tests are computed from a lag-augmented levels VAR that preserves valid chi-squared inference under nonstationarity.

The White-robust covariance addresses the major violation: we reject the null hypothesis of homoscedastic residuals at p<.001 for each equation. We reject the null hypothesis of no serial correlation of residuals, however, only at a marginal level of significance (p=.010 at 12 lags), since the VAR(4) dynamics have absorbed most of the time series dependence. Two additional diagnostic assessments confirmed that these conclusions are independent of this specification. The TY and Granger statistics were re-estimated using Newey and West's (1987) HAC covariance matrix and, because of the significant nonnormality indicated by the Jarque-Bera statistic, they also were estimated via a fixed design wild bootstrap that is appropriate under conditional heteroskedasticity of unknown form (Rademacher weights and 1999 replications; Gonçalves & Kilian, 2004). Appendix Table A2 lists the p-values associated with these tests. Every one of our decisions holds at the 10% level under all three test methods. While our decision regarding the weak equity-to-gold relationship slipped from the 5% to the 10% level under robust inference (indicating that this relationship may be transitory), our decision regarding the exchange rate to gold price relationship actually strengthened.

5.2. TY Causality

Table 5. TY Causality Test Results (White-robust MWald Statistics)

Direction	**Wald Statistic**	**p-value**	**Decision**
XU100 → USDTRY	27.66	0.000***	Strong causality from XU100 to USDTRY
USDTRY → XU100	5.07	0.281	No evidence of causality from USDTRY to XU100
XAUUSD → USDTRY	20.54	0.000***	Strong causality from XAUUSD to USDTRY
USDTRY → XAUUSD	10.91	0.028**	Moderate causality from USDTRY to XAUUSD
XAUUSD → XU100	5.19	0.268	No evidence of causality from XAUUSD to XU100
XU100 → XAUUSD	8.83	0.065*	Marginal causality from XU100 to XAUUSD
*** denotes $p < 0.01$, indicating strong evidence of causality ** denotes $p < 0.05$, indicating moderate evidence of causality * denotes $p < 0.10$, indicating marginal evidence of causality No asterisk indicates no statistically significant causality			

Table 5 presents the results of the level-based TY causality analysis across all nexuses. For the XU100–USDTRY nexus, XU100 → USDTRY exhibits strong causality ($p < 0.001$), indicating that shocks to the equity market persistently propagate to the exchange rate. Conversely, USDTRY → XU100 shows no evidence of causality ($p = 0.281$), demonstrating that changes in the exchange rate do not affect the equity index persistently.

In the XAUUSD–USDTRY nexus, XAUUSD → USDTRY shows strong causality ($p < 0.001$), indicating that the influence of global gold prices on the exchange rate is strong. In contrast, USDTRY → XAUUSD shows moderate causality ($p = 0.028$), indicating a weaker but significant causal link from the exchange rate to global gold prices.

Regarding the XAUUSD–XU100 nexus, XU100 → XAUUSD presents marginal causality ($p = 0.065$), indicating a weak but detectable influence running from the equity index to global gold prices. Conversely, there is no significant causality for XAUUSD → XU100 ($p = 0.268$), indicating the absence of a direct causal link from global gold prices to the equity index.

Overall, the level-based TY analysis highlights two dominant and persistent channels: strong causality in XU100 → USDTRY and XAUUSD → USDTRY. There is also moderate causality in USDTRY → XAUUSD, and marginal evidence of causality in XU100 → XAUUSD.

5.3. Classical Granger

Table 6. Classical Granger Causality Test Results (Log Returns)

Direction	F Stat.	p-value	Decision
XU100 → USDTRY	13.42	0.000***	Strong causality from XU100 to USDTRY
USDTRY → XU100	1.66	0.157	No evidence of causality from USDTRY to XU100
XAUUSD → USDTRY	4.80	0.001***	Strong causality from XAUUSD to USDTRY
USDTRY → XAUUSD	1.95	0.099*	Marginal causality from USDTRY to XAUUSD
XAUUSD → XU100	1.44	0.219	No evidence of causality from XAUUSD to XU100
XU100 → XAUUSD	2.55	0.038**	Moderate causality from XU100 to XAUUSD

*** denotes $p < 0.01$, indicating strong evidence of causality
** denotes $p < 0.05$, indicating moderate evidence of causality
* denotes $p < 0.10$, indicating marginal evidence of causality
No asterisk indicates no statistically significant causality
The lag order is fixed at $p = 4$, the AIC-selected order of the trivariate VAR (Table 3). Sensitivity across $p = 1, ..., 5$ is reported in Appendix Table A1.

Table 6 presents the results of the return-based Granger causality analysis. For the XU100–USDTRY nexus, XU100 → USDTRY exhibits strong evidence of short-run causality ($p < 0.001$), indicating that shocks in the equity market rapidly transmit to the exchange rate. In contrast, no evidence of short-run causality is found for USDTRY → XU100 ($p = 0.157$), suggesting that abrupt currency fluctuations do not immediately affect domestic equity returns.

In the XAUUSD–USDTRY nexus, XAUUSD → USDTRY demonstrates strong short-run causality ($p < 0.001$), indicating a strong and immediate influence of global gold prices on the exchange rate. By contrast, USDTRY → XAUUSD shows only marginal short-run causality ($p = 0.099$), indicating a weaker and less consistent causal link from the exchange rate to global gold prices.

Regarding the XAUUSD–XU100 nexus, XAUUSD → XU100 shows no significant short-run causality ($p = 0.219$), indicating no immediate causal link from global gold prices to the equity index. Conversely, there is moderate short-run causality for XU100 → XAUUSD ($p = 0.038$), indicating a short-run causal link from the equity index to global gold prices.

Overall, the return-based Granger analysis highlights three dominant short-run dynamics: strong causality from XU100 → USDTRY and XAUUSD → USDTRY, and moderate causality from XU100 → XAUUSD. No significant short-run causality is detected for USDTRY → XU100 or XAUUSD → XU100, indicating limited immediate feedback effects in these directions.

5.4. BC Frequency-Domain Causality

Table 7 reports the BC frequency-domain causality results, offering a horizon-specific understanding of the interactions among the equity market (XU100), the exchange rate (USDTRY), and global gold prices (XAUUSD). By examining multiple frequencies, from long-term (120-day and 72-day cycles) to medium-term

(24-day cycles) and short-term (12-day and 4-day cycles), this framework identifies where and when causal relationships are most significant, revealing dynamics that are not captured by level- or return-based approaches.

Table 7. BC Frequency-Domain Causality Test Results

Direction	ω (rad)	Approximate Period (days)	Wald Statistic	p-value
XU100 → USDTRY	π/60 (0.05236)	120	1.3207	0.517
XU100 → USDTRY	π/36 (0.08727)	72	1.3438	0.511
XU100 → USDTRY	π/12 (0.26180)	24	2.2069	0.332
XU100 → USDTRY	π/6 (0.52360)	12	12.9175	0.002***
XU100 → USDTRY	π/2 (1.57080)	4	26.5097	0.000***
USDTRY → XU100	π/60 (0.05236)	120	4.0904	0.129
USDTRY → XU100	π/36 (0.08727)	72	4.0663	0.131
USDTRY → XU100	π/12 (0.26180)	24	3.7680	0.152
USDTRY → XU100	π/6 (0.52360)	12	3.2866	0.193
USDTRY → XU100	π/2 (1.57080)	4	6.0246	0.049**
XAUUSD → USDTRY	π/60 (0.05236)	120	9.6817	0.008***
XAUUSD → USDTRY	π/36 (0.08727)	72	9.5729	0.008***
XAUUSD → USDTRY	π/12 (0.26180)	24	8.2326	0.016**
XAUUSD → USDTRY	π/6 (0.52360)	12	5.5654	0.062*
XAUUSD → USDTRY	π/2 (1.57080)	4	9.2830	0.010***
USDTRY → XAUUSD	π/60 (0.05236)	120	7.0448	0.030**
USDTRY → XAUUSD	π/36 (0.08727)	72	7.0387	0.030**
USDTRY → XAUUSD	π/12 (0.26180)	24	6.9358	0.031**
USDTRY → XAUUSD	π/6 (0.52360)	12	6.2075	0.045**
USDTRY → XAUUSD	π/2 (1.57080)	4	0.7056	0.703
XAUUSD → XU100	π/60 (0.05236)	120	4.4357	0.109
XAUUSD → XU100	π/36 (0.08727)	72	4.4348	0.109
XAUUSD → XU100	π/12 (0.26180)	24	4.4068	0.110
XAUUSD → XU100	π/6 (0.52360)	12	4.1302	0.127
XAUUSD → XU100	π/2 (1.57080)	4	4.5839	0.101
XU100 → XAUUSD	π/60 (0.05236)	120	2.3577	0.308
XU100 → XAUUSD	π/36 (0.08727)	72	2.2894	0.318
XU100 → XAUUSD	π/12 (0.26180)	24	1.4553	0.483
XU100 → XAUUSD	π/6 (0.52360)	12	0.1094	0.947
XU100 → XAUUSD	π/2 (1.57080)	4	9.3134	0.009***

*** denotes $p < 0.01$, indicating strong evidence of causality
** denotes $p < 0.05$, indicating moderate evidence of causality
* denotes $p < 0.10$, indicating marginal evidence of causality
No asterisk indicates no statistically significant causality

The accompanying figures visualize these results across the frequency spectrum. The blue line shows the Wald statistic over frequencies (ω, in radians). The dashed gray line is the 5% critical level for statistical significance. Red dots show the selected frequencies, described in Table 7, that correspond to the key cycles discussed. When the blue line is above the dashed threshold, it indicates statistically significant causality at that horizon, and this visual displays a clear representation of how causal relationships vary over time.

The causal relationship in USDTRY-XU100 is demonstrated by both Table 7 and Figure 2. XU100 → USDTRY indicates significant causation at the 4-day and 12-day cycles ($p \leq .01$) but fades at the 24-day cycle and disappears at the 72-day and 120-day cycles. Equity market shocks, therefore, affect the exchange rate quickly but briefly. Conversely, Table 7 and Figure 3 show that there is no causality from USDTRY → XU100 in either the medium or long-horizon directions; also, weak evidence exists for the very short horizons at the 4-day cycle ($p = .049$); therefore, changes in exchange rates have little systematic predictive power for return on equities over any time period.

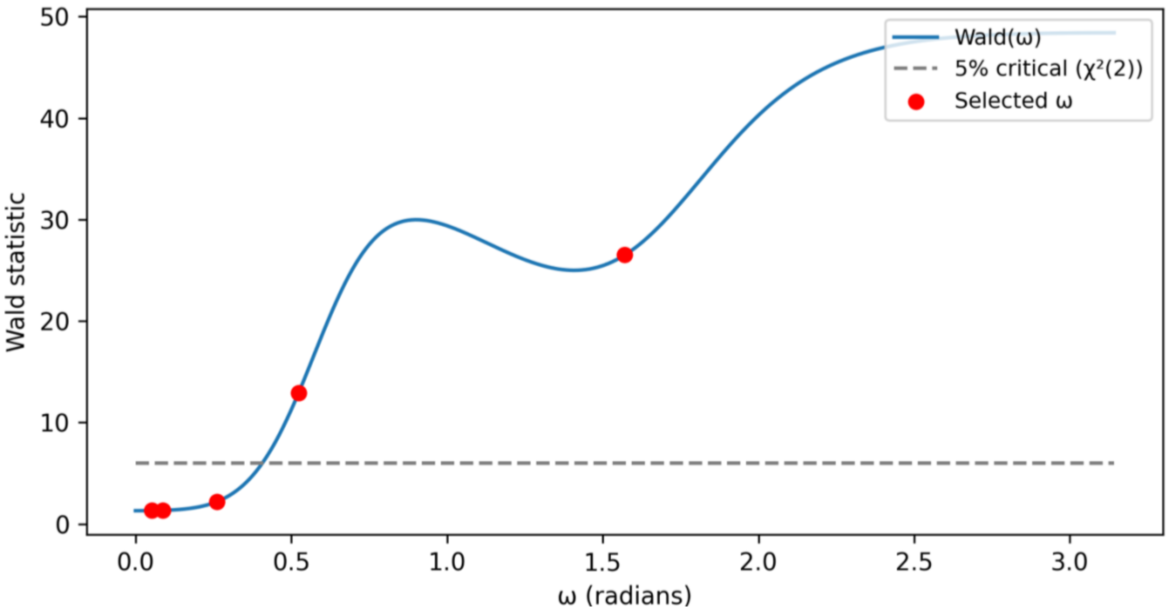

Figure 2. BC Frequency-Domain Causality: XU100 → USDTRY

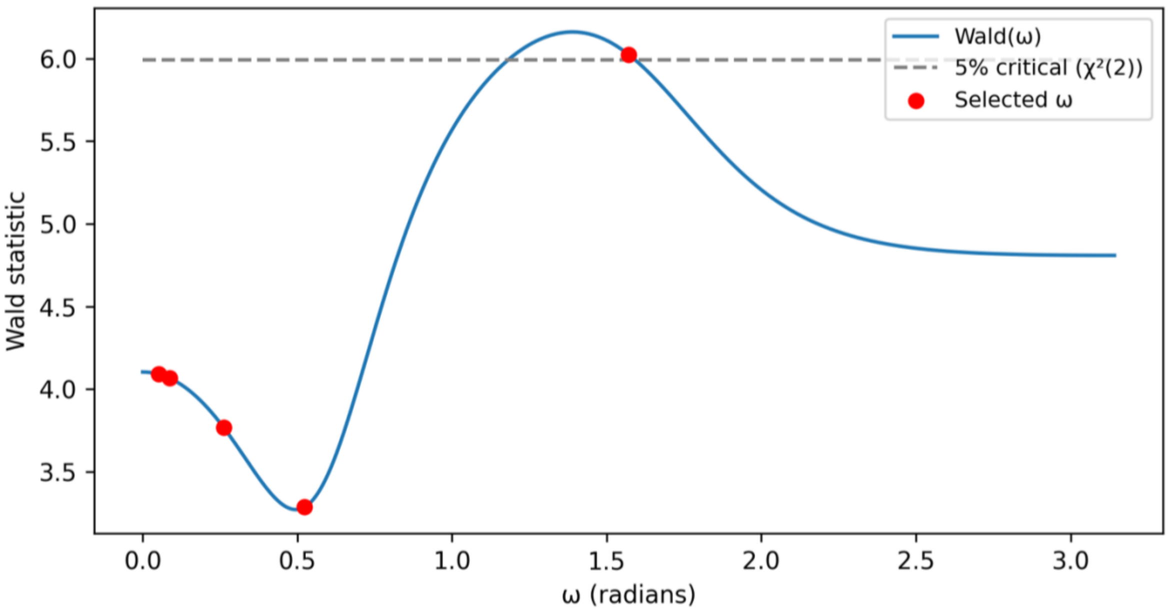

Figure 3. BC Frequency-Domain Causality: USDTRY → XU100

For the XAUUSD-USDTRY relationships, Table 7 and Figure 4 show that there are significant causality levels from XAUUSD → USDTRY across all of the tested horizons with the following levels of significance: at least at the 5% level or better at the 4-, 24-, 72-, and 120-day cycles and at the 10% level at the 12-day cycle. In contrast, Table 7 and Figure 5 show that there is significant causality from USDTRY → XAUUSD at every cycle from the 12-day through the 120-day cycles; however, we find no significant causality at the very short 4-day cycle.

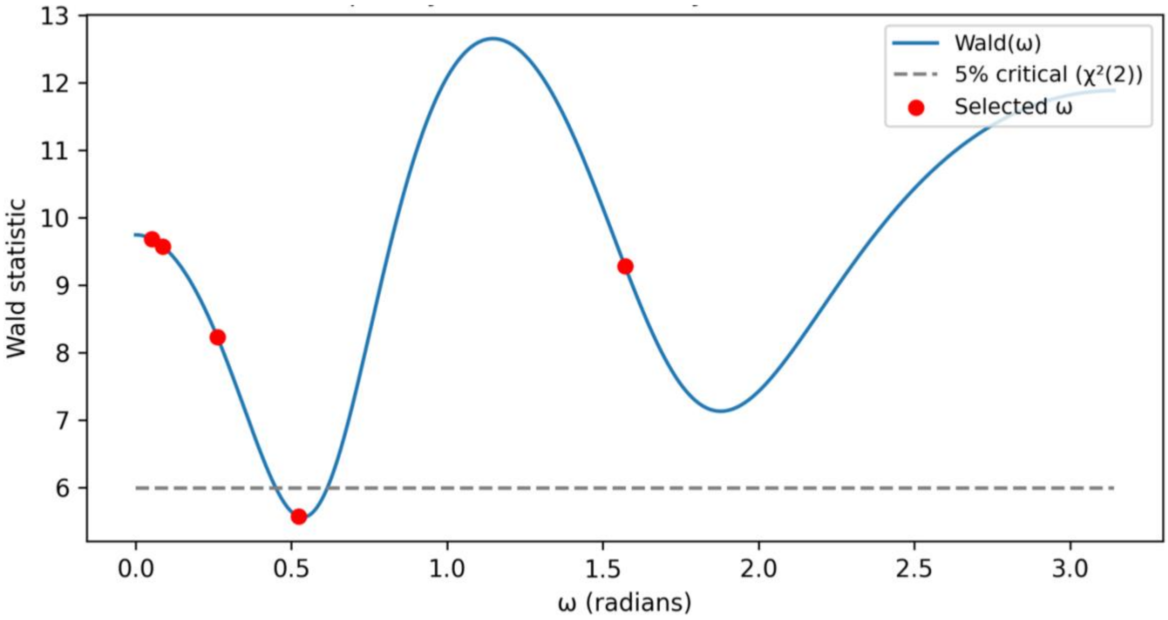

Figure 4. BC Frequency-Domain Causality: XAUUSD → USDTRY

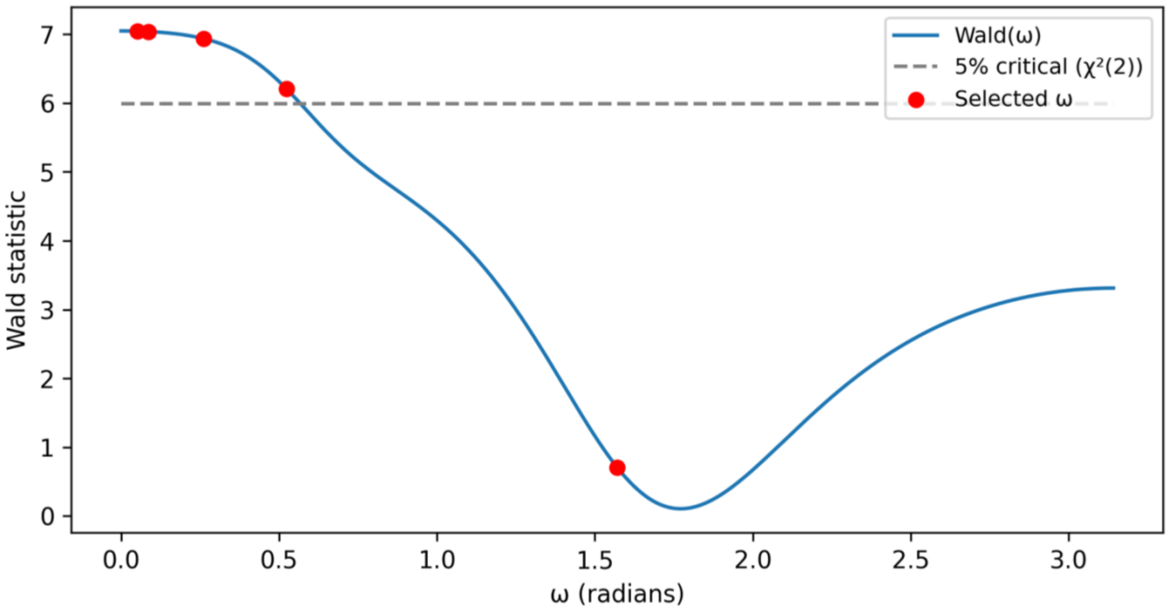

Figure 5. BC Frequency-Domain Causality: USDTRY → XAUUSD

For the XAUUSD-XU100 relationships, Table 7 and Figure 6 indicate that there is no causality from XAUUSD → XU100 at any of the tested horizons (all p values > .10). Table 7 and Figure 7 show that there is causality from XU100 → XAUUSD limited to the very short cycles with only evidence at the 4-day cycle ($p < .01$); this points towards a quickly dissipating link from equities to gold.

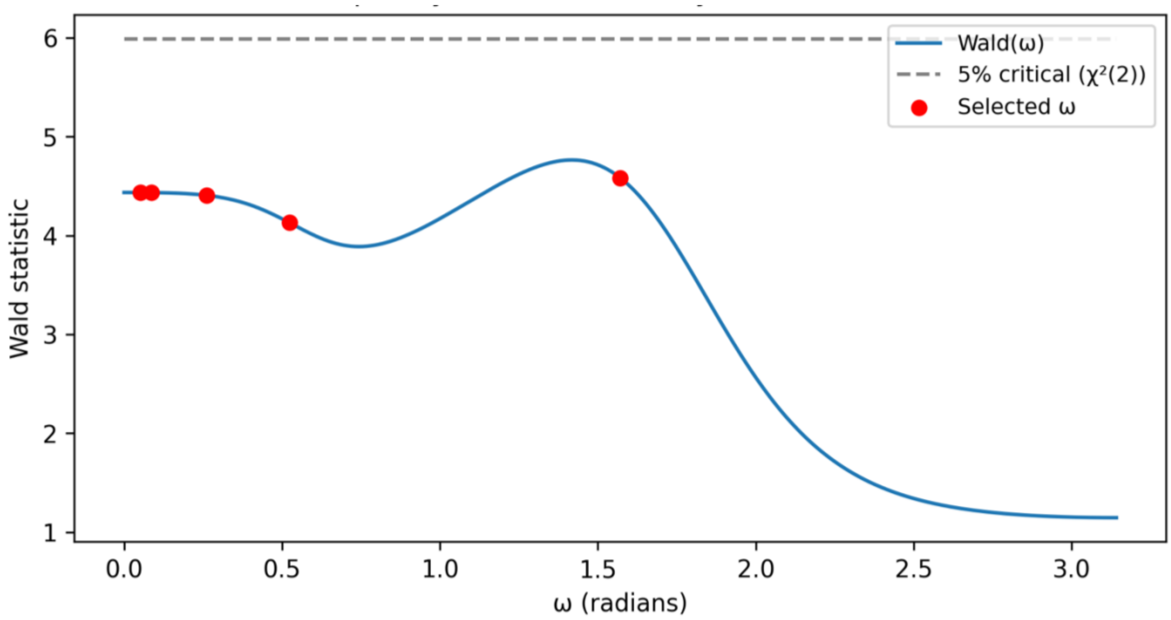

Figure 6. BC Frequency-Domain Causality: XAUUSD → XU100

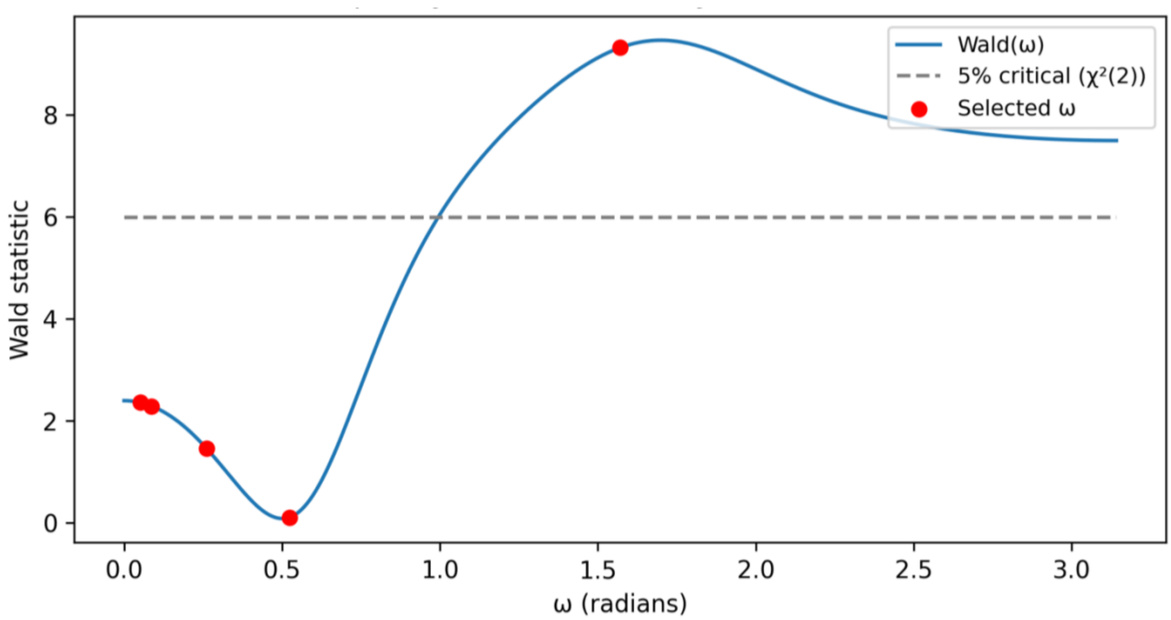

Figure 7. BC Frequency-Domain Causality: XU100 → XAUUSD

In general, the frequency domain BC test added detail to what had already been established using both TY tests and Granger tests, but did not establish any new direction. The overall pattern of causality was clearly established as follows: XAUUSD → USDTRY has been established to cause changes in currency prices at each of the horizons tested. Additionally, XU100 → USDTRY caused currency price movement only at short horizons. Finally, USDTRY → XAUUSD caused changes in gold prices at medium and longer horizons. The two remaining directions are nearly silent; in particular, USDTRY → XU100 shows at most weak evidence at the 4-day cycle; and, XU100 → XAUUSD is limited to the same very short cycle.

5.5. Cross-Method Synthesis

Bringing the three approaches together, as given in Table 8, provides a comprehensive, horizon-sensitive view of the interconnected dynamics among the equity market (XU100), exchange rate (USDTRY), and global gold prices (XAUUSD). The convergence of findings across methods reinforces the robustness of the results and highlights several consistent patterns.

Table 8. Summary of Causality Results Across Methods

Direction	TY	Granger	BC
XU100 → USDTRY	Strong causality	Strong causality	Strong causality at short horizons (4- and 12-day cycles)
USDTRY → XU100	No evidence of causality	No evidence of causality	No causality at medium or long horizons; weak evidence only at the 4-day cycle
XAUUSD → USDTRY	Strong causality	Strong causality	Causality across all horizons (marginal at the 12-day cycle)
USDTRY → XAUUSD	Moderate causality	Marginal causality	Moderate causality at medium and long horizons (12-, 24-, 72-, 120-day cycles)
XAUUSD → XU100	No evidence of causality	No evidence of causality	No evidence of causality at any horizon
XU100 → XAUUSD	Marginal causality	Moderate causality	Moderate causality at the shortest horizon (4-day cycle)

- **Equity - Currency: Horizon-Dependent Lead–Lag Dynamics**

The relationship between the equity market (XU100) and the exchange rate (USDTRY) is strong, asymmetric, and horizon-dependent. Across all three methods (TY, Granger, and BC), XU100 → USDTRY, consistently appears to dominate exchange rate dynamics. The TY analysis highlights a structural and long-lasting influence, while Granger results demonstrate immediate, short-run causality. The BC framework adds further granularity, showing that this impact is concentrated at short horizons, at the 4-day and 12-day cycles ($p \leq 0.01$). These findings together indicate that shocks in the equity market rapidly translate into exchange rate pressure, reflecting the lira's sensitivity to domestic capital market volatility. Such dynamics align with conditions involving swift investor sentiment shifts, rapid portfolio reallocations, and changes in liquidity and capital flows, positioning equity movements as a leading indicator of short-term currency stress.

The results of the study also show there was no indication of causality in the opposite direction for the USDTRY → XU100 model. As such, the TY and Granger tests indicated no evidence of causality, and the frequency-domain analysis provided further support for this asymmetry. Once the levels VAR was augmented with lags to account for nonstationarity, the exchange rates did not have any causal impact on equities at medium or long horizons. There were only some weak indications of a relationship at the shortest 4-day cycle. Therefore, it appears that the two markets are related in an asymmetric way based on this sample period. In the short term, equity shocks appear to influence the exchange rate, whereas depreciation does not systematically feed back into equity returns. A possible interpretation of this data is that the index's largest components have absorbed exchange rate fluctuations contemporaneously because they generate income and hold assets denominated in foreign currencies. As such, there may not be much lagged predictive content remaining after these equities have responded to the initial shock.

- **Gold - Currency: A Strong and Asymmetric Relationship**

Across the three methods, the XAUUSD - USDTRY relationship is the most consistent and stable nexus, although the direction and nature of influence vary. Regarding the XAUUSD → USDTRY channel, there is evidence of a strong and persistent causality in all three techniques in addition to the directional relationship. The TY analysis specifically illustrates how structural and lasting shocks to global gold prices are priced into the lira, indicating how vulnerable the currency is to external risk factors. The Granger results indicate that the shocks to global gold prices are incorporated into exchange rate movements quickly, thus highlighting how global investors and, to a lesser extent, local capital markets can efficiently integrate information from the gold market into currency valuations. The BC results show that this influence spans all horizons, from the 4-day to the 120-day cycle (at the 10 percent level at the 12-day cycle and at the 5 percent level or better elsewhere), demonstrating that gold acts both as a short-lived source of volatility and a long-term pressure force on the exchange rate. Therefore, this suggests that, in an economic sense, gold may act as a global risk and liquidity proxy for Türkiye, although the tests establish statistical precedence rather than the underlying economic mechanism. Fluctuations in international gold markets translate quickly and durably to the lira, which would enhance the sensitivity of the lira to changes in global risk appetite, monetary conditions, and flows into safe-haven assets.

Conversely, USDTRY → XAUUSD shows a weaker, yet meaningful relationship. The TY results reveal moderate feedback from sustained currency depreciation to gold, suggesting that a weaker lira raises domestic demand for gold as a hedge. The Granger analysis only captures small short-run effects, suggesting that shocks to the currency produce only small, short-term effects on global gold pricing. The BC analysis shows that this feedback is present at medium and long horizons (12-day through 120-day cycles, all at the 5 percent level) and absent at the very short 4-day cycle. This suggests that prolonged currency depreciation creates minor international pricing effects. However, as Turkish households and investors create demand for gold, they exert mild upward pressure on USD-quoted gold prices to a modest degree relative to broader international market pressures.

- **Gold - Equity: A One-Sided and Short-Lived Linkage**

There was no link shown in any of the TY, Granger, or BC tests for XAUUSD → XU100. As such, all three tests failed to reject non-causality at any horizon. Therefore, it appears that changes in gold prices do not have a direct effect on equity valuations in Türkiye. However, when gold price changes occur contemporaneously with changes in equity prices, then gold price information appears to reach domestic equity markets via the currency channel and not due to gold providing direct inputs into equity performance.

All three approaches agree that in the reverse direction, there is a causal relationship. Specifically, the TY method showed marginal causality ($p = 0.065$), the Granger method showed moderate short-run effects, and the BC method identified causality only at the very short 4-day cycle. Therefore, overall, it appears that domestic equity shocks can cause temporary portfolio reallocation toward gold as part of short-term hedging or rebalancing activities. It is also apparent that these effects dissipate rapidly and do not create any structural or persistent relationship.

Overall, the results provide strong evidence of a hierarchical structure of the factors driving Turkish financial markets and that this hierarchical structure exists regardless of the methodology used. Global gold prices (XAUUSD) are clearly the dominant and most persistent driver, leading the currency (USDTRY) across all horizons (from 4-day to 120-day cycles). Gold prices are therefore clearly the most relevant external variable for understanding exchange rate risk within this system. This finding is consistent with an interpretation of gold prices as representing a proxy for global risk sentiment and/or liquidity conditions. Domestic equity market shocks (XU100) serve as early warning signals primarily at short horizons where equity volatility is translated most rapidly into exchange rate pressures. Finally, channels of feedback are limited: currency affects gold at medium and long horizons; however, neither currency nor gold demonstrates a strong causal effect upon equities. Thus, the resulting system is highly asymmetric, whereby external forces flow into the system through the exchange rate, yet feedback onto external prices by domestic sources is relatively weak.

The results of this study align closely with prior evidence in the literature. The strong equity-to-currency linkage (XU100 → USDTRY) observed across methods is consistent with findings that Turkish equities often lead exchange-rate dynamics (Köse, Doğanay, & Karabacak, 2010; Köseoğlu & Çevik, 2013), and with time-varying, state-dependent BIST–FX interactions documented for Türkiye (Zeren & Koç, 2016; Yıldırım & Adalı, 2018; Kassouri & Altıntaş, 2020), in line with broader international evidence of two-way stock–FX feedback (Śmiech & Papież, 2013; Piccillo, 2008). The absence of a robust currency-to-equity channel is itself informative when set against this literature (Zeren & Koç, 2016; Baktemur, 2024): relationships that appear intermittently in regime-sensitive designs need not survive in a framework that treats nonstationarity conservatively. The pervasive influence of global gold prices on the exchange rate (XAUUSD → USDTRY) supports work on tight gold–FX linkages and non-linear interdependence (Güriş & Kıran, 2014; Beckmann, Czudaj, & Pilbeam, 2015; Pukthuanthong & Roll, 2011; Pata et al., 2024). The reverse channel (USDTRY → XAUUSD) aligns with Turkish evidence that currency shocks feed into domestic gold demand and pricing (Gülhan, 2020; Gök, 2020), and with studies finding long-run and stress-period sensitivity of gold to exchange-rate conditions (Cingöz & Kendirli, 2019; Tanin, Sarker, & Brooks, 2021). Finally, the short-horizon equity-to-gold effects (XU100 → XAUUSD) are consistent with Turkish evidence of equities leading gold or co-moving in ways dominated by the equity side (Ocaklı, 2020; Açıkalın & Başcı, 2016), whereas the absence of a direct gold-to-equity link

(XAUUSD → XU100) is consistent with the mixed and often insignificant results reported for Türkiye and emerging markets (Doğru & Uysal, 2015; İlarslan, 2017; Raza et al., 2016; Sandal, Çemrek, & Yıldız, 2017).

6. CONCLUSION

This research offers a multi-faceted, multi-horizon, and multi-method perspective on the interconnected dynamics of Türkiye's equity, currency, and gold markets. The evidence consistently suggests a hierarchy of causality: global gold prices are the most persistent source of predictive content for exchange rate movements; equity shocks serve as leading indicators of short-term FX pressures; and feedback from the currency onto equities is limited, so external forces dominate domestic feedback loops. This asymmetric yet interconnected system suggests that both domestic market behavior and external shocks are important to consider when assessing financial stability and preparing actionable responses. The combination of long-run structural aspects highlighted through the TY framework, short-run predictability from the Granger tests, and the temporal distinctions demonstrated using frequency-domain analysis provides a shared understanding of how shocks move through these markets in various time horizons. Causality is used throughout in its Granger sense of statistical precedence: the tests identify predictive ordering across horizons, not structural economic causation, and the interpretations above should be read with that qualification.

The findings of this study provide actionable strategies for policymakers and risk managers. Monitoring equity-market volatility and global gold price activity can inform tradable, forward-looking estimates of FX stress that can enable pre-emptive liquidity support, use of macroprudential policies, or inform the policy approaches to communication to stabilize expectations, especially before accumulating vulnerabilities. Institutional and retail investors and traders can apply the same rationale equally and can leverage this information to design better hedging and portfolio strategies. While a short-term trader may incorporate sudden currency movements driven by equity or gold prices into tactical decisions, long-term investors should note that the data provide no evidence of a delayed valuation drag from depreciation onto equities, so currency risk in Turkish equity positions is better treated as a direct translation exposure than as a predictable lagged fundamental. Additionally, as the framework discussed here implies, equity–gold linkages are primarily transitory. They are driven primarily by tactical decisions within asset allocation strategies rather than structural connections. While this nuanced perspective protects against relying excessively on gold as a hedge against a direct equity investment, it also encourages exploring strategies that allow for indirect currency channels.

At the central bank level, the results indicate a monitoring hierarchy. Gold consistently precedes lira pressure over all horizons. This implies that gold can be used as a prior source of information when determining the appropriate time for reserve action or intervention. Equity volatility is informative mainly over the next one to two weeks. Therefore, equity volatility should be used in the context of short-run liquidity planning. The lack of a statistically significant currency-to-equity transmission mechanism also indicates that exchange rate adjustments (regardless of their other costs) do not mechanically cause instability in the equity market at these horizons.

For portfolio managers, the message is horizon matching. There is very little rationale for hedging Turkish equities with gold since there are no causal links running from gold to equities at any horizon. Instead, the useful signal is the equity-to-currency channel that signals impending near-term lira pressure. Since there was no evidence of a lagged valuation effect due to depreciation in the data, currency hedging of Borsa İstanbul positions can be viewed simply as managing translation risk and not as attempting to predict some future lagged fundamental impact.

For international investors, the results break down country risk. Global risk-off events that drive up gold prices will pass into Turkish asset values primarily through the currency. Therefore, unhedged lira exposure is most exposed to global rather than domestic news.

For regulators and risk managers, the primary result is asymmetry. Stress scenarios based solely on domestic shocks tend to underestimate tail risk. Adding gold price paths to foreign exchange stress testing and using equity volatility as an early indicator of potential short-run currency limits would allow regulatory models to capture the transmission pattern documented here.

There are several limitations. The bivariate nature of the design does not allow us to differentiate between direct causality and indirect causality through an omitted third market. Interest rates, sovereign risk, and global volatility were inferred but not tested due to the limitation of only examining three variables. The findings also relate to the precedence of statistical relationships at specific frequency ranges but not to structural mechanisms. Finally, the VAR model assumed stability across different policy regimes within the time period examined (from 2015 to 2025). These boundaries motivate the extensions below.

In future work building on this framework, expanding the definition of 'external shocks' may be instructive. For example, global factors like oil prices, interest rate differentials, or global risk indices like the VIX could provide more dimensions to assess better the process of external shocks originating from various conditions affecting currency prices. Second, applying high-frequency intraday data might provide more detail on the connectedness of asset prices, particularly during periods of market stress. Third, exploring highly non-linear, regime-switching, or machine-learning-based causality models could help capture structural breaks and asymmetries, particularly during crises such as the COVID-19 pandemic or geopolitical shocks. Lastly, extending the study to other emerging markets may allow cross-country comparisons to determine whether the asymmetric relationships identified in Türkiye are unique to its financial system stressors or common in other economies with similar vulnerabilities.

DECLARATIONS

Generative Artificial Intelligence Statement: Generative artificial intelligence tools were used solely to support language editing and improve the clarity and readability of the manuscript. These tools were not used to generate research data, conduct statistical analyses, interpret the findings, or develop the scientific conclusions. The author critically reviewed and revised all AI-assisted content and takes full responsibility for the accuracy, integrity, and originality of the published work.

CRediT Authorship Contribution Statement: Ahmet Furkan Sak: Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing. The author read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Conflict of Interest Statement: The author declares that there is no financial, commercial, personal, or professional conflict of interest that could have influenced the research, analysis, interpretation, or publication of this study.

Data Availability Statement: The data used in this study were obtained from publicly available financial market sources. The compiled dataset and analysis files are available from the corresponding author upon reasonable request.

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Ethics Committee Approval: This study uses publicly available secondary financial market data and does not involve human participants; therefore, ethics committee approval was not required.

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APPENDIX

Table A1. Sensitivity of Granger Causality p-values to Lag Order (F test, log returns)

Direction	p = 1	p = 2	p = 3	p = 4	p = 5
XU100 → USDTRY	0.000***	0.000***	0.000***	0.000***	0.000***
USDTRY → XU100	0.407	0.377	0.378	0.157	0.251
XAUUSD → USDTRY	0.000***	0.000***	0.000***	0.001***	0.002***
USDTRY → XAUUSD	0.065*	0.127	0.074*	0.099*	0.161
XAUUSD → XU100	0.881	0.339	0.543	0.219	0.282
XU100 → XAUUSD	0.046**	0.036**	0.028**	0.038**	0.071*

Note: Column p = 4 corresponds to the main results in Table 6. The two strong channels are significant at the 1 percent level at every lag order, and the two non-significant channels are insignificant at every lag order. The two weak channels vary around conventional thresholds, consistent with the transitory character attributed to them in the text.

Table A2. Robustness of Causality Decisions to Alternative Inference Methods (p-values)

Direction	TY White	TY HAC	TY Bootstrap	Granger Asymptotic	Granger HAC	Granger Bootstrap
XU100 → USDTRY	0.000***	0.000***	0.001***	0.000***	0.000***	0.001***
USDTRY → XU100	0.281	0.259	0.468	0.157	0.224	0.472
XAUUSD → USDTRY	0.000***	0.001***	0.001***	0.001***	0.001***	0.001***
USDTRY → XAUUSD	0.028**	0.011**	0.023**	0.099*	0.011**	0.025**
XAUUSD → XU100	0.268	0.335	0.298	0.219	0.337	0.306
XU100 → XAUUSD	0.065*	0.072*	0.068*	0.038**	0.073*	0.076*

Note: HAC denotes Wald tests with Newey and West (1987) covariance (Bartlett kernel, 8 lags). Bootstrap denotes fixed-design wild bootstrap p-values with Rademacher weights and 1,999 replications (Gonçalves & Kilian, 2004). Granger tests use the fixed lag order p = 4; TY tests use p = 4 with dmax = 1 on log levels.