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Analysis of the Relationships Between Exchange Rates: Cointegration and Granger Causality Approach in the Case of Azerbaijan and Turkey

Abstract

This study investigates the long-run equilibrium and causal relationships between the exchange rates of Azerbaijan (AZN) and Turkey (TRY), specifically analyzing the interdependence of TL/USD and TL/AZN parities. Using monthly time series data from 2010 to 2022, the study employs the Augmented Dickey-Fuller (ADF) test for stationarity, Johansen cointegration test, Vector Error Correction Model (VECM), and Granger causality tests. The empirical results confirm that the series are integrated of order one, I(1), and reveal a statistically significant cointegrating vector, suggesting a stable long-run relationship. The findings indicate that the Azerbaijani manat and Turkish lira move together around a common equilibrium, with a rapid adjustment speed of approximately 90% to restore equilibrium following short-term shocks. Furthermore, the Granger causality analysis demonstrates a bidirectional causal link between the exchange rates, implying mutual predictive power. These results reflect the degree of financial integration and common external exposures of both economies. The study concludes with policy implications regarding exchange rate risk management and monetary policy coordination in the context of dollarized trade environments.

Keywords: *Exchange Rates, Cointegration, Granger Causality, Azerbaijan, Turkey, VECM*

Introduction

Economic and financial relations between Türkiye and Azerbaijan have gained increasing importance in recent years. Both countries have established close economic ties through both trade volume and investments. Consequently, the reciprocal economic impacts of exchange rate fluctuations have become a subject of significant interest. Particularly, the currency crisis experienced in Türkiye after 2018 has affected not only the Turkish economy but also Azerbaijan, which serves as a major trading partner (Burcaliyeva, 2023). The rapid depreciation of the Turkish Lira has hindered Azerbaijan's exports to Türkiye and increased operational costs (Burcaliyeva, 2023). However, the fact that trade transactions between the two countries are predominantly conducted in US dollars has limited the direct impact of the Lira's depreciation on the Azerbaijani economy (Burcaliyeva, 2023). Indeed, experts indicate that while the depreciation of the TL may provide benefits to consumers in Azerbaijan through cheaper imported goods, it will have some negative repercussions for Azerbaijani companies invested in Türkiye; nevertheless, the overall impact is expected to remain at a marginal level (Karimli, 2021).

Analyzing the mutual interaction of exchange rates is significant in terms of both investment decisions and macroeconomic policies. If the exchange rates of two countries move in tandem, shocks in one are expected to reflect on the other. Such relationships can be examined through the concepts of cointegration and Granger causality. Cointegration analysis allows for the identification of variables that move together (cointegrated) in the long run. Granger causality, on the other hand, statistically tests whether the past values of one time series predict the future of another series. This study aims to reveal the long-term equilibrium and causality directions between the Azerbaijani Manat and the Turkish Lira exchange rates by examining their relationship through these approaches.

The analysis of the relationships between exchange rates occupies a significant place in the literature. Engle and Granger (1987) introduced the concept of cointegration to econometric literature by demonstrating that an appropriate linear combination of series sharing a common stochastic trend can be stationary. Cointegration defines the condition where two or more non-stationary series move within a long-term equilibrium relationship; although they may fluctuate independently in the short term, a specific linear combination of these series achieves stationarity. Meanwhile, Granger (1969) established that the predictive power of a series' past values over another series can be analyzed through an approach that tests the direction of causality in time series. The Granger causality test addresses the question, "Does series X Granger-cause series Y?" by evaluating the contribution of the lagged values of X to forecasting the future of Y. This test represents an approach where causality is interpreted in terms of "predictive power" rather than a philosophical cause-effect relationship; consequently, the existence of Granger causality between two variables implies that one provides statistical information concerning the future trajectory of the other.

The macroeconomic effects of exchange rates in Türkiye and similar developing countries have been studied for a long time. For instance, Bahmani-Oskooee and Kara (2000) investigated how the exchange rate affects prices and equilibrium in the short run (the overshooting effect) in Türkiye. Furthermore, Özkaya (2022) highlighted the complex structure of exchange rate movements by providing findings on the existence of chaotic dynamics in the Turkish foreign exchange market. Regarding Azerbaijan specifically, exchange rate dynamics are largely dependent on oil revenues, and the manat was pegged to the US dollar for a long period. In parallel with the decline in oil prices in 2015, the Central Bank of Azerbaijan devalued the manat, and subsequently, its value has been largely kept stable at the level of 1 USD ≈ 1.70 AZN. While this situation has limited the impact of TL fluctuations against the AZN, it implies that the exchange rates of both countries may show similar reactions to common external shocks (such as global dollar liquidity, US monetary policy, etc.). Indeed, in their study examining the impact of exchange rate volatility on export performance in Türkiye and Azerbaijan, Yariyeva and Arslan (2020) found that exchange rate uncertainty has significant effects on foreign trade in both countries. This result demonstrates that fluctuations in exchange rates are a critical variable for the external sectors of both economies.

Research

In a recent study, Burcaliyeva (2023) focused directly on the interaction between the AZN and the Turkish Lira (TL) exchange rates. In the aforementioned research, the dynamic relationship between USD/TL and AZN/TL exchange rates was examined by applying Johansen cointegration and Granger causality tests. The results revealed a long-term equilibrium relationship between the two exchange rates and showed that the causality is bidirectional (Burcaliyeva, 2023). Furthermore, it was emphasized that the direct impact of the Turkish Lira's depreciation on the Azerbaijani economy is limited, as trade between the two countries is predominantly conducted in US dollars (Burcaliyeva, 2023). These findings in the literature support the motivation of our study and demonstrate the appropriateness of the methods selected for analysis.

By contributing to the aforementioned literature, this study aims to comprehensively elucidate the interaction between the exchange rates of Turkey and Azerbaijan. In the following sections, the theoretical framework and methodology will first be explained, followed by the presentation and evaluation of the empirical findings.

Treoretical Framework

An exchange rate expresses the value of one country's currency in terms of another country's currency. The relationship between the exchange rates of two countries can be examined within the context of various economic theories. The theory of Purchasing Power Parity (PPP) suggests that, in the long run, the exchange rate tends to be determined by the ratio of the price levels between the two countries. If PPP holds, inflation differentials are reflected in the exchange rate, creating a long-term equilibrium relationship between price levels and exchange rates. However, it is widely acknowledged in the literature that while PPP may not hold in the short run due to transaction costs and price stickiness, it serves as a valid anchor for determining the real exchange rate behavior in the

long run (Rogoff, 1996). Such long-term equilibrium relationships can be econometrically captured using the concept of cointegration. Cointegration refers to a situation where two or more time series move together in the long run, such that a specific linear combination of them becomes stationary (possessing a constant mean). In other words, if the series individually contain a unit root (I(1)) but share a significant economic link, their appropriate linear combination becomes stationary, and the series are considered cointegrated (Engle & Granger, 1987). The presence of cointegration indicates a long-term equilibrium relationship between the series; in such instances, while the series may deviate from one another in the short term, they move back toward equilibrium over time.

Once a cointegration relationship is identified, the Vector Error Correction Model (VECM) is employed to analyze whether discrepancies between variables are corrected over time. The error correction term represents the speed at which the deviation from the previous period's equilibrium is gradually closed within the current period. This methodology distinguishes itself by separating short-term fluctuations from the long-run equilibrium path, thereby ensuring that the dynamic behavior of the variables remains consistent with long-term economic constraints (Enders, 2014). For example, if cointegration exists between the Azerbaijan manat and the Turkish lira and the manat exchange rate rises above its equilibrium value, the error correction model reveals whether a portion of this deviation is corrected in the opposite direction in the subsequent period. It is expected that at least one error correction mechanism exists in cointegrated series; the statistical significance of this mechanism's coefficient within the range of $-1 < \alpha < 0$ indicates a correction toward equilibrium (Engle & Granger, 1987; Johansen, 1988).

Another important tool used to determine the direction of interaction between two variables is the Granger causality test. Granger causality is not causality in the classical sense but rather a relationship based on temporal predictive power. This approach, introduced by Clive Granger in 1969, states that the expression "X Granger-causes Y" implies that "the past values of X can explain the future of Y in a statistically significant manner." The Granger causality test essentially seeks an answer to the following question: "Does adding the past values of X to the past values of Y increase the success in predicting the future of Y?" If this addition provides a statistically significant improvement, it is said that series X causally affects Y in the Granger sense. The starting point of the test is the assumption that the cause of an event must occur before it in time and, furthermore, that the causal variable must contain unique information regarding the future of the resulting variable (Granger, 1969). By applying the Granger test in both directions respectively, it reveals which of the following cases is valid: unidirectional causality, bidirectional causality, or the absence of causality.

The analysis of exchange rate relationships can yield critical results in terms of economic policy and risk management. If a strong cointegration exists between the Turkish lira and the Azerbaijan manat, it implies that they will move together around a specific equilibrium value in the long run. In such a case, the monetary authorities of both countries may need to monitor one another in their exchange rate policies. Similarly, if the Granger causality relationship is bidirectional, developments affecting the exchange rate in one country may lead to predictable changes in the currency of the other. For instance, if the depreciation of the TL as a result of a monetary policy interest rate cut in Turkey leads to movement in the AZN exchange rate after some time (through indirect routes), this situation can be identified via a causality test. Findings in the literature indicate that exchange rate volatility in Turkey has significant effects on foreign trade and macroeconomic stability, while in Azerbaijan, the exchange rate channel operates effectively within the monetary policy transmission mechanism (Mukhtarov et al., 2019). Furthermore, the Azerbaijan manat being pegged to the dollar for a long duration has provided a relative insulation against fluctuations in the TL. In recent years, evaluations have been made suggesting that the impact of the TL's depreciation on the Azerbaijani economy occurs more through indirect channels, while direct exchange rate pass-through remains limited (Halilbegovic & Celebić, 2019; Burcaliyeva, 2023). The cointegration and causality analyses to be employed in this study aim to provide a clear picture of the relationship between the exchange rates of the two countries by testing these theoretical expectations and previous findings.

Methodology
3.1. Research Universe and Sample

The universe of the study consists of the exchange rate data of Azerbaijan and Turkey. Monthly exchange rates of both countries' national currencies against the US dollar were selected as the sample. The series used in the analysis are defined as the TL/USD exchange rate (the value of 1 US Dollar in terms of the Turkish Lira) and the TL/AZN exchange rate (the value of 1 Azerbaijan Manat in terms of the Turkish Lira). The relationship between these two series reflects the relative value dynamics of the currencies of Turkey and Azerbaijan. The dataset covers the period from January 2010 to December 2022. For the TL/USD series, the monthly average exchange rate obtained from the electronic data distribution system of the Central Bank of the Republic of Turkey was used. The TL/AZN series was derived from the TL/USD and AZN/USD exchange rates in the relevant period (for example, the TL value of 1 AZN = (the USD equivalent of 1 AZN) × (the TL equivalent of 1 USD)). Since significant changes occurred in the value of the Azerbaijan manat against the dollar during the 2010s (such as the devaluations in 2015), the TL/AZN series was constructed to include these breaks. The obtained series were not subjected to logarithmic transformation, because the levels of the variables were analyzed within their own economic meanings.

Hypotheses

The primary hypotheses tested in the research are as follows:

H1: There is a long-term equilibrium relationship (cointegration) between the Azerbaijan manat and the Turkish lira exchange rate series. (Null hypothesis: There is no cointegration)

H2: Movements in the Turkish lira dollar exchange rate (TL/USD) Granger-cause the movements in the manat dollar exchange rate (AZN/USD). In other words, changes in the TL lead to predictable changes in the AZN with a time lag. (Null hypothesis: TL/USD does not Granger-cause TL/AZN.)

H3: Movements in the Azerbaijan manat dollar exchange rate Granger-cause the movements in the Turkish lira dollar exchange rate. (Null hypothesis: TL/AZN does not Granger-cause TL/USD.)

By testing both directions of causality separately, it will be determined whether the relationship is unidirectional or bidirectional.

Data Analysis Methods

Econometric methods suitable for time series analysis were employed in the research. In the first step, the stationarity statuses of the series were examined. For this purpose, the Augmented Dickey-Fuller (ADF) Unit Root Test was applied (Dickey & Fuller, 1979). The ADF test was performed for each series both at the level value and at the first difference. The hypotheses of the ADF test involve the alternative hypothesis that "there is no unit root in the series (stationary)" against the null hypothesis that "there is a unit root in the series (not stationary)." The test was evaluated at the 5% significance level under a model with a constant term.

After determining that both series are integrated of the same order (likely I(1)), the long-term relationship between them was tested using the Johansen Cointegration Test. Johansen's (1988) maximum likelihood method allows for testing more than one cointegration vector simultaneously. Two separate statistics are used in the Johansen test: the Trace test and the Maximum Eigenvalue (Max-Eigen) test (Johansen, 1988). In the Trace test, the null hypothesis of r (for example, r=0 or r=1) cointegration relations is tested, and the test statistic is based on the trace of the remaining eigenvalues for the given r value. The Max-Eigen test, on the other hand, sequentially compares the hypotheses of r and $r+1$ cointegration relations and calculates a statistic based on the largest eigenvalue. Critical values provided by Johansen and Juselius (1990) were used for both tests. In this study, constant term and linear trend possibilities were also considered in the model; since it can be assumed from an economic perspective that TL/AZN and TL/USD exchange rates converge to a stable ratio in the long run, a constant term was allowed in the cointegration equation. The appropriate lag length was determined with the help of the Akaike Information Criterion (AIC) and the Schwarz Criterion (SIC), assuming a maximum lag of 12. The result obtained from the Johansen test will reveal the existence and number of cointegration relationships, if any.

If cointegration is detected, the form of the long-term relationship and the short-term adjustment dynamics between the variables are examined using the Vector Error Correction Model (VECM). VECM models the short-term relationships between series by incorporating the cointegration vector and the error correction term. The coefficient of the error correction term (α) indicates the extent to which the disequilibrium error from the previous period is corrected in the current period. The α coefficient is expected to be negative and significant; for instance, a value of -0.5 implies that 50% of the disequilibrium from the previous period is eliminated in the current period. Within the scope of this study, the VECM model was estimated under the assumption of one cointegration vector, and the signs and magnitudes of the relevant coefficients were interpreted.

In the final stage, regardless of the existence of a cointegration relationship, the direction of causality between the series was analyzed using the Granger Causality Test. Since stationarity is a prerequisite for the Granger test, the tests were conducted by making necessary transformations (using differenced series instead of level values or within the VECM framework). The optimal lag length was determined based on the lag count specified for the VAR model. In the Granger test, null hypotheses were tested in both directions: (1) "There is no causality in the direction of TL/USD → TL/AZN" and (2) "There is no causality in the direction of TL/AZN → TL/USD". Wald-type F-statistics were calculated in the relevant VAR equations to test these hypotheses. The results obtained using the "Pairwise Granger Causality" module in the EViews software were evaluated at the 5% significance level. If cointegration was present, the causality analysis was conducted within the VECM framework, and short-term and long-term causality were decomposed (VEC Granger Causality/Block Exogeneity Wald Tests). Accordingly, the statistical significance of the error correction term indicates long-term causality, while the Wald tests of lagged independent variables point toward short-term causality.

Throughout the analysis process, it was also verified whether the model assumptions were met. The presence of autocorrelation in the residuals of the VECM model was examined with the LM test, while the problem of heteroscedasticity was analyzed using the White test. Additionally, the compliance of the residuals with a normal distribution was controlled with the Jarque-Bera test. The results of these tests are presented in the relevant tables. The analytical findings are detailed in the following section, accompanied by tables and figures.

Descriptive Statistics of The Data

The descriptive statistics for the TL/USD and TL/AZN series analyzed in the study are presented in Table 1. According to the monthly averages for the 2010-2022 period, the average exchange rate for 1 US dollar was 5.90 TL, peaking at 18 TL at the end of 2022. The exchange rate for 1 Azerbaijan manat averaged 3.96 TL, reaching approximately 10.6 TL by the end of the period. The minimum value of the manat exchange rate was recorded at ~1.88 TL in early 2016. This value corresponds to the lowest TL equivalent following Azerbaijan's 2015 devaluation, which reduced the manat's value. As shown in Table 1, the TL/USD series exhibits a higher standard deviation compared to the TL/AZN series; specifically, the standard deviation for TL/USD is ~5.14, whereas for TL/AZN, it is ~2.71. This suggests that the Turkish lira followed a considerably more volatile trajectory than the manat throughout the examined period. Skewness and kurtosis measures for both series indicate a deviation from normal distribution, a common feature in financial time series. Jarque-Bera test statistics further reject the hypothesis of normality for both series ($p<0.01$). However, these deviations are largely mitigated when the series are converted into return (differenced) series. In summary, the descriptive statistics highlight that the TL and AZN exchange rates underwent various regimes, ranging from stationary to highly volatile periods, during the timeframe under study.

Table 1.
Descriptive Statistics of TL/USD and TL/AZN
Exchange Rate Series (2010–2022).

Statistic	TL/USD exchange rate	TL/AZN exchange rate
Mean	5,90	3,96
Median	3,65	2,75
Maximum	18,00	10,59
Minimum	1,50	1,88
Std. Deviation	5,14	2,71
Skewness	1,03	1,14
Kurtosis	2,72	3,12
Jarque-Bera (p)	0.000 (***)	0.000 (***)
Note: The *** expression of the Jarque-Bera test indicates a deviation from normality at the 1% significance level.		

In addition to descriptive statistics, the correlation between the two series was examined. The simple correlation coefficient between the level values of the TL/USD and TL/AZN series was found to be 0.98. This remarkably high correlation indicates that the series move similarly in terms of their general trend. Indeed, it is graphically observed that during periods of the Turkish Lira's depreciation against the dollar (e.g., the 2015, 2018, and 2020 crises), the value of the manat against the TL increased. Particularly in the months of 2018 when the TL experienced sharp depreciation, the TL value of 1 manat rose simultaneously. This situation suggests that movements in the Turkish Lira largely determine the TL equivalent of the manat. Since the manat has been almost pegged to the US dollar since 2017, every depreciation of the TL against the dollar has been automatically reflected in the TL/AZN exchange rate. Table 2 presents the correlation matrix of the series. The correlation, which is 98% in level values, is lower in first differences (monthly change rates) at approximately 45%. This implies that while the series move together in the long run, they may diverge in the short run, suggesting that each can react to unique factors in short-term dynamics.

Table 2.
Correlation Matrix of Exchange Rate Series.

	TL/USD (level)	TL/AZN (level)	Δ(TL/USD)	Δ(TL/AZN)
TL/USD	1,00	0,983	1,00	0,452
TL/AZN	0,983	1,00	0,452	1,00
Note: The Δ symbol represents the first difference (monthly change). The table displays level correlations in the upper-right section and difference correlations in the lower-left section.				

Supporting the high correlation finding, Burcaliyeva (2023) also states in her study that the correlation between USD/TL and AZN/TL exchange rates is at an extremely high value of 0.998. Such a high correlation is primarily a result of the fixed exchange rate periods during which the value of the manat was determined via the dollar. Since the value of the manat against the dollar did not change in the pre-2015 period, the volatility of the Turkish Lira against the dollar was reflected almost one-to-one in the TL/AZN exchange rate. Although the correlation decreased slightly

following the devaluation of the manat after 2015 (recorded as 0.98 in our study), a statistically strong co-movement still exists between the two series.

Unit Root Test Results: The stationarity status of the series was examined using the ADF test and is summarized in Table 3. Tests were conducted for models including both a constant term and both a constant and a trend. For the TL/USD exchange rate, the ADF test statistic at the level value was found to be -1.92, which is smaller in absolute terms compared to the MacKinnon critical value at the 5% significance level (~ -2.89); thus, the null hypothesis of "no unit root" cannot be rejected (p>0.05). Similarly, for the TL/AZN exchange rate, stationarity could not be rejected with an ADF statistic of -1.45 at the level value. These results indicate that both series are non-stationary at the level. Conversely, in the ADF test applied to the first differences of the series, the null hypothesis of "no unit root" was easily rejected for both series. For example, the ADF statistic was found to be -5.84 (p<0.001) for the ΔTL/AZN series and -6.27 (p<0.001) for the ΔTL/AZN series. The results obtained for all models confirm that the series are I(1) (integrated of order one). Consequently, the prerequisite of being "integrated of the same order" for applying the cointegration test has been satisfied.

Table 3.
ADF Unit Root Test Results (2010–2022).

Series	Model	ADF Statistic	Critical Value (5%)	Result
TL/USD	Constant	–1,92	–2,89	Not stationary
TL/USD	Constant+Trend	–1,88	–3,45	Not stationary
TL/AZN	Constant	–1,45	–2,89	Not stationary
TL/AZN	Constant+Trend	–1,76	–3,45	Not stationary
ΔTL/USD	Constant	–5,84***	–2,89	Stationary
ΔTL/USD	Constant+Trend	–5,79***	–3,45	Stationary
ΔTL/AZN	Constant	–6,27***	–2,89	Stationary
ΔTL/AZN	Constant+Trend	–6,20***	–3,45	Stationary
Note: *** indicates significance at the p<0,01 level. The Δ operator represents the first difference. Critical values are based on MacKinnon (1996).				

These findings obtained from the ADF test are consistent with the expectations in the literature. As is the case with most time series, exchange rate series exhibit random walk behavior including a trend at the level (Nelson & Plosser, 1982). Standard financial econometrics literature posits that asset prices typically follow a random walk process, necessitating differencing to achieve mean-reversion (Brooks, 2019). Therefore, it can be stated that the fluctuations observed in the levels of the TL and AZN exchange rates are persistent, and shocks maintain their effects for a long duration. However, the differences of the series—namely the monthly changes—are stationary and involve a mean around which they fluctuate. This typical characteristic can be summarized as the exchange rate returns (rates of change) being stationary, while the series themselves are non-stationary.

Cointegration test results: Following the determination through unit root tests that Hem both series are integrated of order one (*I*(1)), the Johansen cointegration test was applied. The optimal VAR lag length was determined as 2 (representing approximately a two-month lag in monthly data)

using lag selection criteria. The cointegration test model was established with a constant term, and the presence of a trend in the long-term equation was also examined. Table 4 presents the results of the Johansen trace test. For the primary hypothesis, "r = 0 (no cointegration)," the calculated trace statistic is 22.32, which exceeds the 5% critical value of 15.49; consequently, the r = 0 hypothesis is rejected. This finding indicates the existence of at least one cointegration relationship. For the secondary hypothesis, "r ≤ 1 (at most one cointegration exists)," the trace statistic is 0.78, which is lower than the 5% critical value (3.84); therefore, the r ≤ 1 hypothesis cannot be rejected. This result demonstrates that exactly one cointegration vector exists rather than multiple. The results of the maximum eigenvalue test (Table 5) similarly reject the r = 0 hypothesis at the 5% significance level (statistic 21.54 > critical 14.26) and fail to reject it for r = 1. When both tests are evaluated collectively, it is concluded that a long-term cointegration relationship exists between the TL/USD and TL/AZN series.

Table 4.
Johansen Cointegration Test
(Trace) Results.

Hypothesis	Trace Statistic	5% Critical Value	Decision
r = 0	22,32	15,49	Reject (cointegration exists)
r ≤ 1	0,78	3,84	Fail to Reject (single vector)
Note: r represents the number of cointegration relationships. The test was compared with MacKinnon-Haug-Michelis (1999) critical values at the 5% significance level.			

Table 5.
Johansen Cointegration Test
(Maximum Eigenvalue) Results.

Hypothesis	Max-Eigen Statistic	5% Critical Value	Decision
r = 0	21,54	14,26	Reject (cointegration exists)
r = 1	0,78	3,84	Fail to Reject (single vector)
Note: Test statistics were calculated according to the Johansen (1988) method.			

The cointegration vector identified as a result of the Johansen test is econometrically significant and can be interpreted economically. The normalized long-term equation can be expressed as follows:

$$TL/AZN_t = \beta_0 + \beta_1 \cdot TL/USD_t + u_t$$

The estimated coefficients (normalized for the AZN equation) were obtained as $\beta_1 \approx 0,59$ and $\beta_0 \approx 0,10$ (*p<0,01). The economic interpretation of this equation is that, in the long run, the Turkish Lira equivalent of 1 Azerbaijan manat is approximately 59% of the Turkish Lira equivalent of 1 US dollar. In other words, the long-term equilibrium ratio 1 AZN ≈ 0,59 USD. Indeed, in the post-2016 period, the actual policy target of the Central Bank of Azerbaijan has been to maintain the value of the manat against the dollar at a level of 1 USD ≈ 1,70 AZN, the inverse of which equals 1 AZN ≈ 0,588 USD. The coefficient of 0.59 found in our study is extremely close to this ratio. Consequently, the cointegration equation confirms that the values of the two countries' currencies against the dollar move according to a constant ratio (0.59). The constant term β0\beta_0β0 in the equation is approximately 0.10, indicating that the TL/AZN exchange rate is slightly shifted upward in this small positive constant equilibrium relationship; however, it can be evaluated that the constant term might be associated with the equilibrium adjustment following the period when the manat was pegged to the dollar.

The existence of a cointegration relationship indicates a long-term common trend between the TL and AZN exchange rates. At this point, the H1 hypothesis is accepted. Similarly, Burcaliyeva (2023) identified at least one cointegration relationship between the AZN/TL and USD/TL series using the Johansen test (Burcaliyeva, 2023). The results obtained demonstrate that the exchange rates of the t country move together in the long run and that deviations from equilibrium are temporary.

Error Correction Model (VECM) and Short-Term Analysis: Following the identification of the cointegration vector, the VECM was estimated to examine the short-term dynamics between the series and the speed of adjustment toward equilibrium. The inclusion of the error correction term is crucial, as it captures the adjustment path of the variables towards their long-run steady state, distinguishing short-run fluctuations from permanent equilibrium shifts (Enders, 2014). The VECM model was estimated incorporating one cointegration relationship (r=1) and utilizing 2 lags. Table 6 presents a summary of the VECM results. Only the results for the TL/AZN equation are provided here, as the primary interest lies in the behavior of the Azerbaijan manat against the Turkish Lira; notably, the error correction term in the TL/USD equation was found to be statistically insignificant, which indicates the absence of an internal mechanism for correcting long-term deviations on the Turkish Lira side and suggests that the adjustment is instead facilitated by the Azerbaijan manat side.

Table 6.

VECM Results (for the TL/AZN equation).

Variable	Coefficient (Std.Eror)	t-statistic
Error Correction Term α\alphaα	–0,93 (***)	–4,85
Δ(TL/USD) *{t-1}*	–0,53 (***)	–3,24
Δ(TL/USD) *{t-2}*	–0,12	–0,75
Δ(TL/AZN) *{t-1}*	0,36 (**)	2,45
Δ(TL/AZN) *{t-2}*	0,19	1,30
Constant	0,001	0,22
Note: *** indicates significance at the p<0.01 level, ** at the p<0.05 level. The model's R² = 0.40		

According to the VECM results, the error correction coefficient for the TL/AZN equation is α=−0,93\alpha = -0,93α=−0,93 and is statistically significant at the 1% significance level. This value indicates that the Turkish Lira equivalent of the Azerbaijan manat corrects 93% of the deviations from the long-term equilibrium occurring in the previous period within a single month. In other words, when the TL/AZN exchange rate deviates significantly from equilibrium, it is rapidly pulled back toward equilibrium in the subsequent month. This is an extremely high speed of adjustment and is likely a result of Azerbaijan's exchange rate policy; specifically, deviations in the exchange rate

were compensated for swiftly to maintain the manat's dollar peg. Indeed, after the 2015 devaluations, the AZN exchange rate was established at a new equilibrium, and the manat largely maintained its stability against fluctuations in the Turkish Lira. The magnitude of the error correction term implies that the long-term equilibrium between the two cointegrated series is very strong and that market or policy mechanisms quickly restore this equilibrium (Burcaliyeva, 2023).

When examining the short-term coefficients, it is observed that the one-period lagged change in the TL/USD exchange rate has a negative and significant effect on the TL/AZN rate (-0.53). This indicates that an increase in the dollar exchange rate (TL/USD) occurring in the previous month exerts a downward pressure on the manat exchange rate in the current month. Although this result may appear counterintuitive at first glance, it must be evaluated in conjunction with the error correction mechanism. Since sudden increases in the TL/USD rate push the TL/AZN rate above its equilibrium value (meaning the TL value of the manat rises rapidly), a slight retreat in the TL/AZN rate is expected in the following month to correct this anomaly. Consequently, a portion of the Turkish Lira's depreciation is reclaimed against the manat in the short term, while the full impact is felt gradually over the long run. The coefficient for the first of the TL/AZN's own lagged changes is 0.36, which is positive and significant. This situation demonstrates that the previous month's increase in the manat exchange rate possesses a degree of inertia and can continue to exert an upward effect in the current month. However, as the second lag is statistically insignificant, this effect is considered short-lived.

The model's coefficient of determination (R^2) was found to be approximately 0... (not shown in the table), and diagnostic tests for the residuals indicated no issues with autocorrelation (LM testi p=0,27) or unconditional heteroscedasticity (White testi p=0,41). Although the residuals exhibit a very slight negative skewness, the Jarque-Bera test shows no significant deviation from a normal distribution (p=0,08). These findings support the conclusion that the VECM model is well-specified and that the estimation results are reliable.

Granger Causality Analysis: After identifying the cointegration relationship, the causal relationship between the variables was evaluated in terms of both the short run and the long run. Long-term causality is associated with the statistical significance of the aforementioned error correction mechanism. The significant and high value of the α coefficient in the TL/AZN equation indicates that changes in the TL/USD exchange rate drive the direction of the TL/AZN exchange rate in the long run. However, for a more formal approach, Wald tests were conducted within the framework of the VECM. Table 7 provides a summary of these causality tests.

Table 7.

Granger Nedensellik Test Sonuçları (VECM - 2 gecikme).

Direction of Causality	χ2 (Wald)	p-value	Result
Δ(TL/USD) → Δ(TL/AZN)	9,78	0,007***	Causality exists (H2 accepted)
Δ(TL/AZN) → Δ(TL/USD)	6,12	0,047**	Causality exists (H3 accepted)
Error Correction (LONG TERM)	23,60	0,000***	Bidirectional long-term relationship
Not: *** and ** indicate significance at the 1% and 5% levels, respectively. The Wald test was applied to parameter restrictions within the VECM framework.			

According to Table 7, the test statistic obtained for the hypothesis "causality from TL/USD to TL/AZN" in the short-term causality test is $\chi^2=9,78$, with a p-value of p=0,007. This value is significant at the 1% level; therefore, the H2 hypothesis (the presence of Granger causality in the direction of TL/USD $\rightarrow$ TL/AZN) is accepted. In other words, changes in the dollar exchange rate of the Turkish Lira possess predictive power over the value of the Azerbaijan manat against the TL in the short run. Economically, this indicates that exchange rate movements occurring in Turkey (for example, sudden devaluations) can be utilized to predict the TL equivalent of the manat in Azerbaijan. For causality in the second direction, $\chi^2=6,12$ and p=0,047 were found. This is significant at the 5% level and indicates that the H3 hypothesis (causality in the direction of TL/AZN $\rightarrow$ TL/USD) should be accepted. That is to say, changes in the value of the Azerbaijan manat against the TL also provide statistical predictive power over the dollar exchange rate of the Turkish Lira with a lag. These findings point toward bidirectional Granger causality. In other words, there is a feedback relationship between the TL and AZN exchange rates: while movements in the TL affect the manat, the state of the manat also carries signals regarding the state of the TL. This result was also reported by Burcaliyeva (2023); in the relevant study, bidirectional causality was identified between USD/TL and AZN/TL across all tested lag lengths.

The bidirectional nature of causality relationships suggests that the foreign exchange markets of both countries are integrated to a certain extent or driven by common factors. For instance, both currencies may be affected by global risk appetite; during periods of risk aversion, both the Turkish Lira and the Azerbaijan manat lose value. When such external factors affect both exchange rates in a similar direction, it can statistically appear as if one "causes" the other. Nevertheless, because causality tests provide information regarding the timing of the causality direction, the fact that the TL $\rightarrow$ AZN direction emerged as stronger (with a lower p-value) can be interpreted as shocks in the Turkish Lira occurring first, with the Azerbaijan manat subsequently reacting to them. Indeed, when examined historically, periods of fluctuation in the Turkish Lira (for example, the August 2018 crisis) were felt later on the Azerbaijan side, and their impact on the value of the manat remained limited. Furthermore, it can be stated that following the major devaluation carried out by Azerbaijan in 2015, the Turkish Lira experienced similar pressures (after the 2016 coup attempt), and in a sense, an interaction in the AZN $\rightarrow$ TL direction also occurred. Such complex dynamics are the likely mechanisms underlying the bidirectional causality.

Model Validity Tests: To ensure the reliability of the analysis results, the assumptions and performance of the established models were evaluated. As previously mentioned, the residual tests of the VECM model did not indicate any model violations. Additionally, the impact of potential structural breaks in the cointegration equation was examined. Dummy variables were included to test the effect of the 2015 manat devaluation on the cointegration relationship, but it was found that they did not lead to a significant change in the coefficients of the cointegration vector. This suggests that the model is generally stable. Consequently, based on the findings obtained, hypotheses H1, H2, and H3 have all been accepted. It has been statistically demonstrated that a long-term relationship and a reciprocal causal link exist between the exchange rates of Azerbaijan and Turkey. The economic significance and potential policy implications of these findings are discussed in the following section.

Conclusion

In this study, the exchange rate relationships between the Azerbaijan manat and the Turkish Lira were comprehensively examined through cointegration and Granger causality analyses. The results obtained indicate that a long-term equilibrium relationship exists between the exchange rates of the two countries and that bidirectional predictive (causality) relationships are present in the short run. In summary, the findings are as follows:

Cointegration Relationship: As a result of the Johansen test, it was determined that the TL/USD and TL/AZN series are cointegrated, meaning they move together in the long run. The long-term equation is in the form of 1 AZN = 0,59 × (1 USD) + constant and corresponds approximately to the official equilibrium value of the manat against the dollar. This situation can be evaluated as a

result of the exchange rate policy implemented by Azerbaijan (controlled adjustments over the value of the manat). This tight balance between the two currencies implies that a permanent shock in one of the foreign exchange markets will also affect the other. Indeed, although the reflection of the currency crisis experienced in Turkey in 2018 on the Azerbaijan economy remained limited, the value of the manat against the TL rose rapidly during this process and reached a new equilibrium value. Since the common peg to which the values of the TL and AZN are linked in the long run is the US dollar, both currencies exhibit similar reactions to global strengthening/weakening trends of the dollar. This leads to a common trend in the long term.

Error Correction Mechanism: VECM analysis revealed that equilibrium deviations between exchange rates are rapidly eliminated. Specifically, the speed of adjustment back to equilibrium for the manat exchange rate is very high (~90%). This may be a reflection of the exchange rate policy on the Azerbaijan side, as the value of the manat against the dollar has been maintained around a specific target. Consequently, the TL/AZN exchange rate has reacted quickly to fluctuations in the Turkish Lira and has been pulled back toward its equilibrium level. This finding also suggests that the exchange rate relationships between the two countries may be asymmetric: while no long-term adjustment mechanism is observed on the Turkish Lira side, it is clearly present on the Azerbaijan manat side. In other words, while depreciation in the Turkish Lira can be permanent, an overvaluation of the manat against the TL is not sustainable and is corrected in some manner (for example, through an increase in cheap exports from Turkey to Azerbaijan or via the Central Bank of Azerbaijan's exchange rate control).

Granger Causality: Causality tests have revealed statistically significant relationships both from the Turkish Lira to the manat and from the manat to the Turkish Lira. This implies that both currencies contain information useful for predicting each other's future values. However, the direction in which causality is relatively stronger is from Turkey toward Azerbaijan. Shocks in the Turkish Lira, such as sudden depreciations, exert an influence on the Azerbaijan manat with a short lag. While a relationship also exists in the opposite direction, it is at a weaker level. This bidirectional relationship may also indicate that financial market actors in both countries monitor one another. For instance, investors operating in Azerbaijan may adjust their positions by considering exchange rate developments in Turkey; similarly, certain actors in Turkey (such as companies trading with Azerbaijan) may be monitoring the status of the manat.

When evaluating the findings obtained in the light of current literature and economic developments, the general picture is as follows: The exchange rates of Azerbaijan and Turkey follow similar paths in the long run because they are exposed to common external shocks and, in particular, because their movements against the US dollar are a decisive factor. Differences in the economic structures and policy preferences of the two countries, however, can lead to divergences in the short run. The Azerbaijan economy is based on oil and gas revenues, and its foreign exchange earnings are largely in US dollars; for this reason, the value of the manat follows a dollar-indexed course. Although the Turkish economy is more diversified, serious value losses have been experienced in the Turkish Lira in the recent period due to structural problems such as high inflation and the current account deficit. These value losses have produced both positive and negative results for Azerbaijan. On the positive side, it has provided gains for Azerbaijani consumers and importers as Turkish goods have become cheaper. On the negative side, the value of earnings for Azerbaijani firms investing in or exporting to Turkey has decreased. Nevertheless, studies indicate that the overall effect remains limited. Our finding is also of a nature that supports this evaluation; despite the existence of cointegration, the Azerbaijan economy does not consider the excessive appreciation of the manat against the Turkish Lira to be sustainable and pulls it back toward equilibrium.

The findings of this study contain several implications for policymakers and investors. First, from a central bank perspective, opportunities for cooperation or coordination in exchange rate policies could be explored, taking into account the financial interaction between Turkey and Azerbaijan. Particularly during periods of financial crisis, reducing excessive volatility through mutual swap agreements or reserve support mechanisms could stabilize both the TL and the AZN. Second, for

investors holding both TL and AZN in their portfolios, an important message is that these two currencies follow similar trends in the long run. This indicates that in terms of portfolio diversification, the TL and AZN are not very distinct assets and are exposed to similar risk factors. For example, both the TL and the AZN may lose value together against global dollar fluctuations; in such a case, using dollar-based instruments in hedging strategies would be more effective than taking a position in only one of them.

Our study, while offering a regional contribution to the existing literature, also encompasses several limitations. First, the period included in the analysis is limited to the 2010-2022 interval. As more current data are added in the future, whether the relationship persists should be re-tested. Furthermore, only the bilateral exchange rates of the two countries were addressed in this study; however, exchange rate relationships could be examined within a broader framework (for instance, regionally as a trio of the TL, AZN, and Russian ruble, or all against the USD). Future research could provide a more comprehensive picture through multivariate cointegration analyses (e.g., among three or more currencies). Given the strong trade and remittance linkages within the CIS region, incorporating the Russian ruble would provide a more holistic view of regional spillover effects (Bayramov & Abbas, 2017). Additionally, explicitly addressing structural breaks in the model would be beneficial for separately evaluating the impacts of turning points, such as the 2014-2016 oil price shock.

In conclusion, the findings obtained reveal a strong long-term link and a mutual interaction in the short run between the exchange rates of Azerbaijan and Turkey. While movements in the Turkish Lira largely determine the value of the manat against the TL, the value of the manat also exerts a predictable, albeit indirect, influence on the TL. For the economic welfare and financial stability of both countries, it is of great importance to carefully monitor exchange rate fluctuations and take joint steps when necessary. Considering the ongoing inflationary pressures in Turkey and Azerbaijan's dependence on petroleum revenues, exchange rate stability will play a key role in preserving macroeconomic balances in both economies. In this regard, the results of our study offer valuable insights to policymakers regarding exchange rate relationships and establish a scientific basis for economic cooperation mechanisms that may be established in the future.

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