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Linear and Nonlinear Relationship Between Real Exchange Rate, Real Interest Rate and Consumer Price Index: An Empirical Application for Countries with Different Levels of Development

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Abstract: The research population of this study consists of Australia, Azerbaijan, Egypt, Brazil, Chile, Canada, Hungary, Pakistan, India, Ukraine and the United Kingdom. For these countries; T, the relationship between Exchange Rate Index (exc), Real Interest Rate (int) and Consumer Price Index (cpi) variables were examined. Data from 2000Q1 to 2021Q3 were used in the study. The data are taken from the IMF's data bank. Analysis was done in R-Studio. Wo Seasonality Test, Augmented Dickey-Fuller Test, Linear Granger Causality Analysis and Nonlinear Granger Causality Analysis were used to investigate the relationship between variables. The theory claims that there is causality in both directions between exchange rate, interest rate and inflation. In the study, the relationship between these variables was investigated with linear and nonlinear causality tests. It is thought that the empirical results that contradict the theory are caused by the development levels of the countries, their macroeconomic structures, the applied fiscal and monetary policy instruments, the conjuncture and the analysis methods. The study aims to investigate these claims. For this reason, the development levels, sociocultural and socioeconomic structures of the selected countries were requested to be different. In addition, two different test methods, linear and non-linear, were preferred for the causality relationship. It was observed that the selected analysis methods significantly affected the results. Linear causality analysis results are closer to theoretical implications. However, the level of development of the countries does not have a significant effect on the relationship between the variables.

Keywords: linear and nonlinear Granger causality test; development levels of countries; time series analysis.

JEL classification: P33; P34; F37; F42.

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1. INTRODUCTION

Price inflation refers to the change in the prices of goods and services between two periods. In the literature, the variables that cause inflation are defined with different approaches. However, it is seen that the most influential variables are the exchange rate and interest rate (Turna & Özcan, 2021). On the other hand, in countries that implement a free exchange rate system, the nominal interest rate is very effective in the formation of the exchange rate.

The relationship between exchange rate, interest rate and price inflation is theoretically discussed with three different models.

The traditional model discusses the relationship between the interest rate and the exchange rate. According to the model, it says that in a market where deposits are given high-interest rates, the investor turns to the financial system. The theory argues that the expectation of profit due to higher interest rates will increase the value of the local currency and the value of the exchange rate will decrease. This situation continues until the interest rate reaches equilibrium (Sağlam & Yıldırım, 2007). The Interest Rate Parity Approach considers the interest rate as the dependent variable. The two-country model claims that the difference in domestic interest rates is due to spot and forward exchange rates (Keynes, 1923). The exchange rate difference between countries is balanced by the change in interest rates. The investor makes an investment decision in the direction of the country where the balance is disturbed. This trend continues until the exchange rate stabilizes in the spot market. In this way, both the exchange rate and the nominal interest rate are automatically balanced in a completely free market. If the interest rate in a country is above the market equilibrium, the investor invests in the local currency. In the opposite case, it invests in foreign currency. In the first case, the value of the domestic currency increases, in the second case the value of the domestic currency decreases (Sünbül, 2022).

The second model discusses the additional financing costs that businesses incur due to high-interest rates. High-interest rates negatively affect operating profitability and cash flow slows down. At the same time, high-interest rates increase the risk of bad credit. For this reason, the balance sheet balance of financial institutions may deteriorate. When a lower interest rate is applied, the exchange rate rises and the value of the local currency falls.

The third model discusses the impact of changes in exchange rates and interest rates on the prices of goods and services. It also examines the effects on the public debt stock. It is claimed that exchange rates and interest rates will increase the public debt stock and disrupt macroeconomic balances with high inflation. Therefore, high inflation and increased risk perception decrease the value of the local currency and increase the risk premium (Sağlam & Yıldırım, 2007).

As a result, the Interest Rate Parity Approach claims that there is an inverse relationship between the interest rate and the exchange rate (Keynes, 1923), and the Capital Market Approach (Frenkel, 1976; Bilson, 1978) claims that there is a relationship in the same direction between the interest rate and the exchange rate. The Money Supply Demand Equilibrium Approach; on the other hand, states that domestic prices must increase in order for the relationship between domestic goods and services prices and exchange rates to be in the same direction (Frenkel, 1976; Bilson, 1978).

Theoretical implications are self-consistent. However, empirical studies may differ according to theory. Sünbül (2021) attributes the differences between theory and empirical studies to the development levels of countries, their macroeconomic structures, the applied fiscal and monetary policy instruments, the conjuncture and the differences in analysis methods.

The aim of the study is to test the claim of Sünbül (2021). In this context, it was requested that the development levels, macroeconomic structures, cyclical structures, fiscal and monetary policy instruments of the countries in the study universe be different. In addition, two different research methods, linear and non-linear, were used to reveal the measurement differences arising from the methodology. As a result, the sample of the study consists of Exchange rate, Interest Rate and Inflation variables of Australia, Azerbaijan, Egypt, Brazil, Chile, Canada, Hungary, Pakistan, India, Ukraine and the United Kingdom, between 2000Q1 and 2021Q3.

Data were obtained from the IMF's website. Time series analysis methods were used to examine the relationships between variables. The "wo" Seasonality Test (Ollech & Webel, 2020) was used to analyze the seasonality of the data. Augmented Dickey-Fuller Test (Fuller, 1996) was conducted for stationarity research. Linear Granger Analysis (Granger, 1980) and Nonlinear Granger Causality Analysis (Baek & Brock, 1992; Hiemstra & Jones, 1994) were used to analyze the relationship between variables. Functions for seasonality analysis are available in the R-Studio "stats" and "seats" library. Functions for stationarity testing, linear causality analysis, and nonlinear causality analysis are in the "NlinTS" library.

2. LITERATURE REVIEW

Empirical studies have shown that the exchange rate expectation is more effective than the interest rate in investor decisions (Coleman, 2010; Vasilyev *et al.*, 2017). In addition, some studies have proven that the risk premiums and financial structures of countries are also effective in investor decisions (Bhatti, 2014). Vasilyev *et al.* (2017) attribute investment decisions to risk premiums. Bhatti (2014) found that the most effective investment decision factor in Commonwealth of Independent States member countries is arbitrage expectation.

Parveen *et al.* (2012) used the Least Squares Method (OLS) and Simple Linear Regression models in their study examining the factors affecting the exchange rate change with the annual data of Pakistan for the 1975-2010 period. They found that the most important variable affecting the exchange rate is inflation. Based on the results of the study, they suggested that first of all, fiscal policies should be aligned with monetary policy, and then both policies should be effectively associated with trade policy. Leigh and Rossi (2002) examined the permeability between price inflation and the exchange rate and found that the transition from the exchange rate to the price inflation takes 4 to 12 months. Kara and Ogunc (2005) saw a unidirectional causality between the variables in the floating exchange rate system, but they could not find any relationship in the fixed exchange rate system. Kayhan *et al.* (2013) examined the nonlinear relationship between real exchange rate and real interest rate in BRIC-T countries. They have not found a relationship between variables for China and India, but they have found a relationship between variables for Brazil and Russia. Öner (2018) investigated the effects of Consumer and Producer Price Indices on exchange rates using Granger Causality Analysis. He could not find a relationship between the variables. Yalcinkaya and Tunalı (2019) examined the causality between the USD/TL index and SWAP rates in the London market between 2017 and 2018 interest rates and USD/TL rate. They saw that the change in TL SWAP rate caused a bidirectional change in both the policy rate and the USD/TL rate. Cevher (2016) examined the relationship between deposit interest rate and exchange rate with the data of the 2010M8-2015M12 period. He found that there is Partial and Conditional Granger Causality in the same direction from exchange rate to deposit interest. Agenor *et al.* (1997) found that the real exchange rate has a significant effect on interest rates. Sekmen and Revanoğlı (2017) investigated the relationship between interest rate and exchange rate using Kazakhstan's data for the period 2005M05-2017M06. In the study, Johansen Cointegration Analysis was performed. They could not find any relationship between the variables. When they extended the analysis with VAR Causality and Unlimited VAR methods, they found a bidirectional causality relationship between the variables.

3. RESEARCH METHODOLOGY AND APPLICATION

In this study, R-Studio program was used for time series analysis. Seasonality and stationarity analyses of the series were performed for preliminary preparation. Then, linear and non-linear causality relationships between the variables providing the assumptions were examined.

There are 11 different countries in the study universe. It was requested that the economic development levels, socioeconomic and sociocultural structures of the countries within the scope of the application be different. These countries are Australia, Azerbaijan, Egypt, Brazil, Chile, Canada, Hungary, Pakistan, India, Ukraine and the United Kingdom.

Selected country datasets cover the period 2000Q1 to 2021Q3. The data were taken from the IMF data bank. Data used; Exchange Rates (Local Currency Per Dollar, End of Period, Exchange Rate), Interest Rate (Interest Rates, Lending Rate, Annual Percent), Inflation (Prices, Consumer Price Index, All Items, Index).

For the analysis of seasonality has been used “wo” tests (Ollech & Webel, 2020). For the analysis of stability investigation, Augmented Dickey-Fuller Test has been used (Fuller, 1996). And, for the analyses of causality Linear Granger Analysis (Granger, 1969) and Nonlinear Granger Analysis have been used (Baek & Brock, 1992; Hiemstra & Jones, 1994).

Functions for seasonality analysis are available in the R-Studio “stats” and “seats” library. Functions for stationarity analysis are “urca” library. And, function for linear causality analysis, and for nonlinear causality analysis are in the “NlinTS” library.

3.1 Data Review

Seasonality checks and seasonal decompositions were made for the preliminary evaluation of the time series. In addition, stationarity checks and difference-taking operations were performed.

3.1.1 Seasonality analysis

It is expected that the averages of non-seasonal time series will be close to 1. Seasonality is determined for periods deviating from the mean. In this study, the "wo" function in R-Studio was used for seasonality control (Ollech & Webel, 2020). Statistical results for seasonality analysis are presented in Table no. 1.

Table no. 1- Statistical results on seasonal analysis

WO Seasonality Analysis				
Country	**Variable**	**P-value**	**Test Statistic**	**Result**
Egypt	exc	1/ 1/ 0.6450	0	
	int	1/ 1/ 0.6450		
	cpi	3.1656/ 1/ 0.0868	0	
Azerbaijan	exc	1/ 1/ 0.8508	0	
	int	1/ 1/ 0.3328	0	
	cpi	2.2637/ 2.3422/ 2.1752	1	Seasonal
Brazil	exc	1/ 1/ 0.3807	0	
	int	1/ 1/ 0.0646	0	
	cpi	0.0319/ 0.2655/ 0.0009	1	Seasonal
Hungary	exc	1/ 1/ 0.5016	0	
	int	1/ 1/ 0.1093	0	
	cpi	1.2663/ 0.0001/ 2.6261	1	Seasonal
India	exc	1/ 1/ 0.1595	0	
	int	1/ 1/ 0.8368	0	
	cpi	9.8809/ 2.6068/ 4.8872	1	Seasonal
Ukraine	exc	0.0225/ 0.0216/ 0.0234	0	
	int	1/ 1/ 0.0823	0	
	cpi	0.0020/ 0.1907/ 5.3475	1	Seasonal
Australia	exc	1/ 1/ 0.5821	0	
	int	1/ 1/ 0.8255	0	
	cpi	0.7223/ 0.7146/ 0.1207	0	
Chile	exc	0.7973/ 0.6495/ 0.2770	0	
	int	1/ 1/ 0.5790	0	
	cpi	0.4849/ 0.1561/ 0.0024	0	
Canada	exc	1/ 1/ 0.3457	0	
	int	1/ 1/ 0.3420	0	
	cpi	0.0001/ 0.0027/ 9.7909	1	Seasonal
United Kingdom	ex	1/ 1/ 0.2951	0	
	in	1/ 1/ 0.9989	0	
	cp	5.4163/ 5.8193/ 5.3670	1	Seasonal
Pakistan	exc	1/ 1/ 0.4763	0	
	int	1/ 1/ 0.7311	0	
	cpi	0.0036/ 0.0071/ 0.0092	1	Seasonal

When Table no. 1 is examined, seasonality was determined in 8 out of 33 variables. Seasonal decomposition was made in these variables.

3.1.2 Stability analysis

Many tests have been developed to test stationarity in time series. ADF Test was preferred for this study. For the ADF Test, the command “ur.df” in the R-Studio “urca” library was used (Hamilton, 1994).

The equations used to test the stationarity are presented in: 3.1, 3.2, 3.3 (Fuller, 1996).

$$\Delta Yt = \gamma Yt\text{-}1 + \varepsilon t \text{ (for model without constant term and without trend)} \quad (3.1)$$
$$\Delta Yt = \beta 1 + \gamma Yt\text{-}1 + \varepsilon t \text{ (for constant term model)} \quad (3.2)$$
$$\Delta Yt = \beta 1 + \beta 2t + \gamma Yt\text{-}1 + \varepsilon t \text{ (for model with constant term and trend)} \quad (3.3)$$

For the test, first of all, unit root tests at I (0) level were performed. Stationarity tests were repeated first according to Equation 3.3, then according to Equation 3.2 and finally according to Equation 3.1. For the model that provides the stationarity assumptions, the stationarity of the series has been decided. Tests were repeated in I (1) for non-stationary series in I (0). The Akaike Information Criterion (AIC) was used to determine the lag length.

• The null hypothesis for unit root research (for ADF) is presented below;

H0= Series is not stationary, (F-p value <0.01, 0.05, 0.1 significance level),

• The null hypothesis for the validity of the model is presented below;

H0= Model significant, (Test statistic <significance levels).

Statistical results for stationarity control are presented in Table no. 2.

Table no 2 – Statistical results for stability control

Augmented Dickey-Fuller Test Unit Root Test				
Country	**Variable**	**Indicator**	**Statistic**	**Result**
Egypt	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.205 tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.01 *	I (1) Trend
		F- p-value:	0.0000	
		Test-statistic:	-4.68 tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.205 tau1 -2.6 -1.95 -1.61	
Azerbaijan	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.434 tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0019 **	I (1) Drift
		F- p-value:	0.000	
		Test-statistic:	-4.952 tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	<0.000	
		Test-statistic:	-8.022 tau1 -2.6 -1.95 -1.61	
Brazil	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-5.708 tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.039 *	I (1) Drift
		F- p-value:	0.0001	
		Test-statistic:	-4.706 tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0150 *	I (0) Trend

Augmented Dickey-Fuller Test Unit Root Test				
Country	**Variable**	**Indicator**	**Statistic**	**Result**
		F- p-value:	0.0000	
		Test-statistic:	-3.205 tau3 -4.04 -3.45 -3.15	
Hungary	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.367 tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0001 ***	I (1) Drift
		F- p-value:	0.0000	
		Test-statistic:	-4.901 tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.0047 **	I (0) Trend
		F- p-value:	0.0000	
		Test-statistic:	-3.213 tau3 -4.04 -3.45 -3.15	
India	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-5.538 tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0075 **	I (1) Trend
		F- p-value:	0.000	
		Test-statistic:	-5.123 tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.944 tau1 -2.6 -1.95 -1.61	
Ukraine	exc	Coefficients: Pr	0.052	I (1) Drift
		F- p-value:	0.000	
		Test-statistic:	-6.854 tau2 -3.51 -2.89 -2.58	
	cpi	Coefficients: Pr	0.032 *	I (1) Trend
		F- p-value:	0.0000	
		Test-statistic:	-4.85 tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0033 **	I (0) Drift
		F- p-value:	0.0010	
		Test-statistic:	-3.559 tau2 -3.51 -2.89 -2.58	
Australia	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-5.46 tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0000 ***	I (1) Drift
		F- p-value:	0.000	
		Test-statistic:	-6.795 tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.0274 *	I (0) Trend
		F- p-value:	0.000	
		Test-statistic:	-3.623 tau3 -4.04 -3.45 -3.15	

Augmented Dickey-Fuller Test Unit Root Test				
Country	**Variable**	**Indicator**	**Statistic**	**Result**
Chile	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-5.949	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0000 ***	I (0) Drift
		F- p-value:	0.0000	
		Test-statistic:	-5.659	
			tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.0194 *	I (0) Drift
		F- p-value:	0.0172	
		Test-statistic:	-2.877	
			tau2 -3.51 -2.89 -2.58	
Canada	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.000	
		Test-statistic:	-6.041	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0007 ***	I (0) Trend
		F- p-value:	0.0039	
		Test-statistic:	-3.615	
			tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0440 *	I (0) Trend
		F- p-value:	0.0000	
		Test-statistic:	-3.603	
			tau3 -4.04 -3.45 -3.15	
United Kingdom	exc	Coefficients: Pr	0.0000 ***	I (1) None
		F- p-value:	0.0000	
		Test-statistic:	-6.428	
			tau1 -2.6 -1.95 -1.61	
	cpi	Coefficients: Pr	0.0008 ***	I (1) Drift
		F- p-value:	0.0001	
		Test-statistic:	-4.06	
			tau2 -3.51 -2.89 -2.58	
	int	Coefficients: Pr	0.081 .	I (0) None
		F- p-value:	0.0000	
		Test-statistic:	-1.777	
			tau1 -2.6 -1.95 -1.61	
Pakistan	exc	Coefficients: Pr	0.076 .	I (1) Drift
		F- p-value:	0.0000	
		Test-statistic:	-4.355	
			tau2 -3.51 -2.89 -2.58	
	cpi	Coefficients: Pr	0.089 .	I (1) Trend
		F- p-value:	0.0000	
		Test-statistic:	-5.606	
			tau3 -4.04 -3.45 -3.15	
	int	Coefficients: Pr	0.0945 .	I (0) Trend
		F- p-value:	0.000	
		Test-statistic:	-3.275	
			tau3 -4.04 -3.45 -3.15	

When Table no. 2 is examined, it can be seen that the 10 series is stationary at the I (0) level, and the 23 series is stationary at the I (1) difference. Both linear and nonlinear causality research was conducted with stationary series.

3.2 Causality Analysis

In the literature, Granger Causality Analysis is mostly preferred in examining the relationship between time series. Granger (1980) uses the Least Squares estimator to analyze causality in time series and calculates the Minimum Mean Squares Estimated Error criterion to evaluate predictive power (Granger & Newbold, 1986). The prerequisite for the analysis is that the variables are stationary (Granger, 1980).

Granger Causality Analysis gives successful results both for I (0) stationary series and for series with I (1) level difference (Sünbül & Benli, 2021). However, Granger Causality Analyses developed for linear analysis are not suitable for detecting the presence of nonlinear causality (Brock, 1991).

Baek and Brock (1992) proposed a nonlinear statistical causality model. This proposed model is a different version of the Granger Causality model. Hiemstra and Jones (1994) and made new contributions to Baek and Brock's model.

Diks and Panchenko (2005, 2006) claimed that the model proposed by Hiemstra and Jones (1994) is not compatible with the Granger model. Therefore, they developed a new test that eliminated the problem. Bell *et al.* (1996), Su and White (2008, 2014) are other examples of nonlinear causality tests in the literature.

In this study, the model proposed by Granger (1980) for linear causality analysis and Hiemstra and Jones (1994) for nonlinear causality research was used.

In the Granger's Causality test, the result is obtained with the equality (X, Y).

$$Y = \sum_{i=1}^{m} \partial_i Y(t-i) + \sum_{j=1}^{m} \varphi_j X(t-j) + u(2t) \tag{3.4}$$

$$X = \sum_{i=1}^{m} \alpha_i Y(t-i) + \sum_{j=1}^{m} \beta_j X(t-j) + u(1t) \tag{3.5}$$

While the error terms u(1t) and u(2t) are considered independent of each other in the equations, m represents the lag length. Equation (3.4) investigates X to Y and Equation (3.5) Y to X causality. In Equation (3.4), the dependent variable is included in the model with the appropriate number of lags. Then the other variable is included in the model. Then the F statistic developed by Wald is calculated.

$$F_{(m,n-2m)} = \frac{ESSr - ESSur}{ESSur \; / \; (n-2m)} \tag{3.6}$$

Equation (3.6) is used to calculate the F statistic. In the equation;

- ESS: Error sum of squares,
- ur: Unlimited models
- r: Indicates the restricted model.

If the F statistic (m;n-2m) calculated at the α-result level in degrees of freedom is large, the null assumption is rejected (Granger, 1980).

Architecture for nonlinear causation (Artificial Neural Networks); The delay coefficient was determined as 2, the number of neurons in the first hidden layer was 2, the number of neurons in the second hidden layer was 4, the learning iteration was 50, the p-value was 0.05, and the learning algorithm was “stochastic gradient descent”. The "NlinTS package" library in R-Studio was used for the non-linear Granger Test.

The null hypothesis of Granger Causality Analysis;

H0= Independent variable is not the cause of the dependent variable. (Data 2 does not cause data 1).

The causality test statistics are presented in Table no. 3.

Table no 3 – Linear and nonlinear causality test statistics

Granger Causality Test					
Country	**Relationship**	**Linear Causality F-test. P-val.**	**None-linear Causality F-test. P-val.**	**Result**	
				Lineer	**None-lineer**
Egypt	from cpi to exc	0.7010	0.9520	H0 Accept	H0 Accept
	from int to exc	0.7217	0.9999	H0 Accept	H0 Accept
	from exc to cpi	0.0007	0.9999	H0 Red	H0 Accept
	from int to cpi	0.0007	1	H0 Red	H0 Accept
	from exc to int	0.8716	0.7919	H0 Accept	H0 Accept
	from cpi to int	0.7010	0.0223	H0 Accept	H0 Red
Azerbaijan	from cpi to exc	0.6257	0.5898	H0 Accept	H0 Accept
	from int to exc	0.3580	5,2534	H0 Accept	H0 Accept
	from exc to cpi	0,0989	0.9999	H0 Red	H0 Accept
	from int to cpi	0.0108	1	H0 Red	H0 Accept
	from exc to int	0.6606	1	H0 Accept	H0 Accept
	from cpi to int	0.7088	1	H0 Accept	H0 Accept
Brazil	from cpi to exc	0.8359	0.8896	H0 Accept	H0 Accept
	from int to exc	0.3421	1	H0 Accept	H0 Accept
	from exc to cpi	0.6546	1	H0 Accept	H0 Accept
	from int to cpi	0.0149	1	H0 Red	H0 Accept
	from exc to int	0.1911	1	H0 Accept	H0 Accept
	from cpi to int	0.1311	1	H0 Accept	H0 Accept
Hungary	from cpi to exc	0.9911	1	H0 Accept	H0 Accept
	from int to exc	0.4364	0.9999	H0 Accept	H0 Accept
	from exc to cpi	0.2750	1	H0 Accept	H0 Accept
	from int to cpi	0.0496	1	H0 Red	H0 Accept
	from exc to int	0.0332	1	H0 Red	H0 Accept
	from cpi to int	0.4851	0.9996	H0 Accept	H0 Accept
India	from cpi to exc	0.7528	1	H0 Accept	H0 Accept
	from int to exc	0.7493	0.9999	H0 Accept	H0 Accept
	from exc to cpi	0.6252	1	H0 Accept	H0 Accept
	from int to cpi	0.4820	1	H0 Accept	H0 Accept
	from exc to int	0.6640	1	H0 Accept	H0 Accept
	from cpi to int	0.4073	1	H0 Accept	H0 Accept
Ukraine	from cpi to exc	0.0982	1	H0 Red	H0 Accept
	from int to exc	0.5779	0.2892	H0 Accept	H0 Accept
	from exc to cpi	5,5664	0.0322	H0 Accept	H0 Red
	from int to cpi	0.3681	0.0983	H0 Accept	H0 Accept
	from exc to int	0.0163	0.9999	H0 Red	H0 Accept
	from cpi to int	0.6411	0.9999	H0 Accept	H0 Accept

Granger Causality Test					
Country	Relationship	Linear Causality F-test. P-val.	None-linear Causality F-test. P-val.	Result Lineer	None-lineer
Australia	from cpi to exc	0.0025	1	H0 Red	H0 Accept
	from int to exc	0.3580	1	H0 Accept	H0 Accept
	from exc to cpi	0,0989	0.9953	H0 Red	H0 Accept
	from int to cpi	0.0108	0.3953	H0 Red	H0 Accept
	from exc to int	0.6606	1	H0 Accept	H0 Accept
	from cpi to int	0.7088	1	H0 Accept	H0 Accept
Chile	from cpi to exc	0.1128	0.9999	H0 Accept	H0 Accept
	from int to exc	0.2070	1	H0 Accept	H0 Accept
	from exc to cpi	0.0916	0.9999	H0 Red	H0 Accept
	from int to cpi	0.0409	1	H0 Red	H0 Accept
	from exc to int	0.1157	1	H0 Accept	H0 Accept
	from cpi to int	0,0580	1	H0 Red	H0 Accept
Canada	from cpi to exc	0.0409	1	H0 Red	H0 Accept
	from int to exc	0.9999	1	H0 Accept	H0 Accept
	from exc to cpi	0.0711	1	H0 Red	H0 Accept
	from int to cpi	0.7129	1	H0 Accept	H0 Accept
	from exc to int	0.0003	1	H0 Red	H0 Accept
	from cpi to int	0.0396	1	H0 Red	H0 Accept
United Kingdom	from cpi to exc	0.0416	1	H0 Red	H0 Accept
	from int to exc	0.8716	1	H0 Accept	H0 Accept
	from exc to cpi	0.1276	0.9947	H0 Accept	H0 Accept
	from int to cpi	0.9605	1	H0 Accept	H0 Accept
	from exc to int	0,0005	1	H0 Red	H0 Accept
	from cpi to int	0.0003	1	H0 Red	H0 Accept
Pakistan	from cpi to exc	0.6703	0.9999	H0 Accept	H0 Accept
	from int to exc	0.0667	0.9475	H0 Red	H0 Accept
	from exc to cpi	0.0090	0.9999	H0 Red	H0 Accept
	from int to cpi	0.7815	0.9999	H0 Accept	H0 Accept
	from exc to int	0.3885	1	H0 Accept	H0 Accept
	from cpi to int	0.0007	1	H0 Red	H0 Accept

Table no. 3 shows the causality statistics between three different variables of 11 different countries. In the study, linear and nonlinear 66 + 66 tests of “exc ⇒ cpi”, “exc ⇒ int”, “cpi ⇒ int”, “cpi ⇒ exc”, “int ⇒ exc” and “int ⇒ cpi” tests were performed. According to linear causality statistics; There was a causality between the variables in 44 of the 66 tests. According to non-linear causality statistics; There was a causality between the variables in 2 of the 66 tests.

4. CONCLUSION

Theoretically, no causality is predicted between inflation to interest rate “cpi ⇒ int” and inflation to exchange rate “cpi ⇒ exc”. In the study, the causality between all these variables was investigated with linear and non-linear causality tests. The theory assumes causality in both directions between exchange rate, interest rate and inflation “exc ⇒ cpi, exc ⇒ int, int ⇒ exc, int ⇒ cpi, cpi ⇒ exc and, cpi ⇒ int”.

In this context, when the results of the analysis are examined in detail; There was causality between variables in 44 of 66 linear causality tests. These; For Egypt, cpi to cpi and int to cpi, cpi to cpi and int to cpi, for Azerbaijan, int to cpi, for Brazil, int to cpi, for Hungary, int to cpi and exc to int, for Ukraine, cpi to exc and exc to int, for Australia, cpi to exc, exc to cpi and int to cpi, for Chile, cpi to cpi, int to cpi and cpi to int, for Canada, cpi to exc, exc to cpi, exc to int and cpi to int, for UK, cpi to exc, exc to int and cpi to int and for Pakistan, int to exc, exc to cpi and cpi to int. Nonlinear causality was not found for India.

Two of the 66 nonlinear causality tests showed causality between variables. These; For Ukraine, exc to cpi and for Egypt, cpi to int. Except for these two, nonlinear causality was not found.

When the results of the study are compared with the literature; While there is no causal relationship from inflation to exchange rate for Pakistan, Parveen *et al.* (2012) have come to a different conclusion. While there is no causal relationship between real exchange rate and real interest rates for India, Kayhan *et al.* (2013) have reached different results for India and similar results for Brazil in their nonlinear causality analysis. From exchange rate to inflation, linear causality was found in six countries and non-linear causality in 10 countries. These results are similar to those of Leigh and Rossi (2002). Linear causality relationship between inflation and exchange rate was determined in seven countries and non-linear causality relationship was determined in 11 countries. These results are consistent with Öner (2018) study. Linear causality running from exchange rates to interest rates have found in four countries. These results are Cevher (2016), Agenor *et al.* (1997) is compatible with the study. However, the majority of the results obtained from the study are different from this study in the literature.

It can be said that linear causality tests are more successful when the theoretical inferences are assumed to be correct. In addition, no significant relationship was found between the factors such as the development levels, socioeconomic and sociocultural differences of the countries, and the causality relations of the variables.

Suggestions of researchers; Sünbül (2021) attributes the differences between theory and empirical studies to the development levels of countries, their macroeconomic structures, the applied fiscal and monetary policy instruments, the conjuncture, and the differences in analysis methods. This claim has been tested in research. In this context, it was requested that the development levels, macroeconomic structures, cyclical structures, and fiscal and monetary policy instruments of the countries in the study universe be different. In addition, two different research methods, linear and non-linear, were used to reveal the measurement differences arising from the methodology. Therefore, it is recommended that these differences be taken into account in future comparative analyzes and that the results be viewed critically.

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