İSTANBUL UNIVERSITY PRESS

EKOIST Journal of Econometrics and Statistics
EKOIST 2023, 39 : 65–75
DOI: 10.26650/ekoist.2023.39.1271842

RESEARCH ARTICLE

A Causal Relationship Among the Financial Indicators of Bitcoin, Gold, and VIX: An Empirical Analysis of the Fragile Five

Emin Karataş[1], Ayyüce Memiş Karataş[2]

[1](PhD Candidate), Ankara Yildirim Beyazit University, Institute of Social Sciences, Ankara, Türkiye
[2](Res. Asist. Dr.), Niğde Ömer Halisdemir University, Faculty of Economics and Administrative Sciences, Niğde, Türkiye

ABSTRACT
This research discusses the causal relationship among the exchange rates, 10-year bond yields, and Central Bank policy rates with regard to the countries known as the Fragile Five (F5) by comparing them to global indicators such as gold, Bitcoin price, and the Volatility Index (VIX). The study takes into consideration the bond yields, exchange rates, and interest rates of Türkiye, India, Indonesia, South Africa and Brazil in terms of their causal relationship with one another. The study also identifies some causal relationships among gold, bitcoin, and VIX with each other as global indicators by using the Toda Yamamoto approach to the Granger causality test. This study has arrived at the conclusion that a causal relationship exists between exchange rates and interest rates for Türkiye, Indonesia, and South Africa but not for Brazil or India. VIX is the most significant variable, as it is affected by seven different variables, including policy rates and different exchange rates. In addition, none of the variables are seen to Granger cause bitcoin's price.

Keywords: *Causality, Toda Yamamoto Analysis, Exchange Rate, Interest Rate, Bond Yield, VIX*

JEL Kodu / JEL Code: F30, F62, J52

Introduction

Morgan Stanley published an economic report in 2013 that looked at countries' current account deficits in relation to GDP rates. The majority of the countries were rated according to their sentimentality to capital inflows. In this report, Türkiye, Brazil, Indonesia, India and South Africa were mentioned as the Fragile Five (F5) because these countries are more dependent on foreign financing and foreign resources. As a result, their economies are greatly affected by global crises and global developments (Morgan Stanley, 2013).

The primary reasons for concentrating on the F5 are as follows. First of all, these countries have encountered more massive asset price drops than other emerging countries over the course of the recent strong rise in worldwide risk aversion. Secondly, these countries encountered notable capital inflows after the global financial crisis of 2008. Furthermore, a correlation and relationship are expected among these countries' long-term bond yields, currency rates, and interest rates. While the international capital influx is significant for emerging economies that rely heavily on foreign investment, investors' mitigation of associated risk is essential (Bayraktar et al., 2016), which is why this study has preferred to examine the countries of Brazil, Türkiye, Indonesia, South Africa, and India.

While a change in global indicators may affect these countries' economic indicators, so can a rise in fragility due to these countries' risk also affect their policy rates, exchange rates, and long-term interest rates. Many scholars have examined the connection country risk has with exchange and interest rates, and the research outcomes show a broad spectrum of diversity on account of the studied data frequencies, specific countries, different time periods, and utilized analysis method. Thus, interpreting and assessing the results several researchers have reported would be reasonable in light of their exceptional research conditions and aspects.

When considering this fact, few former studies are found to have tested the interrelationships among six different variables combined over the example of the F5 economies. Moreover, the reaction of short-term and long-term interest rates and exchange rates to internal as well as political and global economic advancements in the reporting countries seems to be more powerful in

Corresponding Author: Emin Karataş **E-mail:** 195205406@aybu.edu.tr

Submitted: 27.03.2023 • **Revision Requested:** 12.09.2023 • **Last Revision Received:** 18.09.2023 • **Accepted:** 21.09.2023

connection to other emerging countries. This case causes the F5 to be unprotected against rapid economic shocks. Exchange rate volatility and interest rate instability also make the subject more notable for all the analyzed countries (Şen et al., 2020).

As one of the variables this article investigates, gold is frequently regarded as a safe haven asset and diversification hedge against the supreme activity of stock indexes, especially in periods of political turmoil (Baur & Lucey, 2010). Akkoc and Civcir (2019) highlighted the demand for gold to also be higher in Türkiye, India, and other emerging economies. In most countries, gold is regarded as a safe haven asset in the face of that region's economic and political turmoil. Also, a strong relationship exists between exchange rates and gold prices, and any uncertainty regarding exchange rates could generate uncertainty around gold prices and vice versa (Sari et al., 2010). Additionally, stock market crashes around the world increases the actual demand for gold in fragile and emerging countries.

Another contribution of this article is the use of recent volatility indices presented by the Chicago Board Options Exchange (CBOE). The CBOE Volatility Index (VIX) is regarded as an uncertainty index that intends to measure the economic prospect of future volatility indicated by options pricing. VIX serves as a kind of key indicator for international investors, and VIX levels influence investor decisions. The volatility in the stock and bond markets is indeed a result of stock market uncertainty according to Chiang et al. (2015). Hence, gold, Bitcoin, VIX, and interest rates are linked to stock markets, particularly in countries that are dependent on foreign financing such as the F5, whose stock markets and exchange rates have rather high uncertainty and volatility.

The outstanding and rapid rise in Bitcoin's price has piqued the interest of many traders and investors, as well as researchers. Whether this cryptocurrency market behaves as another primary factor that affects the commodity and stock markets is worth investigating, especially in emerging economies. According to Bouri et al. (2017), Bitcoin is also a potential safe haven against the steep plunges in Asian stock movements. Gulec et al. (2018) noted a causal link to be present between interest rates and the price of Bitcoin alongside Bitcoin's rising trend with market volatility. Several analyses in the literature have suggested the price of Bitcoin to not only be affected by many variables such as VIX, interest rates, and exchange rates but to also be able to affect these variables. Examining such effects in fragile economies has emerged as another significant contribution this paper makes to the field.

The role of interest rates and exchange rates is another main concern that needs to be addressed when investigating any causal relationship among the variables. The perception of financial risk toward these economies would also increase as interest rates and currency rates start rising. In this manner, when interest rates and exchange rates change dramatically, the investors in these countries start to find alternative investment opportunities such as gold and Bitcoin. Thus, revealing the relationships among these countries' main indicators is important.

This paper aims to investigate the effects of certain global indicators such as gold and Bitcoin prices and VIX on the F5's government bond yields, interest rates, and foreign exchange rates (FX with local currency converted to USD) using the correlation matrix and the Toda-Yamamoto (1995) causality test over weekly data for the period of 1/1/2015–3/28/2021.

After the related research review discussed in Section 2, Section 3 will display the data construction and the methodology used to figure out the relationship among the variables. Sections 4 and 5 will respectively involve the empirical findings and conclusion.

Most causality studies in the literature include countries' relationships with stock exchanges, exchange rates, and global indicators. Few researchers have included the central bank policy rate and bond yields of the F5 in their studies. The fragility risks these countries have can be thought to be directly related to their policy rates and long-term interest rates (Şen et al., 2020). Additionally, by integrating more significant variables and offering more thorough research, this study seeks to resolve this deficiency in the literature. In this respect, the study aims to yield a current analytical view while contributing to the literature and drawing the interest of decision makers.

Literature

Previous studies have employed various sampling and analytical procedures to explore the causal relationship among countries' financial indicators. This section will first mention the empirical findings on bitcoin, gold, and global indicators, then discuss some studies on the F5 that had used similar variables as those conducted in this research.

Mensi et al. (2019) investigated the relationships among Middle East and North Africa (MENA) stock markets, gold, oil, VIX, and Bitcoin using a wavelet-based dependence-switching copula method, thus indicating a considerable tail dependence between the basic parameters and the MENA stock markets. Their findings suggested Bitcoin, gold, and VIX to be able to function as hedge assets long term. Korkmaz (2018) used the Toda-Yamamato causality test and the generalized supremum augmented Dickey-Fuller (GSADF) test for Türkiye between 2011-2018 and concluded returns for the dollar, gold, and the euro to affect bitcoin's returns. Koçoğlu et al. (2016) conducted the Johansen cointegration analysis and Pearson correlation matrix and were unable to find any significant relationship with Bitcoin or other currencies. Gulec et al. (2018) discovered a substantial correlation between interest rates and Bitcoin price using the Johansen cointegration analysis for the period of 2012-2018.

Korap (2008) investigated the exchange rate determinations between the Turkish Lira (TL) and USD using the cointegration approach. Korap used the variables of short-term interest rates, TL and USD conversion rates, M2 money supply, GDP, and one-year treasury rate for Türkiye and the USA between 1987-2006 and concluded the nominal exchange rate to be cointegrated with the other variables. Bilgehan (2018) identified the causal relationships between the E7 countries' stock markets using the Toda-Yamamoto causality test and stated causal relations to weaken as the distance between geographical regions increases. Ucan et al. (2014) explored the exchange rate determinations in F5 using the Johansen-Juselius cointegration analysis. Their results showed cointegration to occur between the money supply and exchange rate and between GDP and the short-term interest rate. Sen et al. (2020) applied the autoregressive distributed lag test for threshold cointegration method to explore the long-run interrelationships among the variables of exchange rates, interest rates, and inflation in fragile EMEs. They supported the existence of a cointegrating relationship between the exchange and interest rates for India, Türkiye, and Brazil but not for South Africa or Indonesia.

Using a structural vector autoregression model with daily data, Yildirim (2016) stated global economic risk shocks to have significant effects on credit default swap (CDS) spreads, equity prices, government bond yields, and exchange rates in the F5. Yildirim also reached the conclusion that global financial risks have a substantial impact on CDS markets and bonds issued in national currency than on foreign exchange markets. Akin and Isikli (2020) examined the relationship among currency rates, sovereign bonds, and sovereign credit risk premiums in the three F5 countries of South Africa, Türkiye and Brazil using the Johansen cointegration test. The authors reached the conclusion that these factors greatly influence one another in these three F5 countries. On the long run, the CDS market, interest rates, and local currencies of these countries had comparable behaviors.

Method

The data generated for this research article were gathered from the investing.com and stooq.com website databases for the period of 1/1/2015-3/28/2021. The weekly closing prices for each variable were converted to their natural logarithmic values for this study. While not the preferred approach for interest rates, the use of logarithmic transformations for interest rates and other variables has been studied in the literature. The method for using logarithmic transformations on interest rates is typically employed to achieve linearity, enable analysis of relative changes, and address issues related to heteroscedasticity. This article also aims to remove the scale effect between variables by taking the natural logarithm into account using the Toda-Yamamoto causality analysis method. Table 1 provides an overview of the variables.

Table 1. *Variable Overview*

#	Series Name	Variable	Description
1	GOLDUSD	lngoldusd	gold price (XAU/USD)
2	VIX	lnvix	CBOE Volatility Index
3	BTCUSD	lnbtcusd	Bitcoin's price (BTC/USD)
4	CBPOLID	lnCBPOLID	Central Bank Policy Rate (Indonesia)
5	CBPOLIN	lnCBPOLIN	Central Bank Policy Rate (India)
6	CBPOLTR	lnCBPOLTR	Central Bank Policy Rate (Türkiye)
7	CBPOLZA	lnCBPOLZA	Central Bank Policy Rate (S. Africa)
8	CBPOLBR	lnCBPOLBR	Central Bank Policy Rate (Brazil)
9	IDYBOND	lnidybond	10-Year Indonesia Bond Yield (10INY.B)
10	INDIABOND	lnindiabond	10-Year India Bond Yield (10INY.B)
11	TRYBOND	lntrybond	10-Year Türkiye Bond Yield (10TRY.B)
12	ZARBOND	lnzarbond	10-Year S. Africa Bond Yield (10ZAR.B)
13	BRAZILBOND	lnbrazilbond	10-Year Brazil Bond Yield (10BRY.B)
14	USDIDR	lnusdidr	Dollar / Indonesian Rupiah Exchange Rate
15	USDINR	lnusdinr	Dollar / Indian Rupee Exchange Rate
16	USDTRY	lnusdtry	Dollar / Turkish Lira Exchange Rate
17	USDZAR	lnusdzar	Dollar/ South African Rand Exchange Rate
18	USDBRL	lnusdbrl	Dollar / Brazilian Real Exchange Rate

The Toda-Yamamoto Approach to Granger Causality

Ordinary Granger causality tests for an unconstrained vector autoregression (VAR) relies on the presumption that principal variables are steady, namely I(0). The stability criterion of VAR is deemed to have been violated when the time series follow no stationary pattern. Cointegration ought to be identified when dealing with non-stationary time series; if cointegration is observed, then the vector error correction model (VECM) should be performed in place of the basic unconstrained VAR. If the series are found to not be integrated at the I(1) level or found to be integrated at different levels, a long-term interaction analysis can fail. Cointegration tests and unit root tests can also result in a loss of power in the series (Ghosh & Kanjilal, 2009).

Furthermore, the employment of difference values can lead to information loss. Toda and Yamamoto (1995) developed a procedure to remove the concerns monitored in the conventional Granger causality test. They employed the modified Wald (MWald) test to restrict the variables of the VAR model's lag length k variable to the components of the VAR (k) system. The unit root test is used to evaluate the variables' maximum integration level (d_{max}) in the Toda-Yamamoto approach (TY), and the optimal lag length for the VAR structure is then raised by d_{max}. Eventually, Granger causality investigation takes place in the VAR (k + d_{max}) concept, which ensures the asymptotic distribution of the modified Wald statistic even in the presence of cointegration. As Toda and Yamamoto stated, regardless of if a series is I(0), I(1), or I(2) or cointegrated at any order or not, the modified Wald statistic will remain valid.

As the TY technique only requires the VAR to be at level values, it does produces no loss risk in the information that could be experienced in the difference process. Hence, the TY procedure can be used as another long-term measurement. The TY approach to the Granger causality test involves the prediction of the subsequent models.

$$X_t = \alpha_\circ + \sum_{i=1}^{k+dmax} \alpha_2 X_{t-1} + \sum_{i=1}^{k+dmax} \alpha_3 Y_{t-i} + \eta_1 \tag{1}$$

$$Y_t = \beta_\circ + \sum_{i=1}^{k+dmax} \beta_2 Y_{t-1} + \sum_{i=1}^{k+dmax} \beta_3 X_{t-i} + \eta_2 \tag{2}$$

In these equations, X_t and Y_t symbolize the investigated variables. This model requires each variable to be regressed over one another using a set of lags ranging from 1 to k + d_{max}, where η_1 and η_2 state the error terms, k indicates the highest achievable quantity of lags, and d represents the integration degree of the variables (Bilgehan, 2018).

Having determined the maximal order of integration and the optimal lag length, a VAR model should be constructed with total of (k+d_{max}) lags in their levels. For the first equation involving X, Y does not Granger cause X if the parameter α_3 = 0 for i ≤ k. Similarly for the second equation involving Y, X does not Granger cause Y if the parameter $ß_3$ = 0 for i ≤ k.

The significance of the modified Wald statistics in both the hypotheses specify the rejection of the null hypothesis of non-Granger causality from Y to X or vice versa. This states the presence of Granger causality between the variables. Here, note that the additional lags (d) are not restricted. When conducting causality tests between integrated variables, Toda and Yamamoto (1995) asserted that their goal is to ensure that the asymptotical critical values can always be applied.

Unit Root Test

The degree of integration of the variables in the analysis is the initial issue that must be identified in a time series analysis. The augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) unit root test are used mostly for this aim. As said above, the TY causality test disregards whether the variables have a unit root. Indeed, the unit root test is utilized to identify the maximal stationary degree (stated as d_{max}). The ADF test statistic for a time series is represented by the following equation:

$$\Delta Y_t = \varepsilon + \delta Y_{t-1} + \Sigma_{j=1}^{d}(a_j \Delta Y_{t-j}) + \beta t + \omega_t \tag{3}$$

where ε is the equation's drift term, t indicates the time trend, and d is the longest possible lag. The above equation is employed to predict whether δ = 0 or not. Using δ's accurate estimation divided by the standard error, one can calculate the ADF test statistic. If the Fuller table's critical value is greater than the computed ADF statistic, then Y is considered to be integrated of order zero (i.e., stationary; Bahmani-Oskooee, 1993).

The unit root's **null hypothesis** can be expressed as H_0: δ =0 (the series features a unit root) while the alternative hypothesis is represented as H_1: δ ≠0 (the series is stationary). The standard unit root tests conducted by Dickey and Fuller (1979, 1981) and Phillips and Perron (1981) should not consider the influence of structural breaks in the time series. However, the majority of time series exhibit structural breaks, which weakens the credibility of the study results.

Zivot and Andrews (1992) later developed a unit root test permitting a single structural break that is defined internally. The Zivot-Andrews test can be used in order to consider the possible structural breaks in a selected series that may give biased results when traditional tests are applied. In the Zivot and Andrews test, structural breaks are properly considered with regard to intercept, trend, or both. Allowing for one structural break while evaluating the unit root hypothesis may prevent results from being biased in favor of a unit root, and this test may also specify the timing of the structural break.

Findings

This study, first found the correlation coefficients to measure the basic relationships among the variables. Table 2 shows the Pearson correlation matrix.

Table 2. *Pearson Correlation Matrix*

Pearson Correlation Matrix																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	GOLDUSD	1.00																	
2	VIX	0.52	1.00																
3	BTCUSD	0.71	0.21	1.00															
4	CBPOLID	-0.66	-0.12	-0.80	1.00														
5	CBPOLIN	**-0.94**	-0.49	-0.78	0.77	1.00													
6	CBPOLTR	0.20	0.09	0.55	-0.08	-0.20	1.00												
7	CBPOLZA	-0.78	-0.59	-0.41	0.41	0.78	-0.02	1.00											
8	CBPOLBR	**-0.90**	-0.51	**-0.86**	0.70	**0.91**	-0.43	0.78	1.00										
9	IDYBOND	-0.55	0.14	-0.56	0.71	0.50	0.08	0.26	0.46	1.00									
10	INDIABOND	**-0.81**	-0.32	-0.56	0.70	**0.85**	-0.02	0.59	0.66	0.53	1.00								
11	TRYBOND	0.30	0.17	0.72	-0.38	-0.40	**0.82**	-0.12	-0.57	0.03	-0.13	1.00							
12	ZARBOND	0.29	0.44	0.25	-0.33	-0.42	0.01	-0.22	-0.30	0.11	-0.33	0.29	1.00						
13	BRAZILBOND	**-0.82**	-0.28	**-0.81**	0.64	0.79	-0.46	0.44	**0.82**	0.52	0.73	-0.49	-0.12	1.00					
14	USDIDR	0.46	0.58	0.60	-0.33	-0.54	0.55	-0.39	-0.66	0.18	-0.26	0.77	0.56	-0.48	1.00				
15	USDINR	0.73	0.61	0.64	-0.44	-0.78	0.52	-0.56	-0.78	-0.02	-0.57	0.64	0.56	-0.68	0.79	1.00			
16	USDTRY	0.79	0.44	**0.88**	-0.64	**-0.84**	0.64	-0.56	**-0.92**	-0.28	-0.61	0.78	0.38	**-0.83**	0.79	**0.88**	1.00		
17	USDZAR	0.59	0.60	0.35	-0.25	-0.65	0.19	-0.47	-0.52	0.10	-0.55	0.37	0.74	-0.42	0.61	**0.82**	0.61	1.00	
18	USDBRL	0.79	0.68	0.62	-0.45	**-0.86**	0.34	-0.78	**-0.84**	-0.09	-0.61	0.51	0.54	-0.59	0.75	**0.89**	**0.83**	**0.81**	1.00

The pairwise correlation for the GOLDUSD and BTCUSD indices is practically high and positive. Furthermore, GOLDUSD and BTCUSD have a very high negative correlation with the Central Banks' policy rates except in Türkiye (CBPOLR). BTCUSD also has a strong positive correlation with the Turkish Lira (USDTR). GOLDUSD and BTCUSD can be said to have a positive correlation with the F5's exchange rates. These results suggest that Bitcoin and gold demand can be said to be higher in these fragile five countries due to the higher fragility of these countries' exchange rates.

The table also can show how Türkiye is negatively differentiated from the other F5 countries in terms of correlations regarding interest rate policy. In 2017, while other countries had made changes to their interest rates, the Central Bank of Türkiye kept its interest rate constant for a long time; later faced with the exchange rate crisis in 2018, Türkiye had to increase the interest rate considerably more than other countries. Due to inflationary pressures, a higher interest rate policy was followed in 2019 and 2020 compared to the other F5 countries. Therefore, Türkiye can be said to differ from other countries with regard to interest rate policy. However, these countries can be said to have a generally positive relationship with each other in terms of their currencies. For example, the Indian Rupee (USDINR) exhibits a strong positive correlation with the Turkish Lira (USDTRY, 0.88), the South African Rand (USDZAR, 0.82), the Brazilian Real (USDBRL, 0.89), and the Indonesian Rupiah (USDIDR, 0.79).

When considering the long-term bond yields, both gold and Bitcoin are seen to be negatively correlated with BRAZILBOND and INDIABOND while positively correlated with TRYBOND and ZARBOND.

Table 3 shows the ADF and PP test results. The ADF test results in this table indicate the first differences to appear to have been stationary and the majority of the series to include unit roots. While the lnzarbond, lnusdidr, and lnusdtry series are found to be I(0), namely stationary at level, the unit root is present in each of the other variables and thus are I(1). The Zivot-Andrews unit root test results are presented in Table 4.

According to the Zivot-Andrews test results for Model C (containing intercept and trend) at a significance level of $p < .05$, the level value for the lnvix, lnCBPOLZA and lnusdidr series does not contain a unit root due to the absolute value of the test statistic being greater than the critical value (5.08). These variables are said to be stationary at the level and thus are I(0). While taking the first differences of the other variables, they are seen to become stationary at both levels of significance. Therefore, these other variables are said to be I(1).

The results of the ADF and PP unit root tests, as well as the Zivot-Andrews unit root test which take into account structural

Table 3. *ADF and Phillips-Perron Unit Root Test Results*

	ADF Unit Root Test Results			Phillips-Perron Unit Root Test Results		
Variable	***p*-value at level**	***p*-value at first difference**	**Order of integration**	***p*-value at level**	***p*-value at first difference**	**Order of integration**
lngoldusd	0.4357	0.01	I(1)	0.8384	0	I(1)
lnvix	0.06871	0.01	I(1)	**0.0018**	0	**I(0)**
lnbtcusd	0.6477	0.01	I(1)	0.9582	0	I(1)
lnCBPOLID	0.828	0.01	I(1)	0.8404	0	I(1)
lnCBPOLIN	0.9565	0.01	I(1)	0.9618	0	I(1)
lnCBPOLTR	0.7222	0.01	I(1)	0.7472	0	I(1)
lnCBPOLZA	0.9156	0.01	I(1)	0.9925	0	I(1)
lnCBPOLBR	0.6188	0.04609	I(1)	0.9989	0	I(1)
lnidybond	0.2186	0.01	I(1)	0.1441	0	I(1)
lnindiabond	0.7146	0.01	I(1)	0.7048	0	I(1)
lntrybond	0.3682	0.01	I(1)	0.527	0	I(1)
lnzarbond	**0.01**	0.01	**I(0)**	**0.0035**	0	**I(0)**
lnbrazilbond	0.6233	0.01	I(1)	0.6408	0	I(1)
lnusdidr	**0.02444**	0.01	**I(0)**	0.0529	0	I(1)
lnusdinr	0.3646	0.01	I(1)	0.5886	0	I(1)
lnusdtry	**0.03135**	0.01	**I(0)**	0.88	0	I(1)
lnusdzar	0.3039	0.01	I(1)	0.1633	0	I(1)
Lnusdbrl	0.7098	0.01	I(1)	0.8275	0	I(1)
H_0: Unit root (individual unit root process) with 5% significance level.						

breaks enables one to determine most of the variables to be stationary at the first difference and their highest level of integration to be 1. Consequently, the VAR (k +d_{max}) model can measure the maximal degree of integration as d_{max} = 1.

Table 4. *Zivot-Andrews Unit Root Test Results*

Variable	**t-Statistic at level**	**Break Point**	**t-Statistic at first difference**	**Break Point**	**Order of integration**
Lngoldusd	-3.62	22.04.2018	-18.64	29.03.2020	I(1)
Lnvix	**-6.25**	23.02.2020	-15.44	5.04.2020	**I(0)**
Lnbtcusd	-2.67	5.08.2018	-19.95	24.12.2017	I(1)
lnCBPOLID	-4.53	10.06.2018	-5.38	10.06.2018	I(1)
lnCBPOLTR	-4.98	17.06.2018	-17.77	11.08.2019	I(1)
lnCBPOLZA	**-6.44**	5.04.2020	-9.7	5.04.2020	**I(0)**
lnCBPOLBR	-2.91	2.12.2018	-20.15	5.04.2020	I(1)
lnidybond	-4.05	22.04.2018	-17.99	12.04.2020	I(1)
lnindiabond	-3.87	10.09.2017	-17.2	12.04.2016	I(1)
Lntrybond	-3.66	6.05.2018	-11.2	19.05.2019	I(1)
lnzarbond	-4.87	19.01.2020	-20.66	12.04.2020	I(1)
lnbrazilbond	-3.33	19.05.2019	-19.22	22.03.2020	I(1)
Lnusdidr	**-5.36**	15.04.2018	-7.66	16.02.2020	**I(0)**
Lnusdinr	-3.06	29.01.2017	-17.2	14.01.2018	I(1)
Lnusdtry	-4.72	6.05.2018	-6.72	30.09.2018	I(1)
Lnusdzar	-3.65	1.03.2020	-18.81	24.01.2016	I(1)
Lnusdbrl	-3.7	28.02.2016	-17.23	10.07.2016	I(1)
H_0: Has a unit root with a structural break in both the intercept and trend					
*5% Critical Value = -5.08					

In order to apply the Toda-Yamamoto (T-Y) procedure, the maximal degree of integration was first determined as d_{max} = 1 after applying the unit root tests. Secondly, the 2-equation VAR model was set up to contain an intercept in each equation in the levels of the data. Next, the optimal lag length for the VAR (k + d_{max}) model can be evaluated in accordance with the different information criteria as shown in Table 5. However, after investigating the residuals and applying the Lagrange multiplier (LM) test for serial independence against the alternative of AR(k)/MA(k), for k = 1, ..., 12, a serial correlation problem appears.

Table 5. *Lag Order Selection Criteria*

Lag	LogL	LR	AIC	SC	HQ
0	7,001.345	NA	-44.4799	-44.26497	-44.39402
1	13,505.26	12,220.72	-83.84239	-79.75866*	-82.21061*
2	13,867.38	638.9088	-84.08523	-76.13269	-80.90754
3	14,198.2	545.7471	-84.12866	-72.30733	-79.40508
4	14,477.05	428.0363	-83.84105	-68.15092	-77.57156
5	14,803.63	463.8742	-83.85751	-64.29858	-76.04212
6	15,110.01	400.0564	-83.74531	-60.31758	-74.38402
7	15,416.99	365.6388	-83.63691	-56.34037	-72.72971
8	15,767.17	376.942	-83.80364	-52.6383	-71.35054
9	16,218.49	434.0714	-84.61459	-49.58045	-70.61559
10	16,699.88	407.8015*	-85.61707	-46.71413	-70.07217
11	17,160.61	337.4796	-86.48798	-43.71624	-69.39718
12	17,750.08	364.1944	-88.17887*	-41.53833	-69.54217
* indicates lag order selected by the criterion					

Table 6 shows that this serial correlation could be abolished (at least at the 5% level of significance) by increasing the maximum lag length to k = 11.

Table 6. *VAR Residual* Serial Correlation LM Tests

Lags	LM-Stat	Probability*	
1	576.6641	0	
2	463.4742	0	
3	391.6024	0.0059	
4	473.6594	0	
5	404.0489	0.0016	
6	453.1946	0	
7	392.2522	0.0056	
8	403.0982	0.0018	
9	412.5801	0.0006	
10	368.1532	0.0458	
11	**365.5343**	**0.0556**	k_{max} = 11
12	353.5896	0.1241	
H_0: no serial correlation at lag order h. *Probabilities from chi-square with 324 degrees of freedom.			

Figure 1 indicates the estimated model to also be dynamically stable, as any inverse root of the characteristic polynomial linked to the model is located exactly inside the unit circle. As a matter of fact, the VAR model is well specified.

Because d_{max} = 1, the VAR levels can be re-estimated with an additional lag for each variable in each equation. Rather than reporting the lag interval for all endogenous variables from 1-12 (d_{max} + k), the interval at 1-11 can be used, and the additional (i.e., 12th) lag of each variable can be reported as an exogenous variable. In this case, the parameters of such additional lags won't be implicated while dealing with the Wald tests. If the lag interval could be specified as being from 1-12, the coefficients for these twelve lags would later be implicated in the Wald tests, and that is incorrect. Due to the Wald test statistic appearing to lack its

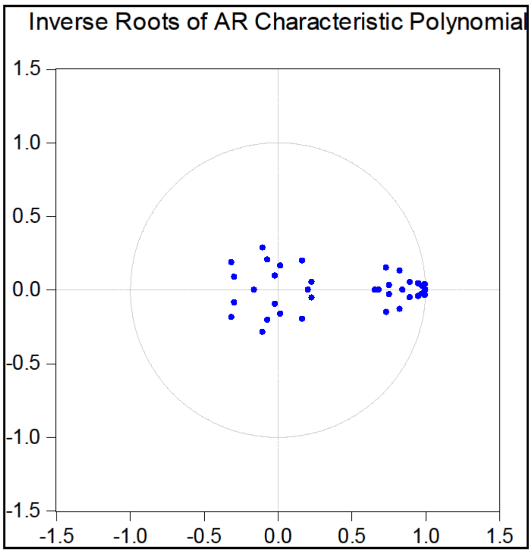

Figure 1. The inverse roots of the AR characteristic equation

ordinary asymptotic chi-square null distribution, all parts of the test have 11 degrees of freedom (i.e., k = 11). The additional 12th lag has not been counted in the tests (Giles, 2011). Ultimately, the Granger non-causality test was undertaken. The findings from the TY causality evaluation are presented in Table 7.

Table 7. *Summary of the Causality Test Results*

CBPOLID, CBPOLTR, CBPOLZA	=>	GOLDUSD
CBPOLID, CBPOLTR, CBPOLBR, BRAZILBOND, USDIDR, USDTRY, USDBRL	=>	VIX
VIX, CBPOLZA, TRYBOND, USDIDR, USDTRY	=>	CBPOLIN
CBPOLIN, INDIABOND, TRYBOND, BRAZILBOND, **USDTRY**	=>	CBPOLTR
TRYBOND, ZARBOND, BRAZILBOND, USDTRY, USDZAR	=>	CBPOLZA
CBPOLZA	=>	CBPOLBR
VIX, BTCUSD, CBPOLZA, **TRYBOND**, BRAZILBOND, USDIDR, USDINR, USDTRY, USDBRL	=>	IDYBOND
GOLDUSD, **IDYBOND**, INDIABOND, USDIDR	=>	TRYBOND
USDIDR	=>	ZARBOND
CBPOLID, CBPOLIN, CBPOLZA, CBPOLBR, TRYBOND, USDINR	=>	BRAZILBOND
GOLDUSD,	=>	USDIDR
VIX, USDIDR, USDZAR	=>	USDINR
CBPOLTR	=>	USDTRY
ZARBOND, USDIDR	=>	USDZAR
Note: => shows causality relationship at the 5% significance level.		

None of the variables were found to Granger cause BTCUSD at the 5% level. Only CBPOLTR was found to Granger cause BTCUSD at the 10% level. This result confirms some previous similar studies about Bitcoin. Al-Khazali et al. (2018) discussed Bitcoin as not being strongly interrelated to macro-developments due to Bitcoin returns' low predictability and higher volatility after macroeconomic shocks. According to their study, cryptocurrencies behave more like a risky asset than a safe haven investment tool. For Türkiye, however, Bitcoin may act more as a safe haven asset against interest rates. According to Taskinsoy's (2019) study, cryptocurrencies are known for their highly volatile nature. However, the significant depreciation of the Turkish lira by 87% against the dollar between January 1 and August 2018 surpassed even the most erratic volatilities observed in cryptocurrencies. This situation led to the perception that Bitcoin could be considered a safe haven asset and an effective hedge against exchange rate shocks.

The authors of another research study (Stensås et al., 2019) indicated Bitcoin to act as a hedge for investors in the majority of developing nations. In developed nations and for those investing in commodities, however, Bitcoin served primarily as a diversification tool rather than a hedging instrument.

In addition, none of the variables Granger cause CBPOLID, INDIABOND, or USDBRL at the 5% level. According to Table 7, the central bank policy rates of Indonesia, Türkiye, and South Africa (CBPOLID, CBPOLTR, CBPOLZA) can be said to have an effect on gold prices, although not as much as other global factors. This result parallels those from previous studies suggesting that many financial indicators may exist that determine gold prices, such as interest rates, inflation rates, and the prices of other securities (Ghosh et al., 2004). Investors usually believe that low interest rates cause higher gold prices, because treasury debt loses its advantage over precious metals like gold as an investment when interest rates are quite low, and a higher interest in gold can be seen, which drives prices higher. This article also shows that this condition is true for three countries. This negative relationship is similar to the results found from the correlation matrix in Table 2 except for Türkiye.

A bilateral relationship was also statistically determined to exist between IDYBOND and TRYBOND. In addition, a bilateral relationship was confirmed between the Turkish Lira (USDTRY) and interest rates in Türkiye (CBPOLTR). In the short run, the volatility of USDTRY affects the short-term interest rate of three countries (CBPOLTR, CBPOLIN, CBPOLZA).

INDIABOND, TRYBOND, and BRAZILBOND affect CBPOLTR, while TRYBOND, ZARBOND, and BRAZILBOND affect CBPOLZA. South Africa's interest rate (CBPOLZA) affects the interest rate of India (CBPOLIN) and Brazil (CBPOLBR); it also influences Indonesia's 10-year bond yield as a long-term interest rate (IDYBOND), as well as Brazil's long-term interest rate (BRAZILBOND). Thus, a bilateral causal relationship exists between BRAZILBOND and CBPOLZA.

Conclusion

A major issue that one must address when investigating the causal relationships among variables is the role of interest and exchange rates. As interest and exchange rates rise, so does the perception of financial risk in emerging markets. As a result, when interest rates and exchange rates change significantly, investors in these countries initiate looking for alternative market opportunities such as gold and Bitcoin. As an outcome, uncovering the relationships between such countries' leading factors is crucial.

As a consequence of this study, some applicable knowledge has been acquired for financiers who want to take advantage of investment opportunities and apply arbitrage transactions between international exchanges. A bilateral relationship was statistically determined to exist between IDYBOND and TRYBOND, between BRAZILBOND and CBPOLZA, and between the Turkish Lira (USDTRY) and Türkiye's interest rate (CBPOLTR). The change in price and volatility of the Turkish lira strongly depends on the Central Bank of the Republic of Türkiye's interest rate decisions. A positive relation was also found to exist between USDTRY and CBPOLTR based on the correlation matrix, contrary to real expectations. However, this result is similar to those in previous studies in the short-run. Namely, Durmus' (2016) study carried out in Türkiye determined a unidirectional causality interrelation between the foreign exchange rate and interest rates. Similarly, Ucan et al. (2014) demonstrated the presence in fragile emerging economies of cointegration between the money supply and the exchange rate, as well as with the short-term interest rate.

VIX is the most significant variable to be affected by seven different variables such as policy rates and different exchange rates while affecting CBPOLIN, IDYBOND, and USDINR. Given the period, USDIDR (Indonesian Rupiah) is the variable with the most effect over the other seven variables while being influenced by only the gold price.

When comparing the exchange rates of the fragile five countries, USDZAR and USDIDR affect only USDINR, while USDIDR affects USDZAR. What's more, not much of a causal relationship was found between the different exchange rates, hence some arbitrage conditions can be found among the five countries' exchange rates. One significant implication of this finding is that opportunities may exist for arbitrage regarding the Turkish Lira and certain currency pairs, indicating potential inefficiencies in the foreign exchange market. This highlights the distinct characteristics and dynamics of Türkiye's exchange rate compared with other F5 countries. Further research and analysis will be needed to understand the specific factors contributing to this divergence and its implications for fragile economies. When looking at the long-term bond yields, a bilateral relationship exists between TRYBOND and IDYBOND, while only a one-way causal relationship could be seen between BRAZILBOND and IDYBOND. In addition, TRYBOND is influenced by INDIABOND while also influencing BRAZILBOND. No causal relationship was found between ZARBOND (S. Africa Bond Yield) and the other countries' bond yields.

As a result of this study, these causal relationships appear to decline as the geographical distance between countries rises. According to this viewpoint, the causality relationship between India and Türkiye is the strongest, whereas the causality relationship between Brazil and Indonesia is the weakest.

Another concluding remark concerns the connection between currency exchange rates and interest rates. Because the F5 are particularly import-dependent countries, their interest rates are influenced by exchange rates. The findings above support the existence of a causal relationship between interest rates and exchange rates for Türkiye, Indonesia, and South Africa but not for Brazil and India. The findings here are fairly consistent with both conceptual beliefs and the relevant empirical literary works.

In line with Akin and Isikli (2020), this study's findings also indicate the investigated variables of the F5 to be substantially influenced by one another. Essential economic policies should be developed to ensure the permanent stability of exchange rates and interest rate indicators in these countries. To attract foreign investments and lessen the perception of risky countries, F5 countries should also reduce their long-term interest rates gradually while simultaneously ensuring stability with their currencies.

The results from this research have some similarities and differences with regard to the types of relationships in the prior studies carried out by Bilgehan (2018) and Şen et al. (2020). Their findings supported the presence of a cointegrating relationship between interest rates and exchange rates for the case of Brazil, India, and Türkiye but not for Indonesia and South Africa. The underlying cause of the differences could be the influence of time series that involve different periods of time, as well as the various index types that were used for the observations and the different methodologies that were applied. Forthcoming research articles may provide more consistent conclusions for policy makers by testing the results of this research with distinct approaches and by also extending the study with investigations into short- and long-term relations using distinct methods.

Peer Review: Externally peer-reviewed.

Conflict of Interest: The authors have no conflict of interest to declare.

Grant Support: The authors declared that this study has received no financial support.

Author Contributions: Conception/Design of study: E.K., A.M.K.; Data Acquisition: A.M.K.; Data Analysis/Interpretation: E.K.; Drafting Manuscript: E.K., A.M.K.; Critical Revision of Manuscript: E.K., A.M.K.; Final Approval and Accountability: E.K., A.M.K.

ORCID:

Emin Karataş 0000-0001-7715-6001
Ayyüce Memiş Karataş 0000-0002-3429-5666

REFERENCES

Akin, T., & Isikli, E. (2020). The relationship among sovereign credit risk premium, sovereign bonds and currency rates in fragile three countries. *Journal of Business Economics and Finance, 9*(3), 262-273.

Akkoc, U., & Civcir, I. (2019). Dynamic linkages between strategic commodities and stock market in Turkey: Evidence from SVAR-DCC-GARCH model. *Resources Policy*, 62, 231-239.

Al-Khazali, O., Elie, B., & Roubaud, D. (2018). The impact of positive and negative macroeconomic news surprises: Gold versus Bitcoin. Economics Bulletin, 38(1), 373-382.

Bahmani-Oskooee, M. (1993). Black market exchange rates versus official exchange rates in testing purchasing power parity: an examination of the Iranianrial. *Applied Economics, 25*(4), 465-472.

Baur, D.G., Lucey, B.M., 2010. Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold. Financial Review 45, 217–229.

Bayraktar, Y., Eğri T., & Yildiz, F. (2016). A causal relationship between oil prices current account deficit, and economic growth: an empirical analysis from fragile five countries. *Ecoforum Journal*, 5(3).

Bilgehan, T. (2018). Toda-yamamoto causality between E7 countries stock markets. *Emc review-časopis za ekonomiju, 16*(2).

Bouri, E., Molnár, P., Azzi, G., Roubaud, D., Hagfors, L., (2017). On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier? Finance Research Letters 20, 192–198.

Chiang, T.C., Li, J., Yang, S.Y., 2015. Dynamic stock-bond return correlations and financial market uncertainty Review of Quantitative Finance and Accounting, 45, 59– 88

Dickey, D.A., & Fuller, W.A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(1), 1057-1072.

Durmus¸, S. (2016). Seytan üçgeni; faiz, döviz kuru ve enflasyon iliskisi: Türkiye için ampirik bir analiz. TURAN-SAM, 8(23), 427–434.

Ghosh, S., & Kanjilal, K. (2009). Impact of oil price shocks on macro-economy: Evidence from an oil importing developing country. *Journal of Policy Modelling*.

Ghosh, Ipak-Levin, Eric J,-MacMillan, Peter-Wright, Robert E (2004), "Gold as an Inflation Hedge?" Studies in Economics and Finance, Vol.22, pp.1-25.

Giles, D. (2011). Testing for Granger causality. Retrieved from https://davegiles.blogspot.com/2011/04/testing-for-granger-causality.html Accessed 12 May 2021.

Gulec, O. M., Cevik, E., & Bahadır, N. (2018). Investigation of the association between Bitcoin and financial indicators. *Journal of the Faculty* *of Economics and Administrative Sciences, 7*(2), 18-37.

Korkmaz, Ö. (2018). The relationship between Bitcoin, gold and foreign exchange returns: The case of Turkey. *Turkish Economic Review, 5*(4), 359-374.

Koçoğlu, Ş., Çevik, Y. E., & Tanrıöven, C. (2016). Efficiency, liquidity and volatility of Bitcoin markets. *Journal of Business Research, 8*(2), 77-97.

Korap, L. (2008). Exchange rate determination of TL/US $: a co-integration approach. *Ekonometri ve İstatistik e-Dergisi*, (7), 24-50.

Mensia, W., Tiwarid, S. H. A. K., & Al-Yahyaeee, K. H. (2019). Is there a relationship between MENA stock markets, oil, Bitcoin, gold, and VIX? A Wavelet based dependence-switching copula approach.

Phillips, P., & Perron, P. (1988). Testing for a unit root in time series regressions. *Biometrica, 7*(2), 345-346. http://dx.doi.org/10.1093/biomet/75.2.335

Sari, R., Hammoudeh, S., & Soytas, U. (2010). Dynamics of oil price, precious metal prices, and exchange rate. *Energy Economics 32*, 351–362.

Stanley, M. (2013), Global EM Investor Fragile Five, http://graphics8.nytimes.com/packages/pdf/business/MorganStanleyFragileFive.pdf Accessed 1 May 2021.

Stensås, A., Nygaard, M. F., Kyaw, K., & Treepongkaruna, S. (2019). Can Bitcoin be a diversifier, hedge or safe haven tool?. Cogent Economics & Finance, 7(1), 1593072.

Şen, H., Kaya, A., Kaptan, S., & Cömert, M. (2020). Interest rates, inflation, and exchange rates in fragile EMEs: A fresh look at the long-run interrelationships. *The Journal of International Trade & Economic Development, 29*(3), 289-318.

Taskinsoy, J. (2019). Bitcoin and Turkey: A good match or a perfect storm?. Available at SSRN 3477849.

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of econometrics, 66*(1-2), 225-250.

Ucan, O., Akin, C. S., & Aytun, C. (2014). Exchange Rate Determination in High Fragile Emerging Countries. *European Scientific Journal.*

Yildirim, Z. (2016). Global financial conditions and asset markets: Evidence from fragile emerging economies. *Economic Modelling, 57*, 208-220.

Zivot, E., & Andrews, D. (1992). Further evidence on the great crash, the oil-price shock and the unit-root hypothesis. *Journal of Business Economic Statistics,10*(3), 251-270. http://dx.doi.org/10.1080/07350015.1992.10509904

How cite this article

Karatas, E., & Memis Karatas, A. (2023). A causal relationship among the financial indicators of bitcoin, gold, and vix: An empirical analysis of the fragile five. *EKOIST Journal of Econometrics and Statistics*, 39, 65-75.
https://doi.org/10.26650/ekoist.2023.39.1271842