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RESEARCH ARTICLE

Bubble Spillover of Assets: Evidence from the Exchange Rates of Some Newly Industrialized Countries

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ABSTRACT
This study investigates the bubble assets of exchange rates in some newly industrialized countries, including Brazil, Indonesia, Mexico, South Africa, and Thailand. This study aims to determine the bubble assets in the exchange rates of the relevant countries according to the critical values obtained from the GSADF unit root test and Monte Carlo simulation, using weekly data for 01/06/2019–04/03/2023. Then, the presence of some of the information in the GSADF variable of the other country in the current values of the GSADF variable obtained for each country's exchange rate is examined. The study's findings show that there is bidirectional causality between the Mexican Peso and the currencies of other countries in the bubble series for each of the five countries. Similar results were found for bidirectional causality between all countries except the South African Rand and the Thai Baht. These findings show that the Mexican Peso and the South African Rand are the currency parity of the countries that both emit and receive the bubbles that occur in the countries in the study.

Keywords: NIC Countries, Exchange Rate, Bubble Presence, Bubble Spillover
Jel Classification: C22, G01, F31

Introduction

Financial asset bubbles have the potential to severely impact both investor wealth and societal welfare, as observed in major crises such as the Dot-Com bubble in the late 1990s (DeLong & Magin, 2006) and the U.S. real estate bubble in 2008. These episodes and historical bubbles like the Tulip Frenzy (Brunnermeier, 2016; Jones, 2016) and the South Sea Bubble (Temin & Voth, 2004) demonstrate that bubbles can transcend national borders and disrupt global markets.

In financial markets, a bubble generally occurs when an asset's price significantly deviates from its fundamental value, often due to speculative trading. This study aims to detect bubbles and their spillover effects in the exchange rates of selected newly industrialized countries—Brazil, Indonesia, Mexico, South Africa, and Thailand—using the GSADF test. By examining the causal relationships and interconnected patterns of bubbles among these countries, this research offers new insights into how speculative bubbles propagate across exchange rates.

The primary research questions guiding this study are as follows:

Do bubbles in the exchange rates of these countries display interconnected or spillover patterns?

Can past bubble formations in one country's exchange rate help explain those in another?

Which exchange rates act as the primary transmitters and receivers of the bubbles?

This study contributes to the literature by providing empirical evidence on bubble transmission between the exchange rates of emerging economies. Findings from this research could inform policymakers about the risks associated with cross-border financial instabilities, helping them describe strategies to mitigate potential economic disruptions.

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Literature Review

It has been observed that the examination of bubble assets with the GSADF test has been researched in the literature with a heavy emphasis on financial instruments. For example, it has been the subject of research into variables such as housing prices and investment tools such as stock markets, crypto assets, and exchange rates. The primary motivation of this study is to investigate whether the bubble assets that occur in the exchange rates of some newly industrialized countries in the explanation of their values in the current period and whether the lagged values of the bubbles in the exchange rates of other countries contribute to the explanation of the bubbles in the current period. Therefore, in this study, the fact that no study has been conducted in the literature on the propagation of bubble assets reveals the study's originality.

Mandacı and Çağlı (2018) examined the bubble assets with the housing prices in Turkey. On the other hand, Gökçe and Güler (2020) discussed the bubble assets in the province of Ankara in their studies on the housing bubble. In another study on the housing market, bubble assets were found at various times when examining the essential cities of Turkey (Abioğlu, 2020). Another study investigated the presence of bubbles in housing prices across Turkey and in the TR71 region (Kartal, 2022). Asal (2019) examined the bubble assets in-house prices in Sweden. Another study provides evidence from Japan's asset price bubble in the 1980s and 1990s (Hu & Oxley, 2018a). Another study proposes how bubble assets can be obtained in the real estate market (Lai et al., 2009; Escobari & Jafarinejad, 2016). Liu et al. (2016) considered the bubbles in housing prices in China. One study provided evidence for speculative bubble assets in the US real estate market (Naoui & Bassem, 2015). It examines the presence of bubbles in regional housing prices in the US (Hu & Oxley, 2018b). Joyeux and Milunovich (2015) investigated speculative bubbles in global real estate investment trusts. Chen and Funke (2013) investigated bubble assets in the housing market in Germany. A similar study was conducted for the housing market in Australia (Shi et al., 2016; Supervised et al., 2018).

They consider rational bubble assets separately for indices within BIST (Çağlı & Mandacı, 2017; Çıtak, 2019). Kılıç (2020), on the other hand, examines the bubble assets in the stock markets of BRICS-T countries. In another study, the bubble assets of MIST countries in the stock markets are discussed (Yurtoğlu, 2022). One study provided evidence of bubble holdings in the emerging stock market (Liaqat et al., 2019). Almudhaf (2017) discussed bubble assets in the African stock market. Another study provides evidence from the Dow Jones market bubble assets during the COVID-19 era (Chang et al., 2021). Balcilar et al. (2016) examined the collapsing bubbles in the South African stock market. Another study provides examples of bubble holdings in cross-listed equities traded on the Chinese stock market (Pavlidis & Vasilopoulos, 2020). Pavlidis et al. (2017) examined the bubble assets in the forward and spot markets in their study. Another study revealed the bubble assets during the hyperinflation period that Germany experienced during the war periods (Pavlidis et al., 2012). Addresses bubble assets in alternative energy stocks in global indices in mid-2000 (Bohl et al., 2015). In one study, bubble assets in the Indonesian stock market were examined (Almudhaf, 2018). Explores bubble assets on the Nasdaq and S&P500 exchanges (Mulla et al., 2018).

On the other hand, Bettendorf and Chen (2013) investigated the bubble assets in the GBP/USD exchange rate. In another study, the BRICS and Turkey provided evidence of exchange rate bubbles (Yildirim et al., 2022). Jiang et al. (2015) examined bubble assets in the RMB-dollar exchange rate. Assaf (2018) explores the presence of bubbles in the prices of the art market. During the COVID-19 era, food price bubbles in countries known as the Fragile Eight have been addressed (Varlık, 2021). Another study provides evidence from bubble assets in the European Union Emissions Trading Program (Cretí & Joëts, 2017). Another study examined the bubble assets in China's Pu'er tea price (Dou et al., 2021). One study revealed the presence of bubbles in the commodity prices of various agricultural products (Areal et al., 2016).

Bubble assets have been investigated in the crypto money market, one of today's remarkable investment tools. Güleç and Aktaş (2019) detected speculative bubble assets in various cryptocurrencies in the crypto money market. Songur (2019), on the other hand, has concluded that there are many bubbles in the Bitcoin market based on the data from the 2015–2018 period. In another study, they examined the bubble assets in Bitcoin, Ethereum, and Ripple altcoins, which are the locomotives of the crypto money market (Mete et al., 2019). Some crypto assets in the crypto money market are being examined with Bitcoin, Iota, and Ripple altcoins (Şahin, 2020). Yılmaz (2022) investigated the bubble assets in the crypto money market during the COVID-19 period. In his study, Işıldak (2022) examined the bubble assets in Bitcoin, the most critical cryptocurrency in the crypto market. Similarly, Liv et al. (2021) attempted to identify the bubble periods in Bitcoin. One study explored speculative bubble assets in Bitcoin araştırmaktadır (Malhotra & Maloo, 2014; Da Costa De Souza et al., 2017; Demmler & Fernández Dominguez, 2022). The existence of bubbles in Bitcoin, the locomotive of the crypto money market, and Ethereum, the locomotive of altcoins, has been investigated (Corbet et al., 2018). Another study examined the existence and deflating of bubbles in Bitcoin (Kyriazis et al., 2020; Z. Z. Li et al., 2019).

Another application area was realized with precious metals. A study examines bubble asset prices in silver (Öncü, 2021). Another study provided evidence of bubbles in crude oil prices (Pavlidis et al., 2018; Khan et al., 2021). Another study addresses bubbles in commodity prices (Sanders & Irwin, 2010). On the other hand, Ozgur et al. (2021) examined the bubble assets in metal prices using GSADF and machine learning methods. In another study, he tried to determine the bubble periods in WTI prices

(Perifanis, 2019). Zhao et al. (2021) investigated the contagion of bubbles between the stock market and oil prices. On the other hand, Su et al. (2020) provided evidence from bubble assets in copper prices. Another study investigated the bubbles in fuel prices in developing economies (Ahmed et al., 2022). On the other hand, Tsvetanov et al. (2016) examined bubble assets for their future prices.

The existing literature predominantly focuses on identifying and analyzing asset bubbles across various financial instruments. However, there are a limited number of studies examining bubble spillovers between the exchange rates of newly industrialized countries and the potential impact of these bubbles on each other. Specifically, a comprehensive analysis of asset bubbles' international transmission tendencies and their effects on financial markets remains underexplored.

This study aims to fill this gap by investigating how bubbles in the exchange rates of newly industrialized countries influence each other. By providing new empirical insights into the process of bubble spillovers among exchange rates, this research contributes valuable knowledge for risk management strategies in international financial markets. The findings may offer policymakers essential information for fostering financial stability across countries.

Theoretical Framework

This study is grounded in the theory of speculative bubbles, which suggests that speculative bubbles can cause asset prices to deviate significantly from their intrinsic values due to investor behavior and market dynamics. According to this theory, bubbles form when investors drive asset prices upward based on expectations of future profits rather than current fundamentals, often leading to an unsustainable price level. Key concepts within this framework include market exuberance, herd behavior, and irrational expectations, which collectively contribute to price distortions in financial assets.

Additionally, this study draws on international finance theories that address the interconnectedness of global markets. Exchange rates, especially in emerging and newly industrialized economies, are susceptible to cross-border shocks due to trade relations, investor sentiment, and macroeconomic interdependencies. Theoretical models such as the Efficient Market Hypothesis (EMH) (Fama, 1970) and the contagion theory provide a foundation for analyzing how information or price changes in one country's currency can influence others, particularly through bubble spillovers.

Application Method: Right Tail Generalized Augmented Dickey-Fuller (GSADF) Test

Referring to the inadequacy of the SADF method proposed by Phillips, Wu, and Yu (2011) and performed for finding bubbles in detecting multiple bubbles, Phillips, Shi, and Yu (2015) developed the SUP ADF (GSADF) method to eliminate this deficiency. This method proposes an iterative backward regression technique for timestamp bubble formation (Phillips et al., 2015, p. 1045). Another difference from the SADF method is that instead of keeping the starting point of the iteration fixed, the GSADF method expands the sample scope by changing both the starting point and the ending point of the iteration in the flexible window (floating window) range. Therefore, the GSADF test is a right-tailed double iterative test for the ADF unit root test. The specification of the GSADF test proposed by PSY (2015) is obtained as in Equation 1 (Phillips et al., 2015, p. 1047):

$$\Delta y_t = \hat{a}_{r_1,r_2} + \delta_{r_1,r_2} y_{t-1} + \Sigma_{i=1}^{k} \hat{\psi}_{r_1,r_2}^{i} \Delta y_{t-i} + \hat{\varepsilon}_t \tag{1}$$

Repeated ADF test regressions on sub-samples given recursively follow Equation 1 in the proposed test. In this test, besides changing the endpoint of the r_2 regression from r_0 (smallest window width) to 1, it also allows the starting point of to r_1 change within a suitable range from 0 to r_2-r_0. Thus, the GSADF statistics are defined as the most significant ADF statistic in this double recursion over all applicable ranges of r_1 and r_2. The GSADF statistics are shown with r_0 as in Equation 2 (Phillips et al., 2015, p. 1049):

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_1]}} \left\{ \frac{\frac{1}{2} r_w [W(r_2)^2 - W(r_1)^2 - r_w] - \int_{r_1}^{r_2} W(r) dr [W(r_2) - W(r_1)]}{r_w^{1/2} \left\{ r_w \int_{r_1}^{r_2} W(r)^2 dr - \left[\int_{r_1}^{r_2} W(r) dr \right]^2 \right\}^{1/2}} \right\} \tag{2}$$

While the related hypotheses are formed as H_0: δ=1 and H_1: δ<1 in the left-tail ADF test, the hypotheses are expressed as follows in the right-tail ADF test:

H_0: δ=1 (has a unit root)

H_1: δ>1 (contains an explosive unit root)

On the other hand, the GSADF in Equation 2 is briefly defined as (Phillips et al., 2015, p. 1049):

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_1]}} \left\{ ADF_{r_1}^{r_2} \right\} \quad (3)$$

This test identifies multiple bubbles, allowing the different window sizes to change from 0 to r_2-r_0, which they highlighted in the SADF statistics proposed by Phillips et al. (2011) (Phillips et al., 2015).

Granger Causality Test

The basic idea behind Granger's (1969) causality analysis is to show the existence of a causal relationship between variables if the lagged values of another variable contribute to the explanation of this variable while explaining the value of a variable in the current period. In other words, if some amount of information carried by a time series is affected by the past values of another time series or can be explained by its historical values, there is a causal relationship between these two series. Suppose the two variables are X_t and Y_t. The equations proposed by Granger (1969) are given below:

$$X_t + b_0 Y_t = \Sigma_{j=1}^{m} a_j X_{t-j} + \Sigma_{j=1}^{m} b_j Y_{t-j} + \varepsilon_t^{'} \quad (4)$$

$$Y_t + c_0 X_t = \Sigma_{j=1}^{m} c_j X_{t-j} + \Sigma_{j=1}^{m} d_j Y_{t-j} + \varepsilon_t^{''} \quad (5)$$

The simple causality model will be valid if b_0=c_0=0 given in Equations 4 and 5. Otherwise, according to the definition by Granger (1969), instant causality will be in question (Işığıçok, 1994).

Unit Root Test

The Dickey-Fuller (DF) unit root test, which was introduced to the literature as the parametric unit root test of Dickey and Fuller (1979, 81), has been generalized and named the ADF unit root test. The unit root test proposed by Phillips and Perron (1988) is frequently used to determine stationarity. Accordingly, the intercept, trend, and intercept models of the ADF unit root test are shown in Equations 6 and 7:

Intercept ADF equation,

$$\Delta y_t = \alpha_0 + \phi y_{t-1} + \beta_i \Sigma_{i=1}^{m} \Delta y_{t-i} + u_t \quad (6)$$

The Trend and Intercept ADF equation,

$$\Delta y_t = \alpha_0 + \alpha_1 t + \phi y_{t-1} + \beta_i \Sigma_{i=1}^{m} \Delta y_{t-i} + u_t \quad (7)$$

Since the PP test equations are similar to the ADF process, their equations are not specified to avoid repetition. The hypotheses for the relevant tests are the left-tail test and are as follows:

H_0: δ=1 (Series contains unit root / Series is non-stationary)

H_1: δ<1 (There is no unit root in the series/The series is stationary)

Application

In this section, the application proceeds in two different ways. First, the USD/BRL (Brazil), USD/IDR (Indonesia), USD/MNX (Mexico), USD/ZAR (South Africa), and USD/THB (Thailand) pairs, 06/01/2019-23/04/2023 The weekly data of the period and the Generalized Supremum Augmented Dickey-Fuller Test (GSADF test), which is frequently used in the research of multiple bubbles brought to the literature by Phillips, Shi, and Yu (2015), are determined by the related parties. First, the window size is:

$$(r_0 = 0.01 + 1.8\sqrt{T})$$

Eq. obtains it. In this equation, T is the number of observations. Therefore, the window size (r_0) was approximately 29. In the application made in Eviews 12, critical values were obtained by making 1000 replications with Monte Carlo simulation in the MATLAB program.

Table 1. GSADF Test Statistics and Critical Values

		USD/BRL	USD/IDR	USD/MNX	USD/ZAR	USD/THB
GSADF (test stat)		3.704935	2.310816	5.144073	3.109544	2.06401
(prob)		(0.0000)	(0.0310)	(0.0000)	(0.0010)	(0.0570)
Critical values:	99% level			2.643951		
	95% level			2.138363		
	90% level			1.858774		

Note: Critical values are based on a Monte Carlo simulation (run with MATLAB)

The results presented in Table 1 show the GSADF test statistics and critical values for the exchange rates of Brazil (USD/BRL), Indonesia (USD/IDR), Mexico (USD/MNX), South Africa (USD/ZAR), and Thailand (USD/THB). According to the findings, the GSADF test statistics for USD/BRL, USD/IDR, USD/MNX, and USD/ZAR exceeded the critical values obtained from the Monte Carlo simulation at the 5% significance level, indicating the presence of bubbles. For USD/THB, a statistically significant result was observed at the 10% significance level.

These results suggest a strong bubble presence in the USD/BRL, USD/MNX, and USD/ZAR exchange rates at the 0.90, 0.95, and 0.99 confidence intervals, while bubble indications are found at slightly lower confidence levels for the USD/IDR (0.90 and 0.95) and USD/THB (only 0.90). This indicates that speculative bubbles have formed in these currencies, with potential spillover effects across different time periods. The similar pricing patterns observed during specific periods across these exchange rates imply the likelihood of bubbles spreading internationally, driven by interactions between these exchange rates.

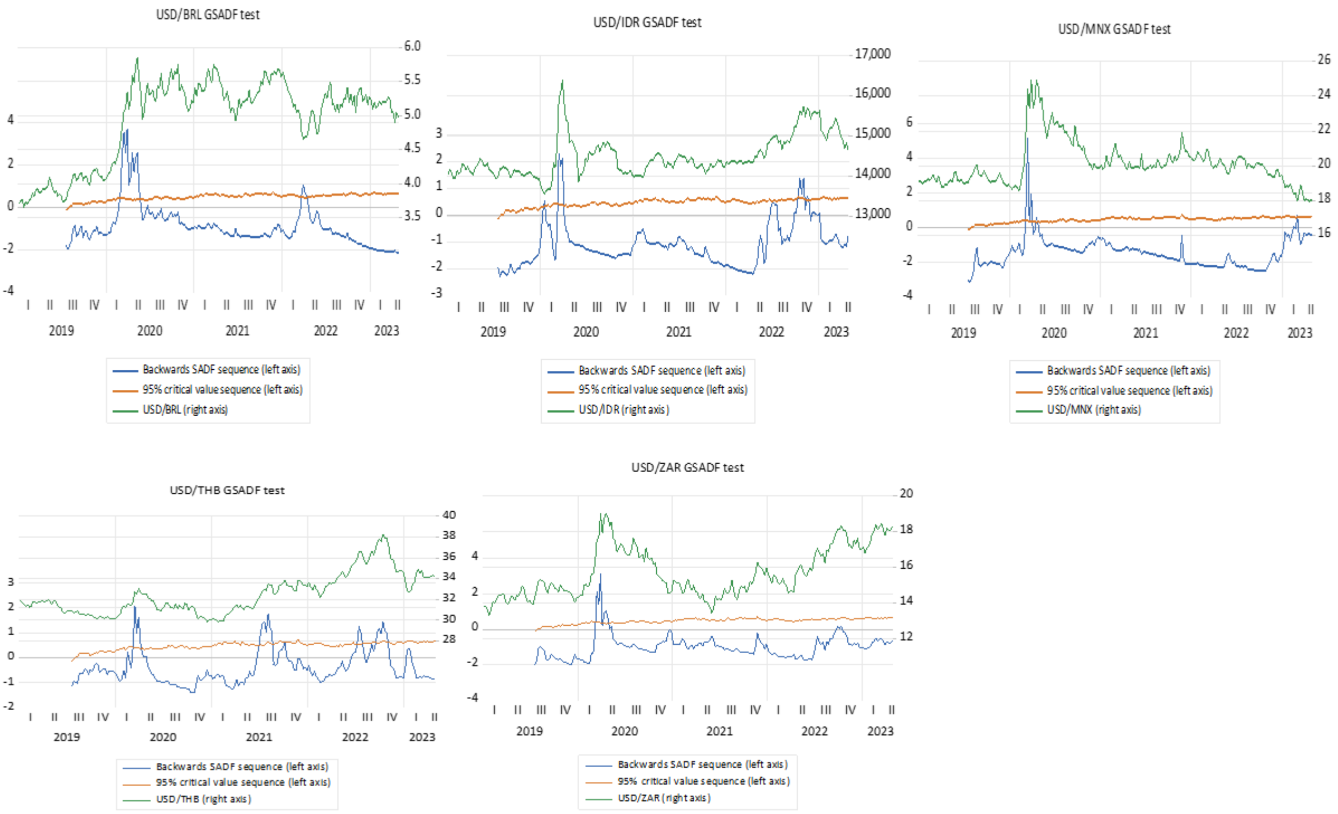

Figure 1. Bubble Formations Regarding the Exchange Rate

Figure 1 illustrates the bubble formations detected in the exchange rates of newly industrialized countries—USD/BRL (Brazil), USD/IDR (Indonesia), USD/MNX (Mexico), USD/ZAR (South Africa), and USD/THB (Thailand)—during the study period. Each bubble formation reflects periods in which exchange rates significantly deviated from their fundamental values, indicating speculative trading and potential instability.

The figure reveals that bubbles in the USD/IDR, USD/MNX, and USD/THB exchange rates occurred more frequently and for extended periods than those in the USD/BRL and USD/ZAR. Specifically, the most prolonged bubble periods are evident in the USD/THB exchange rate, with formations lasting up to seven weeks, while the USD/BRL and USD/ZAR exchange rates exhibit shorter bubble durations. This variation indicates that certain currencies, like the Thai Baht, may be more prone to sustained speculative activity, potentially due to regional or macroeconomic factors unique to Thailand.

Additionally, the timing of these bubbles across currency coincides at certain intervals, implying a level of interconnectedness or contagion between these markets. For instance, simultaneous bubble occurrences in multiple currencies around the early months of 2020 may reflect broader economic uncertainties, possibly tied to the onset of the COVID-19 pandemic, which heightened volatility across global financial markets.

In summary, Figure 1 indicates that bubble dynamics differ across these exchange rates in duration and frequency, with notable synchronizations pointing to potential spillovers. This pattern emphasizes understanding cross-country speculative behavior and its implications for managing exchange rate risks in newly industrialized economies.

Table 2. Bubble Periods and Durations in the Exchange Rate

USD/BRL	USD/IDR	USD/MNX	USD/ZAR	USD/THB
03.01.2020- 05.17.2020 **(12 Weeks)**	01.19.2020 **(1 Week)**	03.08.2020- 03.15.2020 **(2 Weeks)**	03.15.2020- 03.29.2020 **(3 Weeks)**	03.08.2020- 04.05.2020 **(5 Weeks)**
03.20.2022- 04.10.2022 **(4 Weeks)**	03.15.2020- 03.29.2020 **(3 Weeks)**	03.29.2020 **(1 Week)**	04.12.2020- 04.26.2020 **(3 Weeks)**	07.04.2021- 08.15.2021 **(7 Weeks)**
	10.16.2022- 10.23.2022 **(2 Weeks)**	04.19.2020 **(1 Week)**		07.10.2022- 07.17.2022 **(2 Weeks)**
	11.13.2022- 11.20.2022 **(2 Weeks)**	02.26.2023 **(1 Week)**		09.18.2022- 10.23.2022 **(6 Weeks)**

Table 2 presents the bubble periods and durations identified for each currency and the economic conditions influencing these exchange rate bubbles. The emergence of the COVID-19 pandemic led to substantial global economic disruptions, which contributed to bubbles in exchange rates across various countries.

Two bubble periods were observed for the USD/BRL (Brazilian Real). The first occurred before the pandemic was officially declared from 03.01.2020 to 05.17.2020 (lasting 12 weeks). Political uncertainties, financial volatility, and weakened trade relationships increased the demand for the dollar, fostering bubble conditions. Between 03.20.2022 and 04.10.2022 (4 weeks), the second bubble appeared in the middle of global inflationary pressures and rising commodity prices, particularly affecting Brazil's agricultural exports.

The USD/IDR the (Indonesian Rupiah) experienced four distinct bubble periods. On 01.19.2020 (lasting 1 week), early pandemic concerns prompted investors to shift away from riskier assets, creating a speculative spike in the exchange rate. From 03.15.2020 to 03.29.2020 (3 weeks), the declaration of the pandemic and a global shift towards safer assets added pressure on the rupiah. Later, between 10.16.2022 and 10.23.2022 (2 weeks), ongoing recovery challenges and Indonesia's external debt position contributed to speculative conditions. Finally, 11.13.2022 to 11.20.2022 (2 weeks) saw bubbles influenced by fluctuations in energy prices and Indonesia's import dependency, leading to the overvaluation of the rupiah.

For the USD/MXN (Mexican Peso) exchange rate, four bubble periods were identified. From 03.08.2020 to 03.15.2020 (2 weeks), the drop in oil prices—given Mexico's reliance on oil exports—put the peso under pressure. Brief bubbles also occurred on 03.29.2020 and 04.19.2020 (each lasting 1 week) due to ongoing economic uncertainty and trade tensions with the U.S. Another bubble, on 02.26.2023 (1 week), reflected inflationary concerns and pressures from Mexico's trade relations with the U.S.

Two bubbles emerged during the pandemic for USD/ZAR (South African Rand). The first, between 03.15.2020 and 03.29.2020 (3 weeks), aligned with the initial pandemic impacts on South Africa's resource-based economy, affecting export demand. Another bubble from 04.12.2020 to 04.26.2020 (3 weeks) resulted from extended COVID-19 uncertainties and a downturn in tourism revenues.

The USD/THB the (Thai Baht) experienced four bubbles, partly due to Thailand's dependence on tourism. A prolonged bubble from 03.08.2020 to 04.05.2020 (5 weeks) coincided with losses in tourism revenue. Between 07.04.2021 and 08.15.2021 (7 weeks), optimism around economic recovery supported the baht. Shorter bubbles, from 07.10.2022 to 07.17.2022 (2 weeks) and 09.18.2022 to 10.23.2022 (6 weeks), were driven by inflationary pressures and rising import costs from fluctuating commodity prices.

These findings illustrate how global and domestic economic dynamics shaped each country's exchange rate bubbles, with COVID-19 and subsequent global economic shifts playing major roles.

The second application part of the study examines the causal relationship between the GSADF series obtained for each country's exchange rate and the GSADF test. The importance of this application is to determine whether the GSADF variable of any exchange rate can be explained by the lagged values of the GSADF variables of other exchange rates in explaining the current period value. The reason for using the GSADF series as a time series is that:

The foundation of using the blue line from Figure 1 as a time series lies in the theoretical basis of the GSADF test developed by Phillips, Shi, and Yu (2015). The GSADF test, grounded in Equation 1, builds upon a differenced form of the variable y_t, which captures explosive episodes in the data. This differencing process inherently creates a series that reflects deviations from the baseline, highlighting periods of potential bubbles as distinct intervals of explosive behavior.

In Equation 1, y_t is transformed into a form that isolates deviations and captures changes relative to previous values, which are tested recursively across flexible sample windows. This recursive testing yields a continuous measure of deviations, or explosive points, represented as a separate time series in the blue line in Figure 1. Theoretically, this differenced y_t series has all the characteristics of a time series, including temporal dependencies, which makes it analytically valid as an independent sequence.

Thus, by constructing the GSADF test on this differenced y_t, we obtain a series that can stand alone, representing fluctuations and periods of intense deviation as a continuous measure of speculative activity. This approach provides a robust basis for using the blue line as a time series, allowing us to explore further patterns and causative relationships within the data. Before performing the causality test, the stagnation levels of the variables were examined. In addition, the most appropriate lag lengths for the variables were determined. Accordingly, the ADF and PP unit root test results for the relevant exchange rate are shown in Table 3.

Table 3. Unit Root Test Results

	PP		**ADF**	
At Level	**With Constant**	**With Constant & Trend**	**With Constant**	**With Constant & Trend**
	t-Statistic			
$\text{GSADF}_{USD/BRL}$	-2.8530	-3.4355	-2.5903	-3.3333
(prob.)	(0.0529)	(0.0497)	(0.0967)	(0.0640)
$\text{GSADF}_{USD/IDR}$	-3.3792	-3.4871	-3.4591	-3.5302
	(0.0129)	(0.0435)	(0.0101)	(0.0389)
$\text{GSADF}_{USD/MNX}$	-4.5374	-4.5862	-3.7238	-3.7907
	(0.0002)	(0.0014)	(0.0044)	(0.0190)
$\text{GSADF}_{USD/THB}$	-3.5761	-3.5744	-3.3005	-3.2717
	(0.0071)	(0.0346)	(0.0162)	(0.0741)
$\text{GSADF}_{USD/ZAR}$	-4.2428	-4.2317	-3.9422	-3.9593
	(0.0007)	(0.0049)	(0.0021)	(0.0115)

Table 3 presents the unit root test results for the exchange rate series, assessing the stationarity of each GSADF series for the currencies under study. To ensure robustness, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were conducted with constant and trend components.

The findings show that, at the 0.10 significance level, all GSADF series exhibit stationarity. For each currency, the calculated test statistics are below the critical values, leading us to reject the null hypothesis of a unit root. This result implies that the GSADF series for each currency is stationary, meaning that the series tends to revert to its mean over time and lacks a unit root. Consequently, the explosive behavior captured by the GSADF test is episodic rather than persistent, reinforcing the interpretation of bubbles as temporary phenomena that dissipate after certain periods.

These stationarity results validate the use of the GSADF series in further analysis, such as causality tests, by confirming the absence of long-term trends that could otherwise distort the detection of short-term bubble dynamics and spillover effects across the currencies.

Table 4. VAR Lag Order Selection

Lag	LR	FPE	AIC	SC	HQ
0	NA	0.023548	10.44069	10.52645	10.47543
1	1409.139	1.39E-05	3.005025	3.519588*	3.213487
2	87.03109	1.11E-05	2.780637	3.724002	3.162817
3	94.93717	8.37E-06	2.496417	3.868585	3.052315*
4	58.73971	7.71E-06	2.411326	4.212297	3.140943
5	57.56451	7.08e-06*	2.322720*	4.552493	3.226055
6	30.82930	7.64E-06	2.392148	5.050724	3.469201
7	41.73836*	7.64E-06	2.383899	5.471277	3.634670
8	35.18477	7.94E-06	2.410714	5.926895	3.835203

Note: * indicates the lag order selected by the criterion

Considering the information in Table 4, LR reaches the smallest value at seven delays, FPE and AIC at five delays, SC at one delay, and HQ at three delays. Therefore, the five lags determined by the FPE and AIC criteria were considered in this study. After determining the integration levels of the variables and the optimum lag lengths, the causality relationship between the GSADF variables obtained for each country is examined in Table 5.

Table 5. VAR Granger Causality

$\chi_{df:5}$	$GSADF_{USD/BRL}$	$GSADF_{USD/IDR}$	$GSADF_{USD/MNX}$	$GSADF_{USD/THB}$	$GSADF_{USD/ZAR}$
$GSADF_{USD/BRL}$	-	1.522495	20.58007	3.572804	10.70866
(prob)	-	(0.9105)	(0.0010)	(0.6124)	(0.0575) *
$GSADF_{USD/IDR}$	16.50864	-	11.72206	6.555814	25.46431
	(0.0055)	-	(0.0388)	(0.2558)	(0.0001)
$GSADF_{USD/MNX}$	37.2624	19.2943	-	12.25517	65.80208
	(0.0000)	(0.0017)	-	(0.0315)	(0.0000)
$GSADF_{USD/THB}$	3.405942	6.005125	18.38865	-	7.208941
	(0.6377)	(0.3057)	(0.0025)	-	(0.2056)
$GSADF_{USD/ZAR}$	21.4455	8.232068	12.42038	3.42867	-
	(0.0007)	(0.1439)	(0.0295)	(0.6342)	-

Not: * 0.10 indicates the level of significance.

Table 5 presents the Granger causality test results, examining whether past values of the GSADF series from one currency can predict or explain the current values of the GSADF series in another. The results offer insights into the interconnectedness and spillover effects among the currencies of the newly industrialized countries under study. The key findings from Table 5 indicate several significant causal relationships:

1. Bidirectional Causality: Bidirectional causality at the 0.05 significance level exists between
    - USD/MXN (the Mexican Peso) and USD/ZAR (South African Rand)
    - USD/BRL (Brazilian Real) and USD/MXN
    - USD/MXN and USD/THB (the Thai Baht)

    These bidirectional links indicate a strong feedback mechanism, where speculative bubbles in one currency can influence and be influenced by bubbles in another. Such relationships highlight the interconnected nature of these exchange rates, indicating that bubbles may propagate through these markets in both directions.
2. Unidirectional Causality: Unidirectional causality is observed from
    - USD/MXN to USD/IDR the (Indonesian Rupiah) at the 0.05 level
    - USD/ZAR to USD/THB at the 0.10 level

    These unidirectional relationships imply that the Mexican Peso and South African Rand exert a one-way influence on the Indonesian Rupiah and Thai Baht, respectively. This unidirectional spillover effect indicates that bubbles in USD/MXN and USD/ZAR may trigger or amplify speculative behavior in USD/IDR and USD/THB without receiving reciprocal influence.

The dominant role of the Mexican Peso (USD/MXN) in multiple causal relationships reflects its position as a central currency in transmitting bubble effects to other markets in the study. Overall, these causality results reveal complex linkages among the currencies, with both bidirectional and unidirectional influences suggesting that bubble dynamics in one market can significantly impact others, underlining the potential for cross-market contagion in speculative episodes.

Implications and Recommendations

Theoretical Implications

Enhanced Bubble Detection and Analysis: Applying the GSADF test and using the blue line as a new time series highlight an advanced methodology for identifying and analyzing bubbles. This approach provides a dynamic view of bubble periods across time, enabling researchers to track the temporal evolution of bubbles more effectively than traditional methods. The use of differenced y_t values from the GSADF outputs as a standalone time series presents a novel analytical avenue, as it captures explosive episodes while maintaining the statistical properties necessary for further causality and spillover analyses.

The interconnectedness of Bubble Dynamics: The Granger causality findings indicate that bubbles are not isolated phenomena but are likely to spill over across currencies, demonstrating complex bidirectional and unidirectional causal relationships. The Mexican Peso, for instance, acts as a significant transmitter of bubbles, influencing other currencies. This interconnectedness indicates that bubbles should be analyzed within individual markets and in the context of their influence on other financial systems. Theoretically, this supports the concept of bubble contagion, where speculative pressures in one market can propagate and destabilize others.

Stationarity as a Stabilizing Force: The stationarity of the GSADF series implies that bubbles are inherently mean-reverting, supporting the idea that speculative episodes are temporary and do not persist indefinitely. This characteristic aligns with the theoretical understanding of bubbles as episodic deviations from fundamental values, reinforcing models that incorporate bubbles as cyclical rather than permanently destabilizing forces.

Policy Recommendations

Monitoring Cross-Market Bubble Contagion: Given the bidirectional causality between certain exchange rates, policymakers should consider cross-market monitoring systems that detect early signs of bubble spillovers between related currencies. For example, any speculative activity in the Mexican Peso should be closely monitored for potential spillovers into the South African Rand, Thai Baht, and other linked currencies. Such monitoring could help policymakers preemptively address risks and implement interventions before bubbles spread across markets.

Implementing Macroprudential Controls: The presence of bubbles and their contagious effects call for stronger macroprudential policies that stabilize currency markets. Regulators in countries like Mexico, Brazil, and South Africa should explore targeted controls during speculative episodes, such as adjusting interest rates, reserve requirements, or temporary capital controls, to mitigate the impact of bubbles and prevent widespread financial disruptions.

International Policy Coordination: As bubble spillovers indicate a high degree of interdependence among emerging markets, particularly in the exchange rates of newly industrialized countries, international policy coordination becomes essential. Institutions such as the International Monetary Fund (IMF) could facilitate cooperative frameworks where countries exchange real-time data on speculative activity and synchronize intervention policies. Such coordination would enhance the effectiveness of domestic measures by preventing the unintended consequences of isolated policy actions.

Strengthening Economic Fundamentals: To reduce vulnerability to bubbles, policymakers should focus on bolstering economic fundamentals, such as improving trade balances, reducing external debt, and enhancing foreign exchange reserves. Strong economic fundamentals can create a buffer against speculative pressures, making it more difficult for bubbles to form or escalate.

By addressing the theoretical and policy implications of the findings, this study supports a comprehensive approach to understanding and managing exchange rate bubbles, emphasizing the need for proactive monitoring, regulatory measures, and international collaboration.

Conclusion

This study investigates the presence and dynamics of exchange rate bubbles among several newly industrialized countries, specifically Brazil, Indonesia, Mexico, South Africa, and Thailand, using the GSADF test. The findings confirm the occurrence of multiple bubble episodes across these currencies, particularly during significant global disruptions, such as the COVID-19 pandemic. The study identifies key bidirectional and unidirectional causality relationships among the currencies, highlighting the potential for bubble spillovers and interconnectedness in emerging markets.

The application of the GSADF test and the subsequent transformation of its output into a continuous time series provides a valuable methodological advancement. This approach allows for a more nuanced view of bubble formations, where bubbles are identified and tracked as evolving phenomena. The Mexican Peso, in particular, emerged as a central transmitter of bubble effects, influencing other countries' exchange rates within the sample. Furthermore, the stationarity of the GSADF series indicates that these bubbles are mean-reverting, supporting the notion of bubbles as cyclical deviations rather than long-term market distortions.

Recommendations for Future Research

1. Cross-Country Analysis with More Variables: Future studies could expand the analysis by incorporating more countries and variables, such as interest rates, stock indices, or commodity prices. This would provide a broader understanding of how exchange rate bubbles interact with other economic variables and could help uncover additional contagion pathways.
2. Macroprudential Policy Impact on Bubbles: Examining the role of macroprudential policies in moderating bubble effects would be valuable. Future research could analyze how different policy measures impact the formation, duration, and intensity of the exchange rate bubble, especially in emerging markets with volatile financial systems.
3. Network Analysis for Bubble Spillovers: Building on the causality findings, future research could implement network analysis to map the spillover effects among multiple currencies. This approach would provide a more detailed visualization of bubble contagion across markets, highlighting the currencies that act as central nodes in the bubble transmission.
4. Alternative Bubble Detection Methods: While the GSADF test effectively detects bubbles, comparing its results with alternative bubble detection methods, such as machine learning-based approaches or other recursive tests, could enhance its robustness and offer new perspectives on bubble identification.

In summary, this study contributes to the theoretical and empirical understanding of exchange rate bubbles in newly industrialized countries, emphasizing their interconnectedness and the transient nature of speculative episodes. By advancing bubble detection and exploring causality among currencies, this study provides a foundation for developing theoretical insights and practical policy measures to manage financial stability in emerging markets.

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