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A new look at stock price-exchange rate nexus: Analysis of COVID-19 pandemic waves in advanced and emerging economies

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A B S T R A C T

This study takes a new look at the stock price-exchange rate nexus and attempts contributions to the extant studies in a number of intuitive ways. First, we analyze the reverse relationships given the theory-backed two-way causality between the two variables. We reassess the nexus across the First, Second and Third Waves of the COVID-19 pandemic, as well as comparison between advanced and emerging economies. Third, we adopt a panel modeling approach that simultaneously takes nonstationarity, cross sectional dependence, and asymmetry into account. The data analyses show that the relationship is statistically negative for the two nexuses. The magnitudes were higher during the crisis (the COVID-19 pandemic) although the relationship broke down during the Second Wave as the Delta variant surged. We identify relevant investment and policy implications of the findings.

Introduction

This paper takes a new look at the relationship between exchange rate and stock prices with special attention to the COVID-19 pandemic and comparison between advanced and emerging economies. The need to understand the nexus between the stock and the foreign exchange markets cannot be overemphasized given that the fundamentals in the two markets (i.e. exchange rate and stock price/returns) play vital role in the growth trajectory and as well inform monetary policy actions in many countries [1,2]. Also, financial market actors and policymakers often closely monitor the fluctuations in exchange rates and stock prices because these variables are key measures of macroeconomic performance and investment health of the economy. Consequently, the relationship between exchange rate and stock prices has been well-researched albeit with mixed findings (see for example, [3–5]). The contributions of the present study include comparative analysis between advanced and emerging economies and analyses that cover the period before and during the COVID-19 pandemic with extensions to the different waves of the pandemic, given the impact of the pandemic on financial markets and the real economy globally [6–8].

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The theoretical basis for exploring the exchange rate-stock price linkage can be argued from two complementary views where the direction of causation could run from either exchange rate or stock price to the other (see [9,10] and [4]). The more straightforward approach is the theoretical model of Dornbusch and Fischer [11] which posits that stock market prices could determine the path of exchange rate via the country's current account position. The theory suggests a negative relationship from stock price to exchange rates where asset accumulation improves the current account position of the economy and leads to exchange rate appreciation. The second view, the Portfolio Balance Theory (PBT) (see [12] for the domestic variant of the theory and [13] and [14] for the international variant) posits that the direction of causality runs from exchange rate to stock prices while the expected relationship is still negative. Stylized fact suggests that the relationship between stock price and exchange rate could be negative given evidence of −0.0776 coefficient of correlation between them in advanced economies and −0.0820 in emerging economies. This study therefore conducts the causality analysis as a pre-test to inform the direct of analysis unlike the extant studies which select arbitrary functional form.

The motivation for studying the nexus between stock price and exchange rate becomes imperative during the COVID-19 waves since both markets are susceptible to severe variations during periods of high market risk. For instance, the American stock market experienced two major shocks within a week at the start of the pandemic, and this has been the case in several other markets globally (see [15] and [16]). Beyond this, several studies have also argued that stock prices plunged downwards and exchange rate became more volatile during the pandemic, although the precise reason still remains largely debated (see [3,17–19]). Without the consideration for the pandemic, there is strong evidence for shocks contagion between both variables and markets among countries (see [20,21]). We however expect the connection between the stock and foreign exchange markets to be stronger during the Covid-19 era as informed by some evidence obtained for the same in the South African markets [3].

This paper is a departure from previous studies in the following ways. First, we analyze the stock price-exchange rate relation in selected developed and emerging economies where the choice of the countries comprise large financial markets as this provides a basis for comparing the nexus between the classes of countries. Second, unlike the extant studies which arbitrarily select a direction of causation, we conduct a preliminary panel granger causality test to inform the direction of analysis between stock price and exchange rate. Third, the information obtained from the causality analysis assists us to conduct distinct impact analysis for the groups of advanced and emerging economies across the three waves of the COVID-19 pandemic.[1] On the impact analysis, we improve on the analytical approach of previous studies such as Salisu and Ndako [4], Ashraf [18] and Shehzad *et al.* [19] by not only adopting the Dynamic Common Correlated Effects (DCCE) approach [22,23] given evidence of cross-sectional dependence in the data, but also being the first to explore asymmetry using the DCCE technique. Hence, we examine the linear and non-linear versions of the nexus given that we should not expect similar roles for positive and negative changes in the effect of either of the variables on the other.

The study documents salient findings that reveal that the two directions of causality are valid and the relationship between stock price and exchange rate is largely negative as indicated by theory for advanced and emerging economies. There are also important roles for asymmetry and cross section dependence in the nexus, where the latter was specifically ignored in previous studies. In addition to the study's contributions to the literature, the study also produces relevant policy directions with suggestions to guide investors given that the research involves the study of two major financial markets in an economy. The rest of the paper is structured as follows: Section 2 presents the review of the literature, Section 3 presents the methodology, Section 4 contains the results and discussion, and the last section presents the conclusion to the paper.

Literature review

Two theoretical approaches underlie the relationship between stock price and exchange; namely, the Dornbusch and Fischer [11] approach and the Portfolio Balance Theory (see [12] for the domestic form of the theory and [13] and [14] for the international variant of the theory), and the two theories reach different conclusions as regards the direction of impact. Nonetheless, the two theories inform us of the negative relationship between exchange rate and stock price. The Dornbusch and Fischer [11] model proposes the direction of relationship that moves from stock price to exchange rate. The approach describes a theory of exchange rate determination where exchange rate dynamics and asset markets are linked via the current account. The theory suggests a negative relationship between the two variables as the net asset position of the country improves the current account position of the economy to lead to exchange rate appreciation, and vice versa.

The domestic version of the PBT in line with Tobin [12] could explain the relationship between exchange rate and stock price within an approach where the asset holders either hold money or stocks (or bonds) and this decision is largely driven by the rate of interest. Exchange rate movements could affect inflation expectations (by implication, real interest rate) in the economy causing investors to hold more or less of either assets. Looking at the behavior of international investors, the PBT proposed by Branson [13] and Frankel [14] suggests a negative relationship between stock price and exchange rate and this relationship drives from exchange rates to stock markets. Exchange rate depreciation/depreciation affects the economy through the international competitiveness of the economy and therefore influences the stock markets. As the exchange rate

[1] In line with Adediran *et al.* [6] and Kunno *et al.* [71], we conduct analysis across COVID-19 waves and define the periods of the waves based on the study of Dutta [63] as follows: First Wave (January 2020 to June 2021), Second Wave (July 2021 to November 2021), and Third Wave (December 2021 to September 2022).

influences the way international investors hold more or less assets, this affects the cash flow of firms and therefore the stock price.

The contrasting direction of relationships defined in these two theories have also informed empirical studies in either of the two directions. Exchange rate-stock price nexus which is the opposite of the traditional approach has been widely studied [10,24–27] so as the PBT stock price-exchange rate nexus [28–31] and [4]. There are expected mixed conclusions as some reported a positive relationship [28,32,33], others report a negative relationship [29,31,34], and [4], and a few research studies also reveal insignificant links between the series [35–37].

Similar to what is being done in this study, some empirical studies have investigated the nexus between stock price and exchange rates in both developed and emerging economies over the years (see for example the works of [4,31,37–43]). However, focus is given to one economy at a time in most of these studies [37,38,40,41], while those that study both the advanced and emerging economies together either focus on pairwise correlation between the two economies 42 or captures less emerging economies as the case of Salisu and Ndako [4] that suggested an extension of their study to capture more emerging economies. However, this present study did not only study the relationship between stock and exchange rate in the domestic markets, but also captured more countries (12 advanced and 13 emerging economies).

Taking the COVID-19 pandemic into consideration in recent study of the nexus between the stock prices and exchange rates, studies have found that the pandemic affects exchange rate [7,44–46], stock price [47,48], and the relationship between the two variables [49]. The findings are therefore contrasting given the location of the studies, Amewu *et al.* [50] find strong co-movement equity stock index and exchange rate in Ghana during the period of pandemic. In contrast, Asaad [51] finds no significant relationship between exchange rate and stock prices for Iraq. Thus, we account for the effect of COVID-19 since there is need for further research to confirm the effect of the pandemic on the relationship of the two variables in both advanced and emerging economies.

Finally, oil price has been widely found to affect both stock price [52–56] and exchange rate [57–62], therefore, this present study accounts for the role of the international oil price in all model estimations to compare models with and without oil price as a control variable. This is to check if oil price will have an effect on the relationship and also to examine the consistency of the results.

Data and methodology

The datasets used for this study are daily stock prices and exchange rates of 12 advanced economies (Australia, Belgium, Canada, France, Germany, Italy, Japan, Korea, Netherlands, New Zealand, Spain and United Kingdom) and 13 emerging economies (Argentina, Brazil, Chile, Egypt, India, Indonesia, Malaysia, Mexico, Singapore, South Africa, Thailand and Turkey). Most of these countries are among the worst hit by the COVD-19 pandemic (see similar classification in [16]). The US is excluded from the list of advanced economies considered for this study because we chose the US dollar as a reference currency given its relevance as a major world currency and all the exchange rates used in this study are expressed against US$. The data scope spans from January 4, 2017 to September 15, 2022, yielding 772 observations for each country. These are then divided into different samples with full samples having the complete data, pre-COVID-19 sample ranges from January 4, 2017 to December 30, 2019, and COVID-19 sample ranges from January 1, 2020 to September 15, 2022. The COVID-19 subsamples are informed by the study of Dutta [63] and divided into first wave (January 1, 2020 to June 30, 2021), second wave (July 6, 2021 to November 30, 2021), and the third wave (December 1, 2021 to September 15, 2022). The stock prices and exchange rates are obtained from https://investing.com/ and oil price from the Federal Reserve database (https://fred.stlouisfed.org/).

In order to explore the bidirectional relationship between stock price and exchange rate in advanced and emerging economies before and during COVID-19 pandemic, we opted for the Dynamic Common Correlated Effect Model [22,23,64] which helps to circumvent problems of nonstationarity, cross-sectional dependence, and we improve on the estimation by exploring the method for conducting tests for asymmetry. This model is estimated in this paper for linear and non-linear effects of the two nexuses considered for both advanced and emerging economies in the six (full, pre-COVID-19, COVID-19, first wave, second wave and third wave) sample periods.

The symmetric model

- Stock price-exchange rate nexus

$$exr_{i,t} = \alpha_{0,i} + \alpha_{1,i}exr_{i,t-1} + \sum\nolimits_{j=t}^{t-\rho T} \alpha_{2,i}B_{i,j} + \beta_i stock_{i,t-1} + u_{i,t} \tag{1}$$

$$exr_{i,t} = \alpha_{0,i} + \alpha_{1,i}exr_{i,t-1} + \sum\nolimits_{j=t}^{t-\rho T} \alpha_{2,i}B_{i,j} + \beta_i stock_{i,t-1} + \delta_i oil_{i,t} + u_{i,t} \tag{2}$$

- Exchange rate-stock price nexus

$$stock_{i,t} = \alpha_{0,i} + \alpha_{1,i}stock_{i,t-1} + \sum\nolimits_{j=t}^{t-\rho T} \alpha_{2,i}B_{i,j} + \beta_i exr_{i,t-1} + u_{i,t} \tag{3}$$

$$stock_{i,t} = \alpha_{0,i} + \alpha_{1,i}stock_{i,t-1} + \sum\nolimits_{j=t}^{t-\rho T} \alpha_{2,i}B_{i,j} + \beta_i exr_{i,t-1} + \delta_i oil_{i,t} + u_{i,t} \tag{4}$$

Eq. (1)–(4) are specified without and with oil price as a control variable in the stock price-exchange rate nexus (and the exchange rate-stock price nexus) respectively, $i = 1, 2, ..., N$, $t = 1, 2, ..., T$, $exr$and$stock$represent the log of exchange rate and log of stock price respectively. $oil_{i,t}$is the log of WTI international crude oil price included as a control variable in Eq. (2) and (4). The quantity $\sum_{j=t}^{t-\rho T} \alpha_{2,i} B_{i,j}$ introduces cross sectional average to the model in order to correct for endogeneity bias due to the introduction of the dynamic term (when $\alpha_{1,i} \neq 0$). The equations also contain a two-way error term ($u_{i,t} = e_{i,t} + \lambda_i f_t$) divided into time variant (f_t), time invariant (λ_i) factor loadings and the remainder error ($e_{i,t}$). In all the four equations above, β_i is the heterogeneous parameter of interest that is obtained through joint significance test (F-test) after including five lags of the regressor series as follows: $\sum_1^5 \beta_i stock_i = 0$ and $\sum_1^5 \beta_i exr_i = 0$

The asymmetric model

This paper formulates a non-linear variant of the original model to estimate the asymmetric response of exchange rate (stock price) to changes in stock price (exchange rate). It further tests whether the nonlinearities matter. The nonlinearities of the variables were captured by decomposing stock price and exchange rate into positive and negative changes following Shin *et al.* [65] approach. The asymmetry perspective in the relationship of stock price and exchange rate has been explored in time series and panel autoregressive distributed lag models ([65] and [4] respectively). Thus, this present study follows up to check the relevance of asymmetry in the DCCE framework across both advanced and emerging economies for the six sample periods. The variables for stock price (*stock*) and exchange rate (*exr*) in earlier equations are now decomposed into positive and negative partial sums as follows:

$$stock_t^+ = \sum_{j=1}^{t} \Delta stock_j^+ = \sum_{j=1}^{t} \max(\Delta stock_j, 0) \tag{5a}$$

$$stock_t^- = \sum_{j=1}^{t} \Delta stock_j^- = \sum_{j=1}^{t} \min(\Delta stock_j, 0) \tag{5b}$$

$$exr_t^+ = \sum_{j=1}^{t} \Delta exr_j^+ = \sum_{j=1}^{t} \max(\Delta exr_j, 0) \tag{6a}$$

$$exr_t^- = \sum_{j=1}^{t} \Delta exr_j^- = \sum_{j=1}^{t} \min(\Delta exr_j, 0) \tag{6b}$$

where Eq. (5a) and (5b) (6a) and (6b) denotes positive and negative partial sum decompositions of stock price (exchange rate) changes. The non-linear variant of Eq. (1)–(4) is then specified as:

$$exr_{i,t} = \alpha_{0,i} + \alpha_{1,i} exr_{i,t-1} + \sum\nolimits_{j-t}^{t-\rho T} \alpha_{2,i} B_{i,j} + \beta_i^+ stock_{i,t-1}^+ + \beta_i^- stock_{i,t-1}^- + u_{i,t} \tag{7}$$

$$exr_{i,t} = \alpha_{0,i} + \alpha_{1,i} exr_{i,t-1} + \sum\nolimits_{j-t}^{t-\rho T} \alpha_{2,i} B_{i,j} + \beta_i^+ stock_{i,t-1}^+ + \beta_i^- stock_{i,t-1}^- + \delta_i oil_{i,t} + u_{i,t} \tag{8}$$

$$stock_{i,t} = \alpha_{0,i} + \alpha_{1,i} stock_{i,t-1} + \sum\nolimits_{j-t}^{t-\rho T} \alpha_{2,i} B_{i,j} + \beta_i^+ exr_{i,t-1}^+ + \beta_i^- exr_{i,t-1}^- + u_{i,t} \tag{9}$$

$$stock_{i,t} = \alpha_{0,i} + \alpha_{1,i} stock_{i,t-1} + \sum\nolimits_{j-t}^{t-\rho T} \alpha_{2,i} B_{i,j} + \beta_i^+ exr_{i,t-1}^+ + \beta_i^- exr_{i,t-1}^- + \delta_i oil_{i,t} + u_{i,t} \tag{10}$$

The Eq. (7)–(10) is for without and with control for stock price-exchange rate nexus (exchange rate-stock price nexus). $\beta_i^+$and $\beta_i^-$are the heterogeneous parameters of interest for positive and negative effects of stock price (exchange rate) changes on exchange rate (stock price) respectively. Like the linear model, they are obtained through joint significance test (F-test) after including five lags of the each of the positive and negative regressor series as follows: $\sum_1^5 \beta_i^+ stock_i^+ = 0$ and $\sum_1^5 \beta_i^+ exr_i^+ = 0$. Other parameters remain as earlier explained.

Results

Preliminaries

We conduct descriptive statistics to demonstrate the unique features of the data based on the averages, standard deviation, minimum, maximum, skewness and kurtosis statistics. The results in Table 1a and Table 1b show that the average stock price is larger in Japan for the advanced countries and Belgium has the lowest average stock price. The standard deviation

Table 1a
Summary statistics [advanced economies].

Countries	Stock Price						Exchange rate					
	Mean	SD	Skew.	Kurt.	Min	Max	Mean	SD	Skew.	Kurt.	Min.	Max.
Australia	4109.09	578.65	0.393	2.403	2374.87	5470.12	1.376	0.078	0.830	4.596	1.235	1.741
Belgium	85.24	12.02	−0.041	2.056	52.66	107.71	0.878	0.042	0.608	3.193	0.803	1.009
Canada	2172.56	255.72	0.728	2.756	1430.56	2778.50	1.299	0.040	0.330	3.593	1.203	1.451
France	161.27	18.60	0.504	2.751	108.38	209.94	0.878	0.042	0.608	3.193	0.803	1.009
Germany	150.26	12.85	−0.445	3.880	96.880	175.99	0.878	0.042	0.608	3.193	0.803	1.009
Italy	59.25	5.570	−0.371	3.148	40.130	72.110	0.878	0.042	0.608	3.193	0.803	1.009
Japan	6658.61	793.47	0.584	2.441	4996.78	8700.31	111.85	7.287	2.397	8.967	102.34	144.55
Korea	743.79	120.19	0.810	2.773	474.51	1037.40	1157.8	58.74	1.075	4.739	1054.94	1398.41
Netherlands	170.88	36.92	1.049	3.040	118.27	271.75	0.878	0.042	0.608	3.193	0.803	1.009
New Zealand	156.08	23.39	0.392	1.882	122.94	205.01	1.473	0.077	0.650	3.122	1.329	1.762
Spain	106.649	11.328	−0.648	3.272	72.290	129.310	0.878	0.042	0.608	3.193	0.803	1.009
UK	2035.69	161.24	−1.324	4.075	1428.42	2251.74	14.58	1.444	0.348	2.970	11.55	19.01

Note: this table presents summary statistics of the stock price and exchange variables in advanced economies. The table reports the statistics for mean, standard deviation (SD), minimum (Min), maximum (Max), skewness (Skew.), and kurtosis for the two variables.

Table 1b
Summary statistics [emerging economies].

Countries	Stock Price						Exchange rate					
	Mean	SD	Skew.	Kurt.	Min	Max	Mean	SD	Skew.	Kurt.	Min.	Max.
Argentina	2363.14	890.49	0.757	2.56	827.10	4529.49	59.51	35.46	0.366	1.979	15.193	143.18
Brazil	1850.52	290.32	−0.252	2.247	1036.30	2383.07	4.353	0.897	0.062	1.465	3.059	5.885
Chile	1430.11	351.63	0.285	1.957	697.86	2164.65	726.36	83.08	0.458	2.428	587.73	972.73
China	598.75	103.93	0.672	3.052	395.43	919.77	6.70	0.242	−0.074	1.791	6.269	7.178
Egypt	2699.35	416.37	−0.456	2.161	1658.29	3419.35	16.91	1.122	0.191	1.588	15.550	19.400
India	1442.37	322.293	0.835	2.337	876.14	2140.94	71.12	4.332	−0.182	2.102	63.400	79.980
Indonesia	6711.96	604.23	−1.005	4.018	4170.33	7799.09	14,154.17	545.63	0.607	4.707	13,162.5	16,575.0
Malaysia	552.73	53.78	−0.030	1.919	414.30	654.57	4.181	0.137	0.277	3.077	3.864	4.533
Mexico	4879.92	681.46	−0.796	3.479	2732.69	6139.47	19.85	1.278	1.120	4.907	17.47	25.33
Singapore	1629.04	150.95	−0.551	2.653	1184.52	1944.25	1.363	0.026	0.467	3.362	1.307	1.459
South Africa	1393.01	102.28	−0.718	5.811	895.94	1653.99	14.58	1.444	0.348	2.970	11.55	19.01
Thailand	543.03	60.15	−0.315	2.866	361.92	661.35	32.36	1.577	0.589	2.81	29.77	36.93
Turkey	1,594,114.	460,683.7	2.132	7.454	1,061,771.	3,693,987.	7.187	3.828	1.482	4.35	3.404	18.26

Note: this table presents summary statistics of the stock price and exchange variables in emerging economies. The table reports the statistics for mean, standard deviation (SD), minimum (Min), maximum (Max), skewness (Skew.), and kurtosis for the two variables.

Table 2
Summary statistics for oil price.

	Oil Price					
	Mean	SD	Skewness	kurtosis	Minimum	Maximum
WTI	60.1872	20.7326	0.4023	4.06965	7.7900	126.470

Note: this table presents summary statistics for the control variable, oil price proxy with West Texas Intermediate (WTI). The table reports the statistics for mean, standard deviation (SD), minimum, maximum, skewness and kurtosis for the oil price variable.

shows a relatively high volatility in the stock price of these countries and Japan also has the highest volatility. Some of the countries reflect a long left tailed stock price series but most of them are positively skewed. The kurtosis recorded for most of the advanced countries ranges between 2.4 to 3.2 which shows that the stock prices may be close to normal distribution. The Emerging countries have average stock prices higher than those of the advanced countries, however the volatility here is extremely higher in emerging economies. The skewness shows that most of the emerging economies have long-left tailed stock price series and the kurtosis is not consistent; some are platykurtic (kurtosis below 3) and others especially Turkey are leptokurtic (kurtosis above 3).

The exchange rates of these countries is also described in Table 1a and b and the results shows that the average exchange rate is lower in the advanced countries as expected compared to the emerging ones with the latter also being more volatile. All the advanced countries have positively skewed exchange rates and although this is also true for most of the emerging countries, few of them still reflect negative skewness. The exchange rate of the advanced countries also seems to be closer to normal distribution compared to that of the emerging countries. Finally on descriptive statistics, the oil price which is used as a control variable in the model estimation is described in Table 2 with positive skewness and peaked distribution.

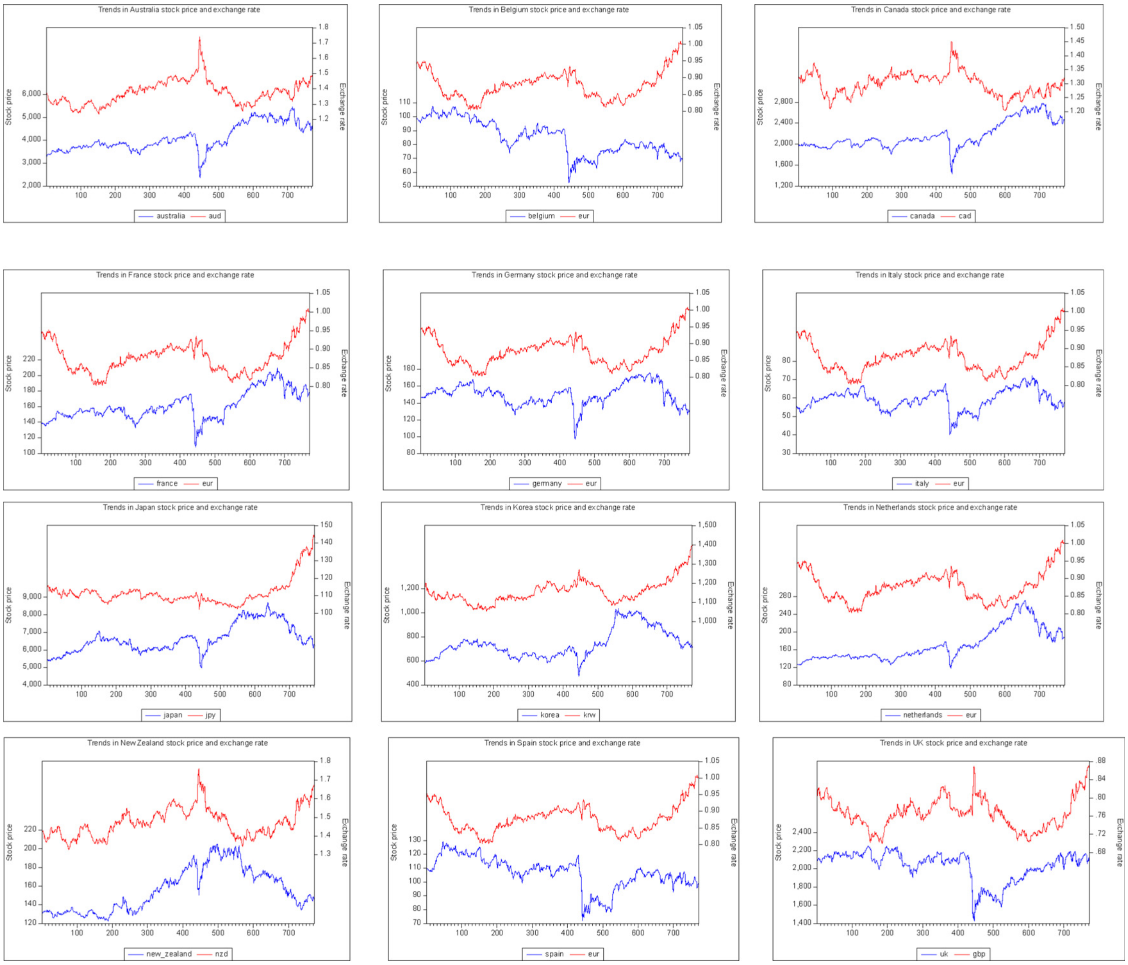

Fig. 1. Trends in Stock Price and Exchange rate [Advanced Economies].
Note: Each graph shows the trend in stock price and exchange rate in each of the advanced economies.

We check the co-movement between stock price and exchange rate in all selected countries used for this study using graphical representation. Fig. 1 and 2 suggest that the relationship between stock price and exchange rate in advanced and emerging economies could be negative, however, there are some variations across the countries. In Fig. 1, all the advanced countries clearly depict the negative relationship. This is also true for some of the emerging countries, however, Fig. 2 shows that the negative relationship, though slightly revealed, is not prominent in a few of the emerging countries like Argentina, Egypt and Turkey. In Turkey for example, the exchange rate and stock price appear to trend in the same direction for some periods. The results could mean that the stock price (exchange rate) in advanced economies responds quickly to changes in exchange rate (stock price) compared to the emerging economies.

In order to justify the choice of estimation technique, we subject the variables to panel unit root tests to ascertain their stationarity using the cross-section dependence augmented Dickey-Fuller test and the results are presented in Table 3. The results reject the null of nonstationarity in the panels for the stock price series at first difference across the different sample groups. Hence, the stock prices are integrated of order 1 for both advanced and emerging economies. Exchange rate on the other hand is stationary at level for full sample and pre-COVID sample in advanced economies but I(1) in other panels and emerging economies. These results indicate that there is a problem of nonstationarity in the data which the estimation model should incorporate in the analysis. Interestingly, the choice model takes this into cognizance.

Table 4 shows the results for the granger causality test using Panel Vector Autoregressive (PVAR) approach ([66] with practical applications of the method in [67]) as the underlying model for conducting granger causality test to test the possible bidirectional causality between stock price and exchange rate as argued from two theories. This is to justify the exchange rate-stock nexuses indicated in the Portfolio Balance Theory and the flow theory presented in Dornbusch and Fischer [11]. The results show that the null hypothesis that stock price does not granger-cause exchange rate is rejected which appears to validate the PBT. Similarly, the null hypothesis that exchange rate does not granger-cause stock price is also rejected.

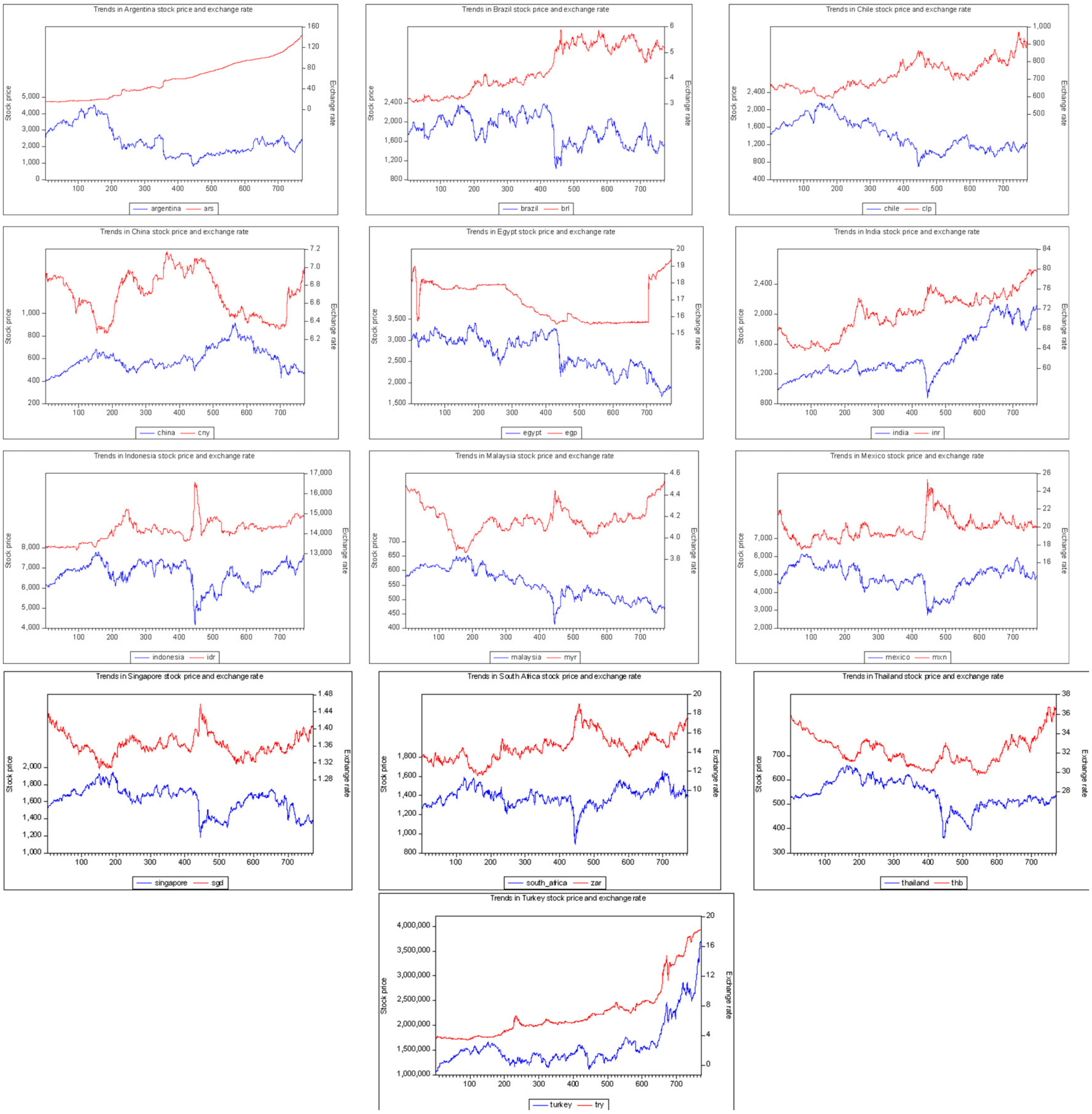

Fig. 2. Trends in Stock Price and Exchange rate [Emerging Economies].
Note: Each graph shows the trend in stock price and exchange rate in each of the emerging economies.

These results suggest that there is bidirectional causality between stock price and exchange rate, which has been unduly overlooked in the literature and would therefore inform the model estimation from two perspectives.

The linear stock price - exchange rate nexus

In order to improve on the study of Salisu and Ndako [4] which adopts the panel ARDL techniques to explain the relationship between stock price and exchange rate with strict adherence to the Portfolio Balance Theory, this study implements the Dynamic Common Correlated Effect (DCCE) model to examine the relationship between the two macroeconomic variables having demonstrated that the two are mutually causing each other. Intuitively, the choice of estimation technique is further justified over the panel ARDL technique as the latter is not designed for variables that exhibit cross-sectional dependence. Interestingly, cross sectional dependence is prevalent in the results as shown with the statistical significance of the cross-sectional dependence (CD) statistics reported in the result tables.

We consider the following for extensive analyses. One, estimation of both the symmetric and asymmetric relationships to differentiate the linear and non-linear effects of stock price and exchange rate on each other, and compare findings between panels of advanced and emerging economies. Two, we bring in the effect of COVID-19 pandemic by estimating the models for the entire COVID-19 sample period, the First Wave, Second Wave, and Third Wave COVID-19 subsamples. For further

Table 3
Unit root test results.

	Stock Price			Exchange rate		
	levels	First difference	I(d)	levels	First difference	I(d)
Advanced Economies						
Full Sample	−1.359	−6.190***	I(1)	−2.416***	–	I(0)
Pre-COVID-19	−1.524	−6.190***	I(1)	−2.486***	–	I(0)
COVID-19 sample	−1.641	−6.190***	I(1)	−1.552	−6.190***	I(1)
First wave	−1.910	−6.190***	I(1)	−2.125*	–	I(0)
Second wave	−1.539	−5.011***	I(1)	−1.995	−4.780***	I(1)
Third wave	−1.826	−6.190***	I(1)	−1.922	−6.190***	I(1)
Emerging Economies						
Full Sample	−1.471	−6.190***	I(1)	−1.916	−6.190***	I(1)
Pre-COVID-19	−2.028	−6.190***	I(1)	−2.006	−6.190***	I(1)
COVID-19 sample	−1.890	−6.190***	I(1)	−1.951	−6.190***	I(1)
First wave	−2.025	−6.190***	I(1)	−1.732	−6.190***	I(1)
Second wave	−1.126	−4.572***	I(1)	−2.085	−4.946***	I(1)
Third wave	−1.575	−6.190***	I(1)	−1.848	−6.153***	I(1)

Note: this table presents the Pesaran PESCADF that takes care of cross section dependence. I(d) is the order of integration of the variables. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

Table 4
PVAR Granger causality tests.

	advanced economies		*emerging economies*	
variables	stock price	exchange rate	stock price	exchange rate
Stock Price	–	18.199***	–	4.764**
Exchange rate	64.737***	–	5.038**	–

Note: this table presents the Panel Vector Autoregressive (PVAR) based granger causality test results to check if there is bidirectional causality between stock price and exchange rate in advanced and emerging countries. It reports the chi-square statistics with its statistical significance. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

Table 5a
Linear stock price-exchange rate nexus [Without control].

	Full Sample	Pre COVID	COVID sample	First Wave	Second Wave	Third Wave
Advanced Economies						
Exchange rate	−0.0533**	−0.0674	−0.1142***	−0.1811***	0.1915*	−0.4924***
	[4.19]	[0.80]	[14.12]	[26.82]	[3.16]	[22.63]
F-Stat	8.49***	17.52***	11.40***	22.40***	4.45***	31.10***
CD-Stat	157.09***	77.39***	111.95***	71.89***	20.12***	47.55***
NOBS	9192	4836	4356	2460	600	1296
No of countries	12	12	12	12	12	12
Emerging Economies						
Exchange rate	−0.1682	−0.3287***	−0.0171	−0.1582*	0.1144	−0.2416**
	[0.86]	[7.59]	[0.02]	[3.77]	[0.59]	[4.87]
F-Stat	137.09***	135.43***	147.71***	23.93***	16.91***	16.49***
CD-Stat	38.51***	12.26***	41.40***	13.45***	10.84***	19.36***
NOBS	9958	5239	4719	2665	650	1404
No of countries	13	13	13	13	13	13

Note: this table presents the Dynamic Common Correlated Effect (DCCE) model results to evaluate the linear effect of stock price on exchange rate without the inclusion of oil price as a control variable in advanced and emerging economies for six sample periods. Stock price is the regressor while exchange rate is the regressand. The Wald test statistics for summing the lagged coefficients are in square brackets "[…]". The CD test statistic tests the null of cross-sectional independence. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

robustness of the results, we exploit all the foregoing analyses by including oil price as a control variable to check for the consistency of the results. Each of the results tables show the relationship of a particular nexus for advanced and emerging economies with and without the inclusion of a control variable. Generally, the results in the tables reflect a significant F-statistics and CD statistics, where the former establish a firm relationship between stock price and exchange rate.

The linear relationship of the stock price-exchange rate nexus is shown in Table 5a. Without accounting for a control variable, a significant negative effect of stock price on exchange rate is recorded for the advanced countries in all the panels

Table 5b
Linear stock price-exchange rate nexus [With control].

	Full Sample	Pre COVID	COVID sample	First Wave	Second Wave	Third Wave
Advanced Economies						
Exchange rate	−0.0738***	−0.0298	−0.2663***	−0.1015	0.1579	−0.5987***
	[3.79]	[0.14]	[23.11]	[2.69]	[1.80]	[40.03]
F-Stat	18.99***	25.10***	39.62***	42.03***	9.49***	34.37***
CD-Stat	157.02***	77.86***	94.00***	65.65***	27.45***	44.66***
NOBS	9192	4836	4356	2460	600	1296
No of countries	12	12	12	12	12	12
Emerging Economies						
Exchange rate	−0.1869	−0.3361***	−0.8000	−0.1329*	0.1063	−0.2510**
	[0.81]	[7.90]	[0.42]	[3.66]	[0.4308]	[5.76]
F-Stat	205.82***	148.36***	146.56***	27.36***	18.55***	18.43***
CD-Stat	35.18***	12.60***	43.93***	8.43***	14.46***	21.28***
NOBS	9958	5239	4719	2665	650	1404
No of countries	13	13	13	13	13	13

Note: this table presents the Dynamic Common Correlated Effect (DCCE) model results to evaluate the linear effect of stock price on exchange rate with the inclusion of oil price as a control variable in advanced and emerging economies for six sample periods. Stock price is the regressor while exchange rate is the regressand. The Wald test statistics for summing the lagged coefficients are in square brackets "[…]". The CD test statistic tests the null of cross-sectional independence. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

with the exception of pre-COVID-19 period which is also negative but not significant. The major exception is the second wave of COVID-19 period which recorded significant positive effects. The results are somewhat identical in the emerging countries, however, pre-COVID-19 sample period is now significant and the second wave of COVID-19 period, though still positive, turns out to be insignificant and with an insignificant negative effect in the full sample period. Another notable difference in the emerging and advanced countries' results is in the value of the coefficient. The emerging economies have a higher effect in the full sample and pre-COVID-19 period compared to other sample periods. However, the reverse case is found for the advanced economies as a higher coefficient value is recorded in the COVID-19 full samples as well as its different waves.

Generally, the results validate PBT in both the advanced and emerging economies, which is consistent with the study of Salisu and Ndako [4] that confirm negative relationships in the stock price-exchange rate nexus. This is mostly reflected in the first and third waves of the COVID-19 pandemic that has a consistent negative and significant relationship for the two economies. The coefficients for the COVID-19 sample are bigger than the pre-COVID sample. This serves as an indication for the need to account for the role of the pandemic in the study and also tow the same line with the study of Chikili and Nguyen [29], which submit that the relationship between stock and exchange rate market amplifies during turbulent times.

Oil price (WTI) is introduced as a control variable to check the consistency of the results and Table 5b shows that the inverse relationship is still dominantly recorded with the exception of the second wave sample period, that remains positive for the advanced and emerging economies. This shows that the negative relationship is consistent in the presence of oil price, however, the statistical significance were affected for some of the sample periods for the two economies in line with Kumeka *et al.* [68] that finds that the relationship between stock price and exchange rate is affected by oil price during COVID-19 pandemic.

To explore the bidirectional causality found in the causality test between the two variables, Tables 6a and b show the linear relationship for the exchange rate-stock price nexus with and without the control variable. Interestingly, the results are quite similar to that of stock price-exchange rate nexus presented in Tables 5a and b. For the advanced economies, a negative significant effect of exchange rate on stock price is recorded for four out of the six samples, while the remaining two, pre-COVID-19 sample is negative but insignificant and the second wave of COVID-19 remains positive and insignificant. The results are the same with and without oil price which again shows the consistency of the results. For the emerging economies, significant inverse relationship is recorded for all the sample periods except for the second wave which is positive and insignificant without the control variable. These results remain the same with a control variable except for the first wave period which becomes insignificant but still negative. The results therefore show that exchange rate leads stock price just as stock price leads exchange rate, which confirms the bidirectional causality and corroborates the understanding of Dahir *et al.* [69].

The linear results show that the negative relationship between stock price and exchange rate may be generic and not affected by the economic size given the consistent negative relationship found throughout the linear relationship model with and without inclusion of oil price. However, higher value is recorded for the emerging economies in the full and pre-COVID-19 sample which becomes lower in the COVID-19 period compared to the advanced economies. In general, the COVID-19 period reports higher magnitudes. Furthermore, the positive relationship shown in the second wave of the pandemic could be due to the Delta variant of the pandemic which surge during the second wave, and therefore have a stand-out effect on

Table 6a
Linear exchange rate- stock price nexus [Without control].

	Full Sample	Pre COVID	COVID sample	First Wave	Second Wave	Third Wave
Advanced Economies						
Stock price	−0.4154**	−0.2472	−0.9182***	−1.6089***	0.04821	−1.2949***
	[4.03]	[0.97]	[10.37]	[20.39]	[0.02]	[28.63]
F-Stat	8.40***	24.26***	17.29***	27.32***	4.62***	43.34***
CD-Stat	91.64***	71.04***	78.61***	61.86***	17.80***	39.89***
NOBS	9192	4836	4356	2460	600	1296
No of countries	12	12	12	12	12	12
Emerging Economies						
Stock price	−0.6940*	−0.7896***	−0.7247*	−1.3856**	3.4144	−0.8015**
	[3.48]	[8.22]	[3.00]	[6.20]	[0.86]	[4.25]
F-Stat	113.07***	136.23***	58.52***	32.24***	9.36***	17.81***
CD-Stat	46.91***	41.47***	39.54***	35.15***	3.40***	23.66***
NOBS	9958	5239	4719	2665	650	1404
No of countries	13	13	13	13	13	13

Note: this table presents the Dynamic Common Correlated Effect (DCCE) model results to evaluate the linear effect of exchange rate on stock price without the inclusion of oil price as a control variable in advanced and emerging economies for six sample periods. Stock price is the regressor while exchange rate is the regressand. The Wald test statistics for summing the lagged coefficients are in square brackets "[…]". The CD test statistic tests the null of cross-sectional independence. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

Table 6b
Linear exchange rate- stock price nexus [With control].

	Full Sample	Pre COVID	COVID sample	First Wave	Second Wave	Third Wave
Advanced Economies						
Stock price	−0.3649**	−0.1948	−0.9693***	−0.8348*	0.7000	−1.1870***
	[5.76]	[0.60]	[2294]	[3.66]	[0.04]	[24.52]
F-Stat	39.30***	29.86***	107.44***	65.17***	5.14***	75.12***
CD-Stat	63.90***	78.86***	78.34***	66.82***	18.74***	40.48***
NOBS	9192	4836	4356	2460	600	1296
No of countries	12	12	12	12	12	12
Emerging Economies						
Stock price	−0.7295*	−0.7366***	−0.8555**	−0.3168	3.2505	−0.7163***
	[3.51]	[8.72]	[5.67]	[0.23]	[0.90]	[3.71]
F-Stat	186.62***	133.55***	118.96***	57.62***	9.85***	20.30***
CD-Stat	31.42***	40.90***	43.60***	47.75***	3.51***	28.31***
NOBS	9958	5239	4719	2665	650	1404
No of countries	13	13	13	13	13	13

Note: this table presents the Dynamic Common Correlated Effect (DCCE) model results to evaluate the linear effect of exchange rate on stock price with the inclusion of oil price as a control variable in advanced and emerging economies for six sample periods. Stock price is the regressor while exchange rate is the regressand. The Wald test statistics for summing the lagged coefficients are in square brackets "[…]". The CD test statistic tests the null of cross-sectional independence. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

the relationship of stock price and exchange rate, although the positive effect has a precedence in Demirandis and Dratos [70].

The non-linear stock price - exchange rate nexus

Sequel to the linear relationship explored between stock price and exchange rate explored with the linear variant of the dynamic common correlated effects model, we investigate whether the linear relationship established between stock price and exchange rate could be specified in asymmetry form such that there could be difference between the positive and negative changes in the variables. In other words, we assess whether the positive and negative changes of stock price (exchange rate) have different effects on exchange rate (stock price) by testing for asymmetry within the panel framework that accounts for cross-section dependence, nonstationarity, and asymmetry. Tables 7a and b and 8a and b show the result to this effect with and without a control variable for stock price-exchange rate nexus and exchange rate-stock price nexus respectively.

The results in Table 7a and Table 7b also corroborates the negative effect of stock price on exchange rate recorded for both positive and negative changes in stock price. The only exception to this still remains the second wave sample period

Table 7a
Nonlinear stock price - exchange rate nexus [Without control].

	Full Sample	Pre COVID	COVID sample	First Wave	Second Wave	Third Wave
Advanced Economies						
Exchange rate	−0.1777***	−0.1722***	−0.1543***	−0.1477***	0.1278	−0.0348
(positive)	[7.70]	[12.81]	[7.07]	[16.67]	[2.40]	[0.43]
Exchange rate	−0.1362***	−0.1955***	−0.1849***	−0.0856**	0.0418	−0.2093***
(negative)	[8.74]	[17.13]	[10.62]	[5.64]	[0.36]	[18.53]
Asymmetry	−0.0184***	−0.0232**	−0.0305**	0.0620***	−0.1697***	−0.1745***
	[14.30]	[5.27]	[4.41]	[49.19]	[22.36]	[38.98]
CD-Stat	130.21***	94.65***	96.58***	66.54***	20.91***	50.35***
Emerging Economies						
Exchange rate	−0.1838**	−0.3302***	−0.1494*	−0.2115***	0.0893	−0.1695**
(positive)	[5.98]	[40.38]	[3.38]	[12.85]	[0.51]	[4.72]
Exchange rate	−0.2285***	−0.3762***	−0.2074***	−0.2435***	−0.0093	−0.3109***
(negative)	[11.71]	[62.93]	[9.84]	[16.29]	[0.01]	[20.81]
Asymmetry	−0.0447*	−0.0460	−0.0579**	−0.0319	−0.0987*	−0.1414***
	[3.70]	[2.24]	[6.31]	[1.73]	[3.36]	[12.59]
CD-Stat	34.61***	34.05	31.46***	17.18***	12.06***	21.33***

Note: this table presents the nonlinear effect of stock price on exchange rate without the inclusion of oil price as a control variable in advanced and emerging economies for six sample periods. Stock price is the regressor while exchange rate is the regressand. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

Table 7b
Nonlinear stock price - exchange rate nexus [With control].

	Full Sample	Pre COVID	COVID sample	First Wave	Second Wave	Third Wave
Advanced Economies						
Exchange rate	−0.1526***	−0.0869	−0.2023***	−0.1010***	0.1457	−0.0614
(positive)	[6.99]	[2.49]	[7.32]	[7.41]	[2.53]	[1.42]
Exchange rate	−0.1709***	−0.1170**	−0.2255***	−0.0426	−0.0261	−0.2384***
(negative)	[8.09]	[4.72]	[9.61]	[1.27]	[0.09]	[25.42]
Asymmetry	−0.1836***	−0.0300***	−0.0231**	−0.0584***	−0.1718***	−0.1769***
	[13.08]	[10.46]	[4.70]	[61.60]	[45.61]	[50.72]
CD-Stat	122.65***	94.99***	93.00***	62.56***	26.57***	44.77***
Emerging Economies						
Exchange rate	−0.2001***	−0.3368***	−0.0934	−0.1480***	0.1071	−0.1228*
(positive)	[9.78]	[65.44]	[1.65]	[15.94]	[0.63]	[3.74]
Exchange rate	−0.2434***	−0.3833***	−0.1605***	−0.1821***	0.0264	−0.2796***
(negative)	[19.84]	[82.68]	[8.56]	[15.46]	[0.04]	[27.68]
Asymmetry	−0.0433*	−0.0464	−0.0671***	−0.0341	−0.0806**	−0.1568***
	[3.35]	[2.46]	[8.06]	[2.11]	[4.84]	[14.61]
CD-Stat	40.58***	35.48***	33.45***	15.01***	14.13***	18.09***

Note: this table presents the nonlinear effect of stock price on exchange rate with the inclusion of oil price as a control variable in advanced and emerging economies for six sample periods. Stock price is the regressor while exchange rate is the regressand. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

which now have some inverse relationship, but still reflect positive relationship in some cases for both advanced and emerging economies. The magnitude of the coefficients does not have a constant pattern in the advanced economies, however, the negative changes in stock price have a higher effect on exchange rate for the emerging economies. The significant effect reveals that asymmetry actually matters in all of the different sample groups for the advanced economies and most of the sample groups in the emerging economies as also observed by Salisu and Ndako [4] which show that asymmetry matters for stock-exchange rate nexus in the study of OECD countries.

For the other nexus, the results in Table 8a and Table 8b validate the negative relationship earlier found in the linear relationship as the positive and negative changes of exchange rate reflect a negative effect on stock price with the second wave period still showing some positive relationship in the emerging economies. However, the asymmetry is less prevalent. Here, only the advanced economies have a significant non-linear relationship for most of the sample groups with and without oil price, while the emerging economies does not have any significant non-linear relationship with and without oil price. This shows that the non-linear relationship between stock price and exchange rate is better reflected in the advanced economies for both nexuses.

Table 8a
Nonlinear exchange rate - stock price nexus [Without control].

	Full Sample	Pre COVID	COVID sample	First Wave	Second Wave	Third Wave
Advanced Economies						
Stock price	−0.5915***	−0.3788**	−0.9009***	−1.0780***	−0.5474***	−0.6216***
(positive)	[7.44]	[4.48]	[13.24]	[11.35]	[7.74]	[7.31]
Stock price	−0.6865***	−0.3917**	−1.1773***	−1.1742***	−1.1102***	−0.2582
(negative)	[7.75]	[5.31]	[17.26]	[16.74]	[7.31]	[0.56]
Asymmetry	−0.0949*	−0.0129	−0.2763***	−0.9617	−0.5627*	0.3634**
	[3.34]	[0.11]	[15.13]	[0.80]	[3.29]	[5.32]
CD-Stat	111.17***	100.84***	82.25***	56.46***	19.24***	43.69***
Emerging Economies						
Stock price	−1.0304***	−1.4548***	−1.3616***	−1.9255***	1.0413	−0.8172*
(positive)	[11.70]	[46.53]	[12.42]	[18.32]	[0.30]	[3.63]
Stock price	−0.8874**	−1.6119***	−2.1924***	0.8537	−0.4621	0.8457
(negative)	[5.21]	[35.32]	[7.63]	[0.00]	[0.07]	[0.31]
Asymmetry	0.1430	−0.1571	−0.8308	2.0109	−1.5035	1.6630
	[1.06]	[1.31]	[1.00]	[0.98]	[1.74]	[1.59]
CD-Stat	53.55***	42.62***	44.86***	38.01***	4.66***	25.34***

Note: this table presents the nonlinear effect of exchange rate on stock price without the inclusion of oil price as a control variable in advanced and emerging economies for six sample periods. Stock price is the regressor while exchange rate is the regressand. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

Table 8b
Nonlinear exchange rate - stock price nexus [With control].

	Full Sample	Pre COVID	COVID sample	First Wave	Second Wave	Third Wave
Advanced Economies						
Stock price	−0.5989***	−0.2852*	−0.8517***	−0.1569	−0.6890***	−0.9873***
(positive)	[10.81]	[2.82]	[12.42]	[0.14]	[10.32]	[36.75]
Stock price	−0.6788***	−0.2816*	−0.9222***	−0.3253	−1.2293***	−0.8870***
(negative)	[9.81]	[3.16]	[9.52]	[0.72]	[7.81]	[25.52]
Asymmetry	−0.0798	−0.0035	−0.0705	−0.1684	−0.5403*	−0.1003
	[2.17]	[0.01]	[0.98]	[2.56]	[2.75]	[1.58]
CD-Stat	114.11***	105.92***	84.53***	59.61***	20.41***	45.32***
Emerging Economies						
Stock price	−0.9391***	−1.4515***	−1.1245***	−1.2680***	1.2571	−1.0364**
(positive)	[13.39]	[53.93]	[9.10]	[15.71]	[0.47]	[6.22]
Stock price	−0.7990***	−1.6098***	−1.9588*	−0.2076	−0.1413	2.5639
(negative)	[6.88]	[35.55]	[3.66]	[0.03]	[0.01]	[0.51]
Asymmetry	−0.1400	−0.1582	−0.8342	1.0603	−1.3984	3.6004
	[1.71]	[1.24]	[0.66]	[1.14]	[1.62]	[1.08]
CD-Stat	46.50***	32.82***	48.89***	46.97***	5.24***	23.74***

Note: this table presents the nonlinear effect of exchange rate on stock price with the inclusion of oil price as a control variable in advanced and emerging economies for six sample periods. Stock price is the regressor while exchange rate is the regressand. ***, **,* indicate 1%, 5%, and 10% statistical significance respectively.

Conclusion

This study revisits the relationship between exchange rate and stock prices with analysis of advanced and emerging economies, the role of the COVID-19 pandemic, and analysis of the two functional forms suggested by theory between the two variables. A preliminary panel granger causality test was conducted to inform the direction of impact analysis between stock price and exchange rate which makes it different from existing studies that arbitrarily select a direction. Other contributions are the inclusion of more countries, accounting for the effect of COVID-19 pandemic with distinct analysis for the waves of the pandemic in the relationship between stock price and exchange rate and checking the consistency of the results in the presence of oil price as a control variable. The Dynamic Common Correlated Effects (DCCE) model was employed since it is designed for variables that are characterized by cross sectional dependence, a feature that we show to be prominent in the data but ignored in previous studies. The analyses cover the full sample, pre-COVID-19 period, COVID-19 period, and the first wave, second wave, and third wave of the pandemic for both symmetric (linear) and asymmetric (nonlinear) relationships.

The main highlight of the findings is that the results validate the theoretical constructs which specify the negative relationship between stock price and exchange rate in advanced and emerging economies with the magnitude of the effects being more prominent during the COVID-19 pandemic. Based on the findings, we offer recommendations to monetary policy authorities (usually central banks) of the countries, financial investors, and researchers in the study area. We recommend that the monetary policy authorities should monitor the forex market and incorporate its fundamentals into their reaction functions to ensure optimal policy decisions given that exchange rate depreciation (i.e. appreciation of the domestic currency) is associated with good performance of the stock market, and vice versa. Financial investors can also make profit by investing in international currencies particularly the US dollar in economies with well performing stock markets. Also, researchers should take note that the relationship between the two variables is asymmetric (positive and negative changes to the variables differ in impacts), and this is more prominent in advanced countries than the emerging counterparts. Finally, our results are largely robust as they are consistent across several subsamples, panels of countries, and model extensions.

Declaration of Competing Interest

We, the authors (Ahmed S. Alimi and Idris A. Adediran) hereby declare that there is no conflict of interest on this manuscript.

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