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THE RELATIONS BETWEEN EXCHANGE RATES AND STOCK INDEXES FOR BRAZIL

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ABSTRACT

This research investigates the dynamic relations between exchange rates and stock indexes for Brazil by adopting the Granger causality test and the quantile regression model. The causality test results show that changes in stock indexes cause changes in exchange rates in the full sample period and all five sub-periods. The results of different quantile regressions reveal an inverse U-shape pattern of the negative coefficients, which indicates that the negative correlation between changes in exchange rates and changes in stock indexes is even clearer when exchange rates become extremely low or high. The empirical results are consistent with the portfolio approach, which suggests that changes in stock indexes result in changes in exchange rates (the stock market leads the foreign exchange market) with the negative sign of correlation.

JEL: F31, G15

KEYWORDS: Exchange Rates, Stock Indexes, Granger Causality, Quantile Regression

INTRODUCTION

The dynamic relations between exchange rates and stock indexes have been an important research topic in academia. However, the literature regarding the direction of causality for these two financial variables is still inconclusive. This is possibly due to the characteristics of different markets, frequency of data adopted, and different time periods used for the studies. Previous studies show the causality between exchange rates and stock indexes can be either unidirectional or bidirectional. For the unidirectional causality, the traditional approach (Aggarwal, 1981; Abdalla and Murinde, 1997) indicates that the exchange rate leads the stock index while the portfolio approach (Krueger, 1983; Bahmani-Oskooee and Sohrabian, 1992) illustrates that the stock index leads the exchange rate. For the bidirectional causality (or feedback interaction), the exchange rate leads the stock index and the stock index also leads the exchange rate so both variables simultaneously interact with each other.

The traditional approach states that changes in exchange rates cause changes in stock prices but the sign of correlation can be either negative or positive. If an individual firm is an exporter, the domestic currency depreciation (appreciation) relative to U.S. dollar will reduce (rise) its exporting cost (quoted in U.S. dollar) and make the firm's products become more (less) competitive in the international market. Therefore, the firm's earnings may increase (decrease) and the good (poor) earnings report drives the firm's stock price up (down). Thus, the domestic currency depreciation (appreciation) has a positive (negative) effect on an exporter and causes its stock price to increase (decrease). On the contrary, if an individual firm is an importer, the domestic currency depreciation (appreciation) relative to U.S. dollar will increase (decrease) its importing cost (quoted in its home currency) and make the firm's products become less (more) competitive in the domestic market. Therefore, the firm's earnings may decrease (increase) and the poor (good) earnings report drives the firm's stock price down (up). Thus, the domestic currency depreciation (appreciation) has a negative (positive) effect on an importer and causes its stock price to decrease (increase). If an individual firm involves in both export and import operations, change in the domestic currency (depreciation or appreciation) could lead to either a higher or a lower stock price, depending on which one (export or import) outweighs the other in the firm. In addition, the overall (aggregate) effect on the stock market index cannot be determined, depending on which one (export or import) outweighs the other in aggregation. Hence, the sign of correlation is uncertain.

Opposite to the traditional approach, the portfolio approach expects that changes in stock prices result in changes in exchange rates and the sign of correlation is negative. When the domestic stock prices go up (down), the wealth of domestic investors will also increase (decrease). As the wealth of domestic investors increases (decreases), the demand for money will also increase (decrease). Increase (Decrease) in demand for money will cause the interest rate to climb (drop). A higher (lower) interest rate will attract more foreign capital to flow into (out of) the domestic market. More foreign capital inflows (outflows) increase the demand (supply) for the domestic currency. Therefore, the domestic currency will appreciate (depreciate). An alternative way to explain the portfolio approach is that increase (decline) in domestic stock prices will attract (alert) foreign capital to flow into (out of) the domestic market for engaging in (ending) speculation. Foreign capital inflows (outflows) mean a higher demand (supply) for the domestic currency, which will lead to appreciation (depreciation) of the domestic currency. The sign of correlation is negative because the exchange rate is expressed as the price of domestic currency per U.S. dollar. Thus, decrease (increase) in exchange rate represents that one U.S. dollar can convert to less (more) amount of domestic currency, which means domestic currency appreciation (depreciation).

Feedback interaction (relation) is the bidirectional causality, which combines the traditional approach and the portfolio approach simultaneously. The causality exists from the stock market to the exchange rate market and the causality also occurs from the exchange rate market to the stock market. Hence, either exchange rates or stock indexes can take the lead and the sign of correlation is uncertain.Although a lot of studies have discussed the relationship between stock price indexes and exchange rates, most of them focus on emerging Asian countries and many of them use the low frequent (monthly) data with the older range of time period. In 1999, Brazil changed from a crawling peg exchange rate arrangement to a floating exchange rate system. There are very few literatures focusing on discussing the dynamic relations between the exchange rate and stock markets for Brazil. In this research, the Granger causality test and the quantile regression model are adopted to examine the relations between exchange rates and stock indexes for Brazil. Moreover, the daily data with more recent time period (from January 2007 to April 2019) are used to see whether there are new findings. During the full sample period of this study, there are important events such as the global financial crisis and Brazilian economic crisis. The impact of these events on the relations between exchange rates and stock indexes is worth observing and analyzing. The remaining sections of this paper are presented as follows. The next section describes the literature review, followed by data and methodology. After that, results and discussion are shown. The conclusion is summarized, finally.

LITERATURE REVIEW

Aggarwal (1981) investigates the impact of changes in exchange rates on U.S. stock prices (the traditional approach) using the monthly data from July 1974 to December 1978, the floating rate period for U.S. dollar. For this time period, the results show that exchange rates and stock prices are positively correlated; a decline (an increase) in the value of U.S. dollar was correlated with a decrease (an increase) in U.S. stock prices. Bahmani-Oskooee and Sohrabian (1992) propose that changes in stock prices could affect changes in exchange rates (the portfolio approach) and the bidirectional causality between exchange rates and stock prices is possible. They use monthly data of the effective exchange rate of the dollar and S&P 500 index from July 1973 to December 1988 to test the causality and cointegration between these two variables. They find that there is a short-run two-way relationship between exchange rates and stock prices but they are not able to find the long-run relationship between these two variables.

Several studies have investigated the relationship between stock prices and exchange rates for Asian emerging countries. Abdalla and Murinde (1997) examine the causal linkages between exchange rates and stock prices in emerging markets of India, Korea, Pakistan and Philippines. Using the monthly data on the International Finance Corporation (IFC) stock price index and the real effective exchange rate from January 1985 to July 1994, they find the unidirectional causality from exchange rates to stock prices in all countries, except for Philippines.

Using the daily data from January 1986 to June 1998 (including the time period of the 1997 Asian financial crisis), Granger *et al.* (2000) apply unit root and cointegration models to test the Granger causality between stock prices and exchange rates for nine Asian economies. They find that exchange rates lead stock prices for South Korea but also find that stock prices lead exchange rates for Philippines. Their results for Hong-Kong, Malaysia, Singapore, Thailand, and Taiwan show strong bidirectional causality. Tabak (2006) uses the daily stock price index and exchange rate data from August 1994 to May 2002 to study the dynamic relationship between stock prices and exchange rates for Brazil. He finds that stock prices lead exchange rates in the linear Granger causality test but exchange rates lead stock prices in the nonlinear Granger causality test.

Lin (2012) uses the monthly data of exchange rate, stock price, interest rate, and foreign reserves from January 1986 to December 2010 and study the comovement between exchange rates and stock prices for six Asian emerging countries. Lin's empirical results indicate that the comovement becomes stronger during the crisis periods, compared to the tranquil periods. Using the monthly data of stock price indexes and exchange rates from January 1992 to December 2009 for six Asian countries, Tsai (2012) examines the relationship between the stock price index and the exchange rate by utilizing the quantile regression model. Tsai finds that the negative relation between stock and exchange rate markets is even greater when exchange rates are extremely low or high.

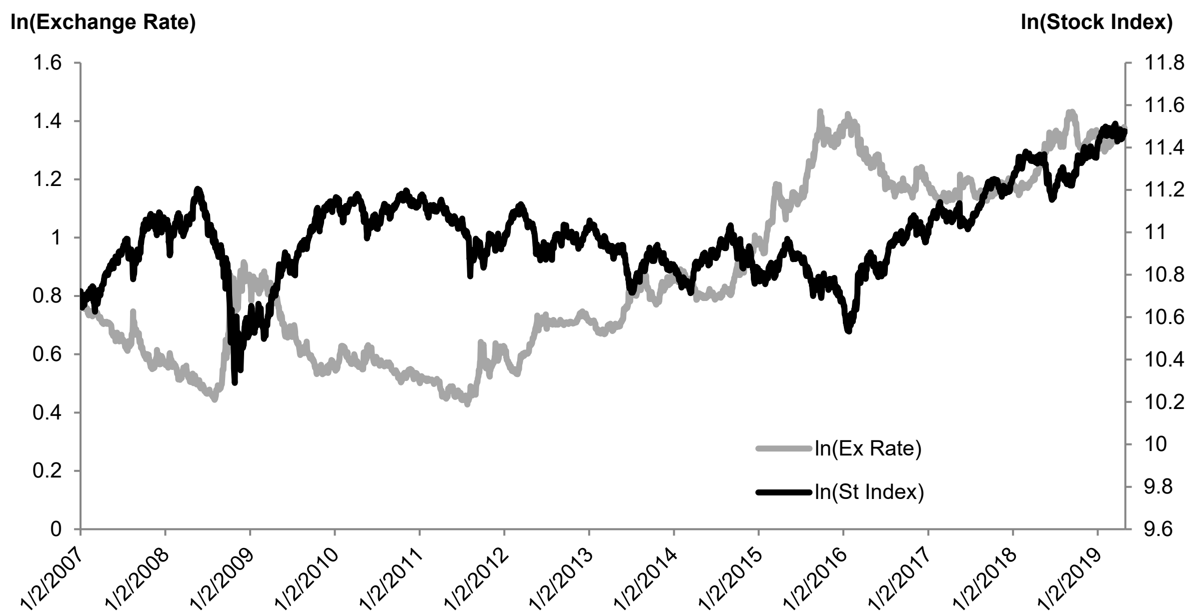
Tudor and Popescu-Dutaa (2012) use the monthly data from January 1997 to March 2012 to examine the Granger causality between movements in stock prices and exchanges rates for thirteen developed and emerging markets (Australia, Canada, France, Hong Kong, Japan, U.K., U.S., Brazil, China, India, Korea, Russia, and South Africa). They collect monthly stock price indexes from the Morgan Stanley Capital International database and monthly exchange rates from the Pacific Exchange Rate Service. They find a two-way causality between stock indexes and exchange rates for Korea, a unidirectional causality from exchange rates to stock indexes for Brazil and Russia, and a unidirectional causality from stock indexes to exchange rates for U.K.Cakan and Ejara (2013) investigate linkages between exchange rates and stock prices for twelve emerging markets from May 1994 to April 2010 by adopting the linear and nonlinear Granger causality tests. Their empirical test results show that there is bidirectional causality in most of markets for both the linear and nonlinear Granger causality tests. However, there is only a unidirectional causality (the direction is only from exchange rates to stock prices) for Korea, Mexico, and Taiwan and the causality direction is only from stock prices to exchange rates for India in the linear Granger causality test. In the nonlinear Granger causality test, only stock prices lead exchange rates for Brazil and Poland but there is no causality in either direction for Taiwan.Mishra (2016) uses monthly data from January 1998 to June 2015 to analyze the dynamic interlinkage between exchange rate changes and stock returns for Brazil, Russia, India, and China (BRIC nations). The estimation of the quantile regression approach shows significantly negative coefficients across quantiles for Brazil, Russia, and India, but not for China. The coefficients estimated from different quantile regressions for Brazil roughly show a pattern of downward trend.

DATA AND METHODOLOGY

In this study, the daily exchange rate and stock index data from January 2, 2007 to April 30, 2019 are collected. The daily exchange rates (bid rates, price of Brazilian real (BRL) per U.S. dollar) are from

Central Bank of Brazil (Banco Central do Brasil) website. Ibovespa is the major stock market index in Brazil and it represents the average performance of most active and benchmark stocks traded in the São Paulo Stock Exchange (Bovespa). The daily closing Ibovespa data are from Bovespa website. All exchange rate and stock index data are transformed into natural logarithmic scale and their time series plots are shown on Figure 1.

Figure 1: Time Series Plots of Exchange Rates and Stock Indexes (Natural Logarithmic Scale) from January 2, 2007 to April 30, 2019 for Brazil



This figure shows the time series plots of exchange rates and stock indexes (natural logarithmic scale) from January 2, 2007 to April 30, 2019 for Brazil. Note: The exchange rate is expressed as the price of Brazilian real per U.S. dollar. Thus, decrease (increase) in exchange rate represents that one U.S. dollar can convert to less (more) Brazilian real, which means that Brazilian real appreciates (depreciates).

Unit Root Test

If the independent and dependent variables exhibit a unit root (nonstationary), the regression result will be spurious. To avoid the false regression, a unit root test is needed. Dickey and Fuller (1979) test a unit root of autoregressive part of relation but include only a first-order autoregressive process. The augmented Dickey-Fuller (ADF) test accommodates a higher-order autoregressive process and includes lagged difference terms of Y_t in the test regression. The equation for the augmented Dickey-Fuller (ADF) test with a linear time trend is as follow.

$$\Delta Y_t = \alpha + \gamma t + \omega Y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

where $\Delta = 1 - L$; L is the lag operator; t is a trend variable; p is the order of lags. Y_t is a financial time series (the exchange rate or the stock index). Y_t is said to have a unit root if we fail to reject the null hypothesis, H_0: $\omega = 0$. The selection of the lag length (p) is based on Schwarz Bayesian information criterion (SBC) and data-dependent selection procedure suggested by Ng and Perron (1995).

Unit Root Test with a Structural Break

A financial time series may happen to a structural change because of a main event, such as a financial crisis. The standard unit root test may be biased if a series of data are stationary with a breakpoint. To resolve the issue of the structural break and make the unit root test remain valid, Zivot and Andrews (1992) suggest a unit root test model with a structural break as follow:

$$\Delta Y_t = \alpha + \gamma t + \omega Y_{t-1} + \rho DU_t(\theta) + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \varepsilon_t \quad (2)$$

where $DU_t(\theta) = 1$ for $t > T\theta$, and $DU_t(\theta) = 0$ otherwise; $\theta = T_b/T$, representing the place where the structural break occurs; T is the sample size and T_b is the structural break date.

Cointegration Tests

If the independent and dependent variables are nonstationary, the cointegration tests could be conducted to test the long-run relationship between these variables. Johansen (1991, 1995) cointegration rank test and Engle and Granger (1987) two-step cointegration test are used to examine whether exchange rates and stock indexes are cointegrated in Brazil for this study. If the test results show that there is no cointegration, the long-run equilibrium relationship does not exist between exchange rates and stock indexes.

Johansen Cointegration Rank Test

A vector autoregressive (VAR) of order p is written as follow:

$$Y_t = \sum_{i=1}^{p} A_i Y_{t-i} + BD_t + \varepsilon_t \quad (3)$$

Y_t is a k-vector of nonstationary I(1) variables, integrated of order one; D_t is a d-vector of deterministic variables (intercept, trend, and/or dummy variables); ε_t is a k-vector of innovations.

We may rewrite this VAR as follow:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + BD_t + \varepsilon_t \quad (4)$$

where $\Pi = \sum_{i=1}^{p} A_i - I$; $\Gamma_i = -\sum_{j=i+1}^{p} A_j$

If the coefficient matrix (Π) has reduced rank ($r < k$), then there exist $k \times r$ matrices α and β so that $\Pi = \alpha\beta'$ and $\beta' Y_t$ is I(0). r is the number of the cointegrating rank and each column of β is the cointegrating vector. The elements of α are known as the adjustment parameters in the vector error correction model (VECM). Johansen's maximum likelihood method is to estimate the Π matrix from an unrestricted VAR and to test the null hypothesis H_0: Rank(Π) ≤ k versus the alternative hypothesis H_1: Rank(Π) > k. The trace statistic of Johansen's cointegration rank test is calculated as $-T \sum_{i=r+1}^{k} \ln(1 - \lambda_i)$ where T is the sample size and λ_i is the eigenvalue.

Engle and Granger Two-step Cointegration Test

Engle and Granger (1987) two-step model is the residual-based cointegration test. The first step is to estimate the following regressions.

$$X_t = \alpha_1 + \kappa_1 t + \beta_1 Y_t + e_{1t} \quad (5)$$

$$Y_t = \alpha_2 + \kappa_2 t + \beta_2 X_t + e_{2t} \quad (6)$$

The second step is to examine whether the estimated residuals, $\hat{e}_{1t}$ and $\hat{e}_{2t}$, are I(0) using ADF test. The null hypothesis is that non-cointegration exists between X_t (exchange rates) and Y_t (stock indexes). If the residuals are not I(0), we fail to reject the null hypothesis and there is no cointergration between X_t and Y_t, If the residuals are I(0), we reject the null hypothesis and there is cointergration between X_t and Y_t,

Granger Causality Test

If the cointegration does not exist, the following linear equations are used in testing the Granger (1969) causality.

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta X_{t-i} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \varepsilon_{1t} \quad (7)$$

$$\Delta Y_t = \gamma_0 + \sum_{i=1}^{p} \gamma_i \Delta X_{t-i} + \sum_{i=1}^{p} \rho_i \Delta Y_{t-i} + \varepsilon_{2t} \quad (8)$$

On equation (7), the null hypothesis is H_0: $\beta_1 = \beta_2 = \beta_3 = \ldots = \beta_p = 0$. Failing to reject the null hypothesis indicates that stock indexes do not Granger cause exchange rates. Similarly, on equation (8), the null hypothesis is H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \ldots = \gamma_p = 0$. Failing to reject the null hypothesis indicates that exchange rates do not Granger cause stock indexes. The selection of the lag length (p) is based on Schwarz Bayesian information criterion (SBC) and data-dependent selection procedure suggested by Ng and Perron (1995). If the cointegration exists, an error correction term is needed in testing the Granger causality. The linear equations are as follows.

$$\Delta X_t = \alpha_0 + \lambda_1 (X_{t-1} - \varphi Y_{t-1}) + \sum_{i=1}^{p} \alpha_i \Delta X_{t-i} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \varepsilon_{1t} \quad (9)$$

$$\Delta Y_t = \gamma_0 + \lambda_2 (X_{t-1} - \varphi Y_{t-1}) + \sum_{i=1}^{p} \gamma_i \Delta X_{t-i} + \sum_{i=1}^{p} \rho_i \Delta Y_{t-i} + \varepsilon_{2t} \quad (10)$$

where λ_1 and λ_2 represent speeds of adjustment. On equation (9), the null hypothesis is H_0: $\beta_1 = \beta_2 = \beta_3 = \ldots = \beta_p = 0$ and $\lambda_1 = 0$. Failing to reject the null hypothesis indicates that stock indexes do not Granger cause exchange rates. Similarly, on equation (10), the null hypothesis is H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \ldots = \gamma_p = 0$ and $\lambda_2 = 0$. Failing to reject the null hypothesis indicates that exchange rates do not Granger cause stock indexes. In this research, in addition to conducting the Granger causality test for the full of sample period (12⅓ years, from January 2, 2007 to April 30, 2019), we also divide it into five sub-periods and conduct the Granger causality test for each sub-period. These five sub-periods are described as follows.

Period I (January 2, 2007 to February 28, 2009): This time period includes the global financial crisis, originally resulted from the U.S. subprime mortgage crisis. Eun and Resnick (2017) point out that the U.S. subprime mortgage crisis began in summer 2007 and Lehman Brothers went bankrupt in September 2008; Dow Jones Industrial Average (DJIA) fell by 50% from October 2007 to February 2009. Brazil is the main producer and exporter of commodities (iron ore, soybean, coffee, sugar, meat, etc.) in the world. Before the global financial crisis, high economic growth in China and other emerging markets increased the demand for commodities and the higher prices of commodities benefited Brazil. Moreover, a stronger consumption growth also fueled the Brazilian economy. According to the International Monetary Fund (IMF), Brazilian real GDP growth was 6.1% and 5.1% in 2007 and 2008, respectively. During the global financial crisis, the low growth in China decreased the demand of commodities, leading to lower prices of commodities. According to the IMF, Brazilian real GDP growth decreased to –0.1% in 2009. To respond the crisis, Brazil enacted policies of increasing public spending and reducing the interest rate to stimulate the economy. Period II (March 1, 2009 to July 31, 2011): This period is from the post global financial crisis to the end of the U.S. debt ceiling gridlock. The Brazilian economy recovered after the global financial crisis, resulting from the recovery of commodity prices and economic stimulation policies. From Figure 1, we can see that the stock market index went up and Brazilian real appreciated in this time period. According to the IMF, Brazilian real GDP growth rose to 7.5% in 2010 and maintained at 4% in 2011. Period III (August 1, 2011 to July 31, 2014): This is the relatively stable time period prior to Brazilian economic crisis. The stock market index was quite stable and the depreciation of Brazilian real was managed. According the IMF, Brazilian real GDP growth was 1.9% in 2012 and 3% in 2013.

Period IV (August 1, 2014 to December 31, 2016): Brazil experienced economic crisis during this time period. Falling commodity prices, excessive spending and subsidies of the government, and multiple corruption scandals negatively affect investment and consumption. Figure 1 shows that the depreciation of Brazilian real escalated in 2015. According to the World Bank (2019), the economic activities in Brazil reduced significantly in 2015 and 2016. Based on the IMF, Brazilian real GDP growth was 0.5% in 2014 and became negative in 2015 and 2016 (–3.5% in 2015 and –3.3% in 2016). Period V (January 2, 2017 to April 30, 2019): This is the post economic crisis period. Brazilian economy began with a gradual recovery in 2017. Economic reforms intend to limit the growth of public spending and restore economic health. The reforms and recovery process may take time to see the result. According to the IMF, Brazilian real GDP growth was 1.1% in both 2017 and 2018 and is projected to be 2.1% in 2019. In addition to the Granger causality test, the dynamic relations between exchange rates and stock indexes can be investigated using the quantile regression.

Quantile Regression

Koenker and Bassett (1978) introduce quantile regression, which extends the ordinary least squares (OLS) regression model to conditional specific percentiles (or quantiles) of the dependent variable. A quantile regression estimates the change in a specified quantile of the dependent variable affected by a unit of change in the independent variable(s). It is especially useful where the extreme values are important in the research. It is also meaningful to estimate quantile regressions of different quantiles to see whether there is a pattern. The quantile regression is described as follows.

For a random sample of Y ($y_1, y_2, y_3, \ldots, y_n$), the sample mean is to minimize the sum of squared residuals, $\underset{\mu \in R}{Min} \sum_{i=1}^{n} (y_i - \mu)^2$, which can be extended to the conditional mean function $E(Y|x) = x'\beta$ by solving $\underset{\beta \in R^p}{Min} \sum_{i=1}^{n} (y_i - x_i'\beta)^2$.

The linear conditional quantile function, $Q(\tau|x) = x'\beta(\tau)$, can be estimated by solving $\underset{\beta \in R^p}{Min} \sum_{i=1}^{n} \rho_\tau (y_i - x_i'\beta)$, where $\rho_\tau(\cdot)$ is the tilted absolute value function. For any quantile τ ($0 < \tau < 1$), the estimate $\hat{\beta}(\tau)$ is the τ-th regression quantile. If $\tau = 0.5$, it is the median regression, which minimizes the sum of absolute residuals.

RESULTS AND DISCUSSION

Table 1 shows the results of ADF unit root test. The tau test statistics for both exchange rates and stock indexes are not significant in level, which indicates that the null hypothesis of unit root cannot be rejected. Therefore, this result suggests nonstationary in level. The tau test statistics for both exchange rates and stock indexes are significant in the first difference, which points out that the null hypothesis of unit root is rejected. Therefore, this result suggests stationary in the first difference. Although not shown on Table 1, Phillips-Perron (PP) (1988) unit root test is also performed and PP test results are consistent with ADF test results. Thus, the unit root test results show that exchange rates and stock indexes are nonstationary and integrated of order one, I(1). If a time series follows the random walk, its first difference will be stationary. The difference stationary for exchange rates and stock indexes indicates the random walk process. Thus, the nonstationary problem can be avoided by using the difference (change) of each time series.

Table 1: ADF Unit Root Test

Time Series	Level (Y_t)	First Difference (Δy_t)
Exchange Rate	–2.3936 (0.3828)	–38.8589*** (< 0.0001)
Stock Index	–2.2442 (0.4643)	–40.2713*** (< 0.0001)

*This table shows the results of ADF unit root test. Tau test statistic is shown first and p-value is shown below in a parenthesis. *** indicates significance at 1% level.*

The time series data used in this research cover twelve and one-third years. It is likely to happen to the structural break because the important event occurred. To address this issue, ADF unit root test with a structural break is conducted and the test results are displayed on Table 2. The test results on Table 2 show that the null hypothesis of unit root cannot be rejected in level and it is rejected in the first difference for both exchange rates and stock indexes. Therefore, the test results of ADF unit root test with a structural break are not different from the test results of standard ADF unit root test. The structural break does not change the test results.

Table 2: ADF Unit Root Test with a Structural Break

Time Series	Level (Y_t)	First Difference (ΔY_t)
Exchange Rate	–2.9328 (0.3009) [0.1821]	–38.8796*** (< 0.0010) [0.1473]
Stock Index	–3.4733 (0.1095) [0.8508]	–40.2863*** (< 0.0010) [0.1397]

*This table shows the results of ADF unit root test with a structural break. $\theta = T_b/T$, representing the place where the structural break occurs; T is the sample size and T_b is the structural break date. Tau Test Statistic is shown first and p-value is shown below in a parenthesis, followed by θ shown in a bracket. *** indicates significance at 1% level.*

Table 3 shows the results of Johansen cointegration rank test. By default, the critical values at 5% significance level are used for testing the null hypothesis (H_0) of no cointegration For the null hypothesis of rank = 0, the trace test statistic of 7.1852 is less than the 5% significance critical value of 15.34 so the null hypothesis cannot be rejected. For the null hypothesis of rank = 1, the trace test statistic of 0.0021 is less than the 5% significance critical value of 3.84 so the null hypothesis cannot be rejected, either. Based on the test results on Table 3, there is no cointegration between exchange rates and stock indexes. The long-run relationship between these two financial series does not exist.

Table 3: Johansen Cointegration Rank Test

H_0	H_1	Eigenvalue	Trace	5% Critical Value
Rank = 0	Rank > 0	0.0024	7.1852	15.34
Rank = 1	Rank > 1	< 0.0001	0.0021	3.84

This table shows the results of Johansen cointegration rank test. H_0 is the null hypothesis and H_1 is the alternative hypothesis. Trace test statistic is computed by $-T\sum_{i=r+1}^{k} ln\,(1-\lambda_i)$ where T is the sample size and λ_i is the eigenvalue.

Table 4 shows the results of Engle-Granger two-step cointegration test. The tau test statistics for both exchange rates and stock indexes are not significant. Therefore, the test results suggest that exchange rate series and stock index series do not cointegrate. Since the test results from Table 3 and Table 4 indicate no cointegration between exchange rates and stock indexes, we can conduct the Granger causality test using system equations (7) and (8), without adding an error correction term.

Table 4: Engle-Granger Two-step Cointegration Test

Time Series	Test Statistic (*p*-value)
Exchange Rate	–1.9003 (0.6667)
Stock Index	–1.8567 (0.6821)

This table shows the results of Engle-Granger two-step cointegration test. Tau test statistic is shown first, and p-value is shown below in a parenthesis.

Table 5 presents the results of the Granger causality test between changes in exchange rates and changes in stock indexes. For the full sample period (January 2, 2007 to April 30, 2019), the test results show feedback interaction (bidirectional causality): changes in stock indexes Granger cause changes in exchange rates (significant at 1% level) and changes in exchange rates also Granger cause changes in stock indexes (significant at 5% level). In addition, we divide the full sample period into five sub-periods. The test result for each sub-period is different from that for the full sample period. Period I (January 2, 2007 to February 28, 2009) includes the event of global financial crisis. The results for Period I show that the stock index leads the exchange rate significantly (at 1% level) but the exchange rate leads the stock index only with a weak significance (at 10% level). Therefore, the stock market significantly takes the lead during this time period. The results for Period II and III show feedback interaction; the bidirectional causality results indicate that either the stock or the exchange rate market can lead the other and the interaction between these two markets is strong.

The results for Period IV and Period V show the unidirectional causality from changes in stock indexes to changes in exchange rates, meaning that only the stock market leads the exchange rate market. The portfolio approach can explain the results. Period IV covers the time period of Brazilian economic crisis. During the economic crisis, the stock prices decline, leading to the decline in the wealth of investors. The decline in the wealth of investors causes foreign capital to flow out the equity market and leave Brazil. Foreign capital outflows result in the depreciation of Brazilian real. Period V is the post economic crisis (recovery) period. When the economy begins to recover, the stock prices gradually increase, and foreign investors regain the confidence. Foreign capital starts flowing into the domestic stock market and the capital inflows result in the appreciation of Brazilian real. Overall, changes in stock indexes cause changes in exchange rate significantly (at 1% level) in the full sample period and all sub-periods as well. Changes in exchange rates cause changes in stock indexes significantly (at 5% level) in the full sample period and only two sub-periods. The portfolio approach matched the situation of the stock and exchange rate markets in Brazil during all of time periods in this study,

Table 5: The Granger Causality Test between Changes in Exchange Rates (ΔEX) and Changes in Stock Indexes (ΔSI) for Brazil

Time Period	H_0: ΔSI → ΔEX F-statistic (*p*-value)	H_0: ΔEX → ΔSI F-statistic (*p*-value)
Period I: 01/02/2007 – 02/28/2009	29.94*** (0.0001)	2.54* (0.0796)
Period II: 03/01/2009 – 07/31/2011	9.43*** (0.0001)	3.97** (0.0191)
Period III: 08/01/2011 – 07/31/2014	8.58*** (0.0002)	4.85*** (0.0080)
Period IV: 08/01/2014 – 12/31/2016	13.74*** (0.0001)	0.57 (0.5642)
Period V: 01/02/2017 – 04/30/2019	10.52*** (0.0001)	1.05 (0.3511)
Full Sample Period: 01/02/2007 – 04/30/2019	75.32*** (0.0001)	3.66** (0.0258)

*This table shows the results of the Granger causality test between changes in exchange rates and changes in stock indexes for Brazil. All exchange rate and stock index data are transformed into natural logarithmic scale. F-statistic is shown first and p-value is shown below in the parenthesis. ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.*

The quantile regression can also examine the dynamic relations between exchange rates and stock indexes. Since Table 5 results support the portfolio approach, indicating the causality from changes in stock indexes to changes in exchange rates, we use change in the stock index at date t (ΔSI_t) as the independent variable and change in the exchange rate at date t (ΔEX_t) as the dependent variable in the quantile regression. The results of estimating quantile regressions for the full sample period are summarized on Table 6. First of all, the coefficients (β_τ) estimated under different quantiles are all negative and significant. This indicates that increase (decrease) in the stock price causes decrease (increase) in the exchange rate, which means the Brazilian real appreciation (depreciation). Second, the absolute value of the coefficient is even higher when the quantile is extremely low (0.05^{th}) or high (0.95^{th}). This indicates that decrease (increase) in the stock price during the economic crisis (boom) will lead to even more depreciation (appreciation) of the Brazilian real.

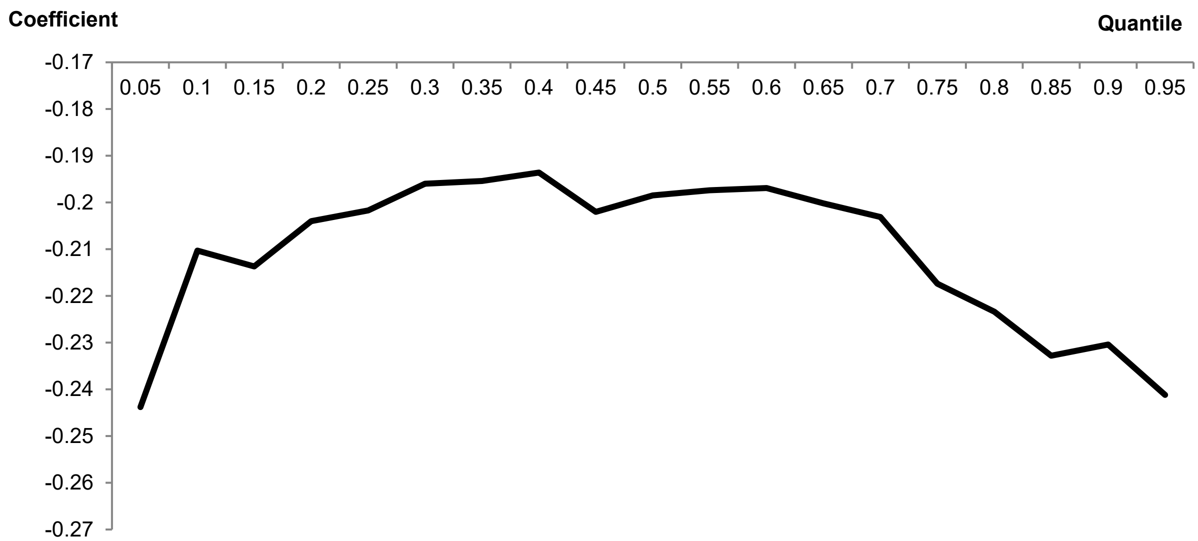
Table 6: The Results of Estimating Quantile Regression: $\Delta EX_t = \alpha_\tau + \beta_\tau \Delta SI_t + \varepsilon_\tau$

Quantile	Coefficient (β_τ)	t-statistic (*p*-value)	Quantile	Coefficient (β_τ)	t-statistic (*p*-value)
0.05	–0.2438	– 9.68*** (<0.0001)	0.55	–0.1974	–22.80*** (<0.0001)
0.10	–0.2103	–13.54*** (<0.0001)	0.60	–0.1969	–23.58*** (<0.0001)
0.15	–0.2137	–15.91*** (<0.0001)	0.65	–0.2002	–22.25*** (<0.0001)
0.20	–0.2040	–19.11*** (<0.0001)	0.70	–0.2031	–30.91*** (<0.0001)
0.25	–0.2017	–21.20*** (<0.0001)	0.75	–0.2174	–22.24*** (<0.0001)
0.30	–0.1960	–22.38*** (<0.0001)	0.80	–0.2234	–36.18*** (<0.0001)
0.35	–0.1954	–22.60*** (<0.0001)	0.85	–0.2328	–17.43*** (<0.0001)
0.40	–0.1936	–23.47*** (<0.0001)	0.90	–0.2304	–11.58*** (<0.0001)
0.45	–0.2020	–23.86*** (<0.0001)	0.95	–0.2412	–10.82*** (<0.0001)
0.50	–0.1985	–22.95*** (<0.0001)			

*This table shows the results of estimating quantile regression: $\Delta EX_t = \alpha_\tau + \beta_\tau \Delta SI_t + \varepsilon_\tau$. All exchange rate and stock index data are transformed into natural logarithmic scale. t-statistic is shown first, followed by p-value in the parenthesis. *** indicates significance at 1% level. $\Delta EX_t = EX_t - EX_{t-1}$; $\Delta SI_t = SI_t - SI_{t-1}$*

The test of equal coefficient across quantiles is also performed. The chi-square (χ^2) statistic is 39.7617 (*p*-value is 0.0022, significant at 1% level), which indicates that the null hypothesis of equal coefficient across quantiles is rejected. Therefore, the coefficients across quantiles are significantly different. Based on Table 6, the graphical presentation of coefficients (β_τ) estimated under different quantiles is shown on Figure 2. The negative coefficients exhibit an inverse U-shape pattern. Therefore, the influence of changes in stock indexes on changes in exchange rates will be greater when exchange rates become very low or very high.

Figure 2: Coefficients of Different Quantile Regressions



This figure shows the graphical presentation of coefficients estimated under different quantiles. The vertical axis represents the coefficient and the horizontal axis represents the quantile.

CONCLUSION

This study examines the dynamic relations between exchange rates and stock market indexes for Brazil by using the linear Granger causality test and the quantile regression model. The standard unit root test and the unit root with a structural break test show a unit root for both exchange rate and stock index series and stationarity for the first difference of both financial series. The cointegration tests show there is no cointegration between exchange rates and stock indexes. Therefore, there is no evidence of the long-run relationship between these two financial series. The results of the linear Granger causality test show that changes in stock indexes cause changes in exchange rates significantly in the full sample period and all five sub-periods. Although the test results also show that changes in exchange rates cause changes in stock indexes in the full sample period, the causality from changes in exchange rates to changes in stock indexes is only significant for two sub-periods and weakly significant (at 10% level) for one sub-period. The results of different quantile regressions reveal an inverse U-shape pattern of the negative coefficients, which indicates that the negative correlation between changes in exchange rates and changes in stock indexes is even clearer when exchange rates become extremely low or high.

The empirical results are in line with the portfolio approach, which suggests that changes in stock indexes result in changes in exchange rates (the stock market leads the foreign exchange market) with a negative sign of correlation. For stock traders who are in the markets exhibiting the characteristics described above, they need to be cautious about the negative event such as the economic crisis. As stock traders perceive the signal of occurrence of a negative event, they should quickly liquidate their investment in the stock market to minimize their potential loss and then buy U.S. dollar (or the other safer currency) to take advantage of its appreciation relative to the domestic currency. As to the limitations of this paper, first, this paper focuses on the relations between exchange rates and stock indexes; other possible determinants of exchange rates are not included in this research. Second, the results are based on the methodologies adopted in this research; the results might be different if different (nonlinear) methodologies are used.

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