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COVID-19 and currency dependences: Empirical evidence from BRICS

Yingying Xu a, Donald Lien b, *

a School of Economics and Management, University of Science and Technology Beijing, Beijing, China
b College of Business, University of Texas at San Antonio, TX, USA

ABSTRACT

The COVID-19 has caused dramatic fluctuations in international financial markets. This paper tests the effect of this pandemic on foreign exchange dependences within the BRICS economies. Upon dividing the COVID-19 episode into four stages, we document negative effects of the COVID-19 on dependences between CNY and other currencies in the BRICS across different stages. In addition, USD flows positively affect the dependencies of BRL-CNY, INR-CNY, and RUB-CNY pairs in response to the transition of the pandemic stages.

1. Introduction

Undoubtedly, the globally spreading coronavirus (COVID-19) pandemic has been a source of systematic risk, therefore causing dramatic fluctuations in financial markets (Zhang et al., 2020). It has created unprecedented economic cost burdens for economies all over the world, including Brazil, Russia, India, China, and South Africa, i.e., BRICS countries. In addition to dire health consequences, the COVID-19 is creating worldwide uncertainty and enormous economic and social impacts. The BRICS represent the most advanced emerging countries during the last two decades (Chkili and Nguyen, 2014), and are closely related with each other in trading, financial markets, local government cooperation etc. Chinese financial markets are the epicenter of the COVID-19 financial contagion (Corbet et al., 2020; Liu et al., 2017). Thereby, it is necessary to analyze the effect of the COVID-19 on BRICS exchange rate markets, one of the largest financial markets, from the perspective of pairwise dependences.

The long-term consequences of the COVID-19 are unknown and subject to policies in each country. However, it has produced significant short-term effects on financial markets and the global economy. For example, Corbet et al. (2020) find that brand names containing “corona” suffered abnormal losses and trading volatilities after the announcement of the COVID-19. The evidence in Conlon and McGee (2020) and Corbet et al. (2020) indicates that cryptocurrencies such as Bitcoin act as amplifiers of contagion across financial markets during the pandemic period. The lockdown, one of the social isolation restrictions to prevent the spread of the COVID-19 has caused environmental and economic impacts, e.g., improved the air quality (Atalan, 2020; Saadat et al., 2020). Sharif et al. (2020) report effects of the COVID-19 on the geopolitical risk and economic uncertainty in the United States and argue that the pandemic can be viewed as an economic crisis. Goodell (2020) highlights possible effects of the COVID-19 on economic and social
issues, including health, employment productivity, tourism, foreign direct investment, banking and insurance, government spending and spillovers across financial markets. Eichenbaum et al. (2020) incorporate the interaction mechanism between the pandemic and economic decisions of consumption and labor supply into a canonical epidemiology model. Janus (2021) highlights that the GDP dynamics and the sensitivity of bond yields to the Chicago Board Option Exchange Volatility Index (VIX) are the two most pronounced determinants of a country’s vulnerability to the COVID-19 pandemic.

The uncertainty caused by the COVID-19 has led to concomitant sharp swings in exchange rates of key emerging market economies (OECD, 2020) and resulted in markedly changed efficiencies of foreign exchange markets. For example, Aslam et al. (2020) note that the efficiency of the Australian dollar declines during the COVID-19 pandemic, whereas the Swiss Franc and the Canadian dollar exhibit improved efficiencies during the COVID-19 outbreak. Wei et al. (2020) confirm that the outbreak of the pandemic changes the spillover effects among currencies of the "Belt and Road" countries. Similarly, significant risk transfers between the stock market and foreign exchange market in large emerging economies during the pandemic period are found by Rai and Garg (2021).

Nevertheless, the effect of the COVID-19 pandemic on the interconnection between foreign exchange markets has not been studied among large emerging markets of BRICS, to the best of our knowledge. Thereby, this paper attempts to address the effect of the COVID-19 on exchange rate dependences across BRICS countries. We adopt one of the most widely used GARCH model to describe marginal distributions of exchange rates (Zhou et al., 2019). Then, we apply the copula approach, which captures bivariate dynamic correlations to measure pairwise dependences between Chinese yuan (CNY) and the currencies of other BRICS economies. Specifically, we apply the Generalized Autoregressive Score (GAS) mechanism to optimize parameters of copula models. The GAS framework uses the lagged score of the density function to force the updating of parameters, which provides the steepest ascent direction for improving the model fitting. Blasques et al. (2015) show that the GAS model improves the local Kullback-Liebler divergence between the true conditional density and the implied density generated by many alternative models. The results suggest robust negative effects of the COVID-19 on exchange rate dependences between CNY and other currencies of BRICS. The results provide additional information on the effects of the on-going spread of virus and the possible second round pandemic on international foreign exchange markets.

The remaining of this paper proceeds as follows. Section 2 reports the method. Sections 3 and 4 present the data and empirical findings, respectively. Section 5 concludes.

2. Methodology

This study is proceeded in three steps. First, following Bollerslev (1986), we adopt the standard GARCH(1,1) model with a Student’s t innovation to model marginal distributions of foreign exchange returns. The GARCH(1,1)-t model takes the following form:

\[
\begin{align*}
    r_t &= \mu + \sigma_t \cdot \epsilon_t \\
    \sigma_t^2 &= \alpha \cdot \epsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2 + \gamma \cdot \chi^2
\end{align*}
\]

where \( r_t \) is the foreign exchange return of investigated economy, \( \mu \) is the conditional mean and \( \sigma_t^2 \) is the conditional variance. \( \epsilon_t \) follows a Student’s t distribution. The variance equation includes the long-term average volatility \( \alpha \), \( \beta \), and \( \gamma \) are unknown parameters, which should satisfy \( 0 < \alpha + \gamma \leq 1 \).

Second, we use the Gaussian copula. Patton (2006) finds other copulas do not produce distinguishable results in modeling foreign exchange dependences. A copula model links marginal distributions of two foreign exchange returns in one joint distribution and calculates time-varying pairwise dependences via the GAS mechanism in Creal et al. (2013). The Gaussian copula is as follows:

\[
c(u_1, u_2; \rho) = \frac{1}{\sqrt{1 - \rho^2}} \exp\left\{ -\frac{\rho^2[\Phi^{-1}(u_1)^2 + \Phi^{-1}(u_2)^2] - 2\rho \Phi^{-1}(u_1)\Phi^{-1}(u_2)}{2(1 - \rho^2)} \right\}
\]

where \( u_1 \) and \( u_2 \) are the transformed standardized residuals of GARCH models for two foreign exchange returns, and \( \Phi^{-1} \) denotes the inverse of the standard Gaussian cumulative distribution function. The correlation coefficient \( \rho \) evolves following the GAS mechanism:

\[
\rho_t = \frac{1 - \exp(-f_t)}{1 + \exp(-f_t)}
\]

\[
f_{t+1} = \omega + \theta \left\{ \Phi^{-1}(u_{t+1}) - \Phi^{-1}(u_{t}) \right\} - \rho_t \left( \Phi^{-1}(u_{t+1})^2 - \Phi^{-1}(u_{t+1}) \Phi^{-1}(u_{t}) + \Phi^{-1}(u_{t})^2 + 2 \right) + \delta f_t
\]

where \( \omega, \theta, \) and \( \delta \) are unknown parameters which can be estimated using the maximum likelihood method. More details about the GAS framework are reported in Creal, Koopman, and Lucas (2103).

Finally, we test the effect of the COVID-19 on exchange rate dependences through a regression model with pandemic dummy variables.

\[
r_t = \xi + \delta p_{t-1} + \sum_{s=1}^{n_s} \text{COVID}_{s,t} + \sum_{j=1}^{n_j} \text{control}_{j,t} + \sum_{p=1}^{n_p} (\text{COVID}_{s,t} \times \text{control}_{p,t}) + \epsilon_t
\]
index as the control variables. Given the significant correlations among target control variables, we calculate the orthogonalized VIX and LIBOR which mitigate effects of the other control variables on currency dependences. For example, we regress the natural log of VIX on the USDX return, LIBOR, and the crude oil return and measure the orthogonalized VIX as the residuals from the regression. More information about the dummy variables and control variables are introduced in the next section.

3. Data

We study the daily exchange rates of BRICS currencies that are quoted in the USD, covering the period of January 1, 2019 to April 26, 2021. The foreign exchange returns are calculated as \( r_t = 100 \times \ln(P_t/P_{t-1}) \), where \( P_t \) is the daily closing exchange rate at time \( t \). We organize the analysis along three periods according to the white paper released on June 7, 2020 by the State Council Information Office of China: Incubation (December 27, 2019 through January 19, 2020), Fever (January 20, 2020 through March 17, 2020), Moderation (March 18, 2020 to April 28, 2020), and Normalization (April 29, 2020 to April 26, 2021). Thereby, four dummy variables regarding the COVID-19 are introduced:

\[
\begin{align*}
COVID_1 &= \begin{cases} 1, & \text{December 27, 2019 to January 19, 2020} \\ 0, & \text{otherwise} \end{cases} \\
COVID_2 &= \begin{cases} 1, & \text{January 20, 2020 to March 17, 2020} \\ 0, & \text{otherwise} \end{cases} \\
COVID_3 &= \begin{cases} 1, & \text{March 18, 2020 to April 28, 2020} \\ 0, & \text{otherwise} \end{cases} \\
COVID_4 &= \begin{cases} 1, & \text{April 29, 2020 to April 26, 2021} \\ 0, & \text{otherwise} \end{cases}
\]

Currencies quoted in the USD tend to co-move with each other because of the USD flows (Cubillos-Rocha et al., 2019). Meanwhile, about two months after the onset of the pandemic in China, Saudi authorities offered discounts in oil prices which caused the largest fall of 20% to 30% in crude oil price since the Gulf war. The oil price shocks exert distinct effects on exchange rates in BRICS (Lin and Su, 2020). Meanwhile, the interest rate and uncertainties of macroeconomies affect exchange rates (Wei et al., 2020). Hence, we control the USDX returns, West Texas Intermediate (WTI) crude oil returns, the overnight LIBOR, and the logarithm of VIX in the empirical study to test whether the COVID-19 itself essentially affects foreign exchange dependences. We also interact the COVID-19 dummy variables with USDX returns, i.e., \( COVID_{i,t} \times \text{USDX}_t \), because previous studies suggest changes in effects of USD returns on foreign exchange dependences in responses to great transitions (Dimitriou et al., 2017).

Exchange rates for five currencies, i.e., BRL (Brazilian Real), RUB (Russian Ruble), INR (Indian Rupee), CNY (Chinese Yuan), and ZAR (South African Rand), the USDX, WTI crude oil prices, and VIX are downloaded from the investing.com, and the overnight LIBOR is available from the DataStream. For exchange rates, we discard the days with missing data. The sample contains 588 daily returns for each currency. According to Table 1, five currencies are stationary; but are not normally distributed with significant leptokurtosis and skewness. The linear Pearson correlation suggests positive relationships between CNY and other currencies which decrease after the outbreak of the COVID-19.

Table 1.
Descriptive statistics of currency returns (January 3, 2019 to April 26, 2021).

|            | BRL        | CNY        | INR        | RUB        | ZAR        |
|------------|------------|------------|------------|------------|------------|
| Mean       | 0.064      | -0.010     | 0.011      | 0.015      | 0.000      |
| Median     | 0.053      | 0.000      | 0.013      | -0.001     | -0.080     |
| Maximum    | 3.685      | 1.577      | 1.615      | 6.955      | 3.983      |
| Minimum    | -3.320     | -1.425     | -1.964     | -3.066     | -2.842     |
| Std. Dev.  | 1.101      | 0.261      | 0.375      | 0.797      | 0.964      |
| Skewness   | -0.114     | 0.413      | 0.132      | 1.405      | 0.447      |
| Kurtosis   | 3.761      | 8.231      | 5.783      | 13.405     | 3.915      |
| Jarque-Bera| 15.457     | 687.011    | 191.499    | 2845.759   | 40.066     |
| ADF test   | (0.000)    | (0.000)    | (0.000)    | (0.000)    | (0.000)    |
| Pearson Correlation (full-sample) | 0.179 | 1 | 0.379 | 0.269 | 0.307 |
| Pearson Correlation (pre-COVID) | 0.258 | 1 | 0.414 | 0.317 | 0.320 |
| Pearson Correlation (post-COVID) | 0.149 | 1 | 0.356 | 0.272 | 0.301 |

Note: Jarque-Bera is the normality test; ADF test considers the case with intercept; Std. Dev. denotes the standard deviation. Pearson Correlation denotes the unconditional Pearson correlation coefficients with CNY. Probabilities are in parentheses. The full-sample covers January 3, 2019 to April 26, 2021 when returns are available, the pre-COVID and post-COVID periods cover data before and after January 19, 2020, respectively.
4. Empirical results

In Table 2, we present the results of GARCH(1,1)-t models which describes marginal distributions of BRICS foreign exchange returns. All five currencies have insignificant conditional means. Estimates of $\gamma$ are significantly positive, showing that BRICS foreign exchange returns have highly persistent volatilities. Meanwhile, estimates for the five currencies satisfy $\beta + \gamma \leq 1$, showing that the GARCH(1,1) model is appropriate in modeling BRICS foreign exchange returns.

Next, we input the transformed standardized residuals into the Gaussian copula and use the GAS mechanism to estimate time-varying dependences. Table 3 summarizes the estimation results of copula models. The estimates of $\theta$ are significantly positive for four currencies, i.e., BRL, INR, RUB, and ZAR, showing that the dependences between these currencies with CNY are highly dynamic and persistent. Comparatively, INR shows less persistent dependences with CNY than the other currencies because of a smaller estimate of $\theta$.

Fig. 1 displays dynamic dependences between the four currencies and CNY. In line with Table 3, the dependence between INR and CNY is less persistent than the other three currency pairs. We observe changes after the breakout of the COVID-19. In the first and second stages of the pandemic, one can find decreased dependences for two currency pairs, i.e., BRL-CNY and RUB-CNY. The INR-CNY pair is different with relatively fluctuating dependences, whereas the ZAR-CNY pair is relatively stable in the first two stages. The dependences between CNY and the other currencies within the BRICS show no significant changes in the third stage when China achieved an initial victory in fighting against the COVID-19. In the fourth stage, when China stepped into the comparatively stable phase with decreasing confirmed cases and deaths, the dependences of CNY with BRL and ZAR increase for a while, whereas the dependence between CNY and RUB decreases for approximately two months. One possible reason is the breakout and fever of COVID-19 in the other countries.

Table 4 presents the effects of the COVID-19 on foreign exchange dependences between CNY and the other currencies in BRICS via the estimation of Eq. (5). In line with observations of Fig. 1, the COVID-19 has an overall negative effect on foreign exchange dependences. Specifically, in stage one, the pandemic exerts a significant negative effect on dependences of BRL-CNY pair. In the second stage, when confirmed cases and deaths in China increased dramatically, the dependences show the steepest descents in the INR-CNY pair. The risk aversion induced by fear sentiments and trading embargos with China are important reasons for decreased dependences with CNY. In stage two, when many countries revealed dramatic news of infections, they implemented international travel control measures and even locked down many cities. In this stage, we find decreased currency dependences. Nevertheless, the third stage shows no significant effect on all currency dependences. In stage four, the COVID-19 maintains a negative effect on the dependence of the RUB-CNY pair.

The pandemic causes drastic capital outflows ever recorded from the emerging markets, which makes the USD flow an important driver of BRICS exchange rates. The USD tends to appreciate during the crisis. A similar trend is observed for BRICS shortly after the breakout of the COVID-19. However, the results in Table 4 suggest that the USDX return has no significant effects on dependences between CNY and other BRICS currencies in stages one and four. Specifically, INR is positively impacted by USDX returns in stage two, whereas BRL and RUB are positively affected in stage three. The United States is an important export market for BRICS, particularly for India and China. Significant appreciations in the USD stimulate imports of the United States and thus improve co-movements between currencies of its main importing partners. This assumption is supported by the study on developed markets (Antonakakis, 2012).

Similarly, we find positive, albeit insignificantly, effects of the USDX returns on dependences between CNY and ZAR for stages two, three, and four. The rapid spread of the pandemic since March 2020 reduced exports of China and India to the United States and dramatic fluctuations in USDX. As expected, in stage two, the USD appears to exert intensified positive effects on co-movements between currencies of its main importing partners. Alternatively, exchange rate contagion is more frequently observed within the same region, e.g., Asia (Cubillos-Rocha et al., 2019), contributing to the intensified effect of the USD on the INR-CNY dependence. The INR is a net receiver of currency volatility spillover (Wen and Wang, 2020), thus significant fluctuations in the USD and CNY transfers to INR.

The other possible drivers are crude oil shocks, the volatility index (VIX), and LIBOR. The oil price triggered a spectacular fall on March 9, 2020 and maintained decreasing until the end of April 2020. The evidence based on the regression analysis suggests that the oil return produces positive effects on the dependences of BRL-CNY, INR-CNY, and RUB-CNY, whereas affects ZAR-CNY dependence.

### Table 2
Estimates of GARCH(1,1)-t models for five currencies.

|       | BRL  | CNY  | INR  | RUB  | ZAR  |
|-------|------|------|------|------|------|
| $\mu$ | 0.053| -0.011| -0.004| -0.029| -0.041|
|       | (0.040)| (0.008)| (0.013)| (0.023)| (0.038)|
| $\alpha$ | 0.018| 0.005| 0.005$^*$| 0.009$^*$| 0.109$^*$|
|       | (0.012)| (0.004)| (0.003)| (0.005)| (0.065)|
| $\beta$ | 0.071$^{***}$| 0.076$^*$| 0.086$^{***}$| 0.112$^{***}$| 0.102$^{**}$|
|       | (0.022)| (0.040)| (0.028)| (0.031)| (0.049)|
| $\gamma$ | 0.916$^{***}$| 0.868$^{***}$| 0.882$^{***}$| 0.879$^{***}$| 0.779$^{**}$|
|       | (0.025)| (0.066)| (0.040)| (0.029)| (0.102)|
| $\nu$ | 11.745$^*$| 3.228$^{***}$| 5.625$^{***}$| 6.336$^{***}$| 10.206$^{***}$|
|       | (6.003)| (0.489)| (1.232)| (1.930)| (3.305)|
| $LL$ | -849.76| 19.752| -207.469| 595.395| -793.083|

*Note:* Standard errors in parentheses. $LL$ represents the Log Likelihood value, and $\nu$ is the degrees of freedom for the Student’s $t$ distribution.
negatively. However, none of the above effects is statistically significant. Differences across BRICS currency dependences are in line with the finding that oil price shocks produce diverse effects on BRICS countries (Lin and Su, 2020). The VIX, usually known as the “fear gage”, displays significant predictive powers for financial market returns and uncertainties (Bekaert and Hoerova, 2014). However, the regression results indicate that the VIX exhibits no significant effect on currency dependences within the BRICS. Similarly, the interest rate measured by LIBOR shows no significant impact on the currency dependences except for the BRL-CNY pair. Such finding is in line with Hameed and Rose (2018) that small and negative interest rates appear to exert little impact on exchange rate behaviors.

Table 3.
Estimates of copula models based on the GAS mechanism.

|       | BRL   | INR   | RUB   | ZAR   |
|-------|-------|-------|-------|-------|
| $\omega$ | 0.556*** | 0.741*** | 0.594*** | -0.079 |
|        | (0.192) | (0.091) | (0.121) | (0.134) |
| $\theta$ | 0.011  | 0.999*** | 0.009  | 0.010  |
|        | (0.006) | (0.031) | (0.009) | (0.011) |
| $\vartheta$ | 0.992*** | 0.412*** | 0.983*** | 0.945*** |
|        | (0.010) | (0.193) | (0.023) | (0.117) |
| $LL$   | 17.266 | 41.482 | 26.331 | 0.456  |

Note: Standard errors in parentheses. $LL$ represents the Log Likelihood value.

**Fig. 1.** Time-varying foreign exchange dependences between CNY and other currencies in the BRICS. Note: The shaded area with the lightest color denotes the first stage of the COVID-19 (December 27, 2019 to January 19, 2020), the darkest colored area is the fourth stage of the COVID-19 (April 29, 2020 to April 26, 2021), and the middle two areas are the second and third stages of the COVID-19 (January 20, 2020 to March 17, 2020 and March 18, 2020 to April 28, 2020).
Overall, empirical evidence shows that the COVID-19 has produced significant effects on currency dependences across BRICS economies.

5. Conclusions

The COVID-19 risk may be firstly viewed as an economic crisis (Sharif et al., 2020). Previous studies find that intensified co-movements between currency markets appear during turmoil periods including financial crisis (Antonakakis, 2012). Nevertheless, we find that the foreign exchange dependences between CNY and other currencies in BRICS are generally negatively impacted by the COVID-19, particularly in stages when China had dramatic increases in confirmed cases and death numbers. The results in this paper suggest that the pandemic can inflict different economic damages from past global crisis.

The COVID-19 pandemic has resulted in dramatic damage to global economic growth through disrupting worldwide trade and causing a myriad of fears in the financial markets. As the largest financial market, the foreign exchange market is not spared. The pair dependences between CNY and the other BRICS countries declined ever since the outbreak of the COVID-19 pandemic, and the USD depreciation caused by the pandemic further weakens the linkage of currencies within BRICS. This study provides an early warning for the further damaging of currency dependences considering the intensified pandemic in India, Brazil, and South Africa. To manage risks, changes in currency dependences should be carefully evaluated by international traders and investors. Also, the exchange rate regime of CNY should consider fluctuations of currency dependences within BRICS because of the substantial multilateral trade.

Authors statement

On behalf of my coauthor, we declare there are no conflicts of interest. The paper is solely under consideration at Financial Research Letters.

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