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Spatial Relationship between Economic Policy Uncertainty (EPU) and COVID-19 in BRICS Economies

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Abstract
The globe has already experienced numerous significant epidemics and pandemics in the first two decades of the twenty-first century. In theory, applying more complex mathematical and computational models to the development and consequences of epidemics should support policy and decision-making. We examine the impact of the novel coronavirus (COVID-19) pandemic on economic policy uncertainty (EPU) in the BRICS economies, namely, Brazil, Russia, India, China and South Africa. The Partial Wavelet Coherence (PWC) and Copula techniques would be used to examine the spatial relationship between Economic Policy Uncertainty (EPU) and COVID-19. The expected results are that the pandemic has a positive, statistically significant impact on EPU in BRICS economies.

Keywords: *COVID-19 pandemic; Economic Policy Uncertainty (EPU); BRICS; PWC; Copula; Wavelet Coherency.*

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1.0 INTRODUCTION

The coronavirus pandemic affected various aspects of daily life to varying degrees. (Caggiano, Castelnuovo & Kima, 2020) and epidemiologists and medical professionals still do not fully understand the virus in many ways (Fauci, Lane & Redfield, 2020). The authors emphasise the importance of international cooperation and concerted efforts among the public, private, and non-profit sectors in developing a vaccine, as neither a return to normal nor the availability of a vaccine can be predicted. (Corey, Mascola, Fauci & Collins, 2020; Gates, 2020).

The spread of COVID-19 has significantly slowed global economic activity and severely affected several economies, including the US, Russia, Brazil, South Africa, Germany, and India, among others. According to Baker, Bloom, Davis, and Terry (2020), the COVID-19 pandemic has triggered massive surges in uncertainty. Moreover, the following are only a few of the notable uncertainties: the virus's contagiousness, pervasiveness, and fatality; the accessibility and dispositioning tests for antigens and antibodies; the capability of medical care administration to perform a unique task; the required amount of time to produce and use secure, efficient vaccines; the magnitude of the impending mortality shock; the effectiveness and durability of social isolation, market closures together with other mitigating mechanisms; the accessibility and use of tests for antibodies and antigens.

COVID-19 has caused the economic collapse of emerging economies such as Brazil, Russia, India, China, and South Africa (BRICS), which have been the engines of world growth

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over the past two decades (Salvatore 2020). As a result of the steep decline in global demand for their primary exports, the financial fragility of these emerging economies has increased. (Salvatore 2020). Furthermore, from both policy and pandemic perspectives, these BRICS economies are expected to allocate more resources and increase healthcare sector spending. Because of a lack of collaboration and underreporting of COVID testing, regions with higher economic development and population density have fewer COVID testing incidences (Dash, Chakraborty, Giri & `Pani, 2021). COVID-19 has a significant economic and social influence on the BRICS countries. For instance, Magazzino, Mele, and Morelli (2021)Postulate that, after the government of Brazil shifted its focus to renewable energy, which eventually became one of the driving forces behind its economy, academics became convinced that there is a link between global energy consumption and economic progress. Although the Brazilian economy was expanding significantly, growth may slow, leading to a broader economic crisis driven by the COVID-19 pandemic.

The conclusion was that Brazil may have foreseen the negative consequences of the COVID-19 pandemic's global epidemic for the entire economy. Similarly, Marinho et al. (2021) The prevalence of the coronavirus disease in Brazil has had a severe impact on the country's economy and the poorest people, highlighting the key challenges faced by health care professionals. Additionally, Maksimov et al. (2021; Malinovsky, Osina, and Trikoz (2021) It is important to note that the recurring nature of the COVID-19 crisis in the Russian economy cannot be overstated; the current crisis is being managed in ways that often resemble previous ones, and its adverse effects on the economy are being addressed in similar ways. The objective, therefore, was to revive the economy, saving businesses among others, but saving human lives was a primary objective. Furthermore, Dev and Sengupta (2020) posit that an unparalleled difficulty has been presented to India by COVID-19. Lockdowns and other social distancing measures are proving to be highly disruptive due to the massive number of the population, the fragile state of the economy, particularly in the financial sector prior to the implementation of COVID-19, and the economy's reliance on informal labour.

Again, the COVID-19 pandemic has had a significant negative impact on the Chinese economy. This pandemic emerged in China at a time when its economy was experiencing steady expansion, and Beijing had built extensive links with the rest of the world; consequently, the current strain from China's rise will have a significant negative impact on the global economy. (Dhar 2020). In addition, South Africa is facing the novel coronavirus. A lockdown has been the only instrument currently available to mitigate the demographic consequences of COVID-19, and it aims to interrupt prevailing social and economic channels and limit the spread of the disease. These actions cause a profound economic shock, with an immediate loss of economic activity, followed by medium- and long-term impacts. (Arndt et al. 2020).

Economic policy uncertainty is characterised in various ways, but it is often understood to involve unanticipated economic changes that could prompt alterations in government policy. Put differently, it symbolises the economy's unpredictability resulting from fiscal, political, regulatory, and monetary policies. Multiple decisions may be postponed when EPU rises, given the unpredictability of economic and financial outcomes. For example, Moody's Investors Service has downgraded Turkey's credit rating following the failed coup attempt. (Davis 2016). It is therefore important to revitalise the economy in general and to make a deliberate effort to develop the financial sector. According to standard economic theory, an increase in a receiving nation's stock of capital and technological know-how leads to improved economic performance. Capital inflows may also increase local savings, encourage capital accumulation, and improve market performance. Another theoretical underpinning of this study is the uncertainty theory founded by Liu (2007).

According to it, the axioms of normalcy, monotonicity, self-duality, and countable subadditivity are the foundations of the mathematical discipline known as uncertainty theory. In addition, it states that uncertainty refers to any phenomenon that can be measured using unreliable data.

In response to the spread of COVID-19, (Ledwani, Chakraborty, and Chenoy 2021) hypothesise that most global stock markets responded too quickly and exhibited a highly volatile pattern in March 2020. This has led to several unanswered questions regarding how the COVID-19 epidemic will affect the BRICS economies. Is there a link between each of the BRICS stock markets and the worldwide economic parameters under discussion? Are the BRICS markets

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symmetric or asymmetrically dependent on each of the distinct global factors? Is the dependency structure different since the latest COVID-19 outbreak? Addressing these issues is critical to understanding how BRICS stock markets are becoming increasingly reliant on global market conditions and the broader economy, and how the current COVID-19 outbreak has affected this dependence. This study examines the spatial connection between Economic Policy Uncertainty (EPU) and COVID-19 on BRICS economies.

stock market, as well as the newly growing literature on how COVID-19 has impacted financial markets. This paper examines the impact of COVID-19 on BRICS economies. It also assesses the extent of dependence between EPU and COVID-19 and further evaluates and quantifies the effect of the COVID-19 outbreak on stock and commodity markets in the BRICS economy. Typically, OLS regression is employed to estimate the parameters required to identify abnormal returns during the event under investigation. However, several assumptions underlying OLS have been challenged. The market model's coefficient, for example, is constant over time, as is the variance of the OLS residuals' homoscedasticity distribution. The regression coefficient in a study can fluctuate with time, leading to variations in anomalous returns. (Iqbal & Dheeriya, 1991), and due to the presence of heteroscedasticity, the impact of an event on the price of a security can be altered (Giaccotto and Ali 1985).

Meanwhile, it is claimed that ignoring the time dependence in the series of stock returns yields inaccurate parameter estimates, which are inconsistent with the test data. (Corhay and Rad 1996). Further study demonstrates that the verifiable features of the return series have the possibility of being explained using the Generalised Autoregressive Conditional Heteroscedastic (GARCH) model, which allows for non-linear intertemporal dependency on the continuing series. (Bollerslev 1986). The resulting residuals from the typical market model also exhibit pronounced ARCH characteristics. (Diebold, Im &Lee, 1988), and in terms of estimating business models, the ARCH method is more efficient (Bera, Bubnys & Park, 1988).

This study employs the PWC approach to achieve this goal (for which our memory tells us has not been used much in such an area of study, especially on BRICS stock markets). This is a significant step forward in verifiable research on co-movements in emerging stock markets. Wavelet analysis has several advantages over other modelling techniques for instance, GARCH, ARCH and correlation, as well as traditional Granger causality or cointegration analysis, including occurrences and timing domain localization, being able to break down of variables after the event with respect to differently measured frequencies to investigate the complexities of collaborative drifts over several durations not compromising on information loss and its potential. The copula concept also enables decomposition of an n-dimensional joint distribution from its univariate marginal distributions and an n-dimensional copula.

The remaining portion of this document is arranged in this order. Section 2 talks about the Partial Wavelet Coherence (PWC) and Copula methodologies. In Section 3, empirical results are presented, and Section 4 provides a conclusion.

2.0 THE PARTIAL WAVELET COHERENCE METHODOLOGY

Partial Wavelet Coherence (PWC) is a method comparable to partial correlation that influences how the outcome of the Wavelet Coherence (WTC) involving two time series, y and x_1 will be following the elimination of the time series x_2's effect. WTC may be viewed as a confined correlation in the time–frequency space because its operating concept is similar to that of the classic correlation coefficient (Grinsted, Moore & Jevrejeva, 2004). Similarly, to improve coherence results, Partial Wavelet Coherence (PWC) is used to reduce the impact of typical dependencies between two time series on the dependent variable. PWC was used to eliminate the influence of the El Niño–Southern Oscillation (ENSO), disclosing the unexpected reliance of tropical cyclone severity on the Bay of Bengal's regional sea surface temperature, according to Ng and Chan, (2012). WTC between y and x_1, y and x_2, and x_1 and x_2 is written as:

$$R(y, x_1) = \frac{\varsigma[W(y, x_1)]}{\sqrt{\varsigma[W(y)].\varsigma[W(x_1)]}};$$

$$R^2(y, x_1) = R(y, x_1).R(y, x_1)^*;$$

$$R(y, x_2) = \frac{\varsigma[W(y, x_2)]}{\sqrt{\varsigma[W(y)].\varsigma[W(x_2)]}};$$

$$R^2(y, x_2) = R(y, x_2).R(y, x_2)^*;$$

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$$R(x_2, x_1) = \frac{\varsigma[W(x_2, x_1)]}{\sqrt{\varsigma[W(x_2)].\varsigma[W(x_1)]}};$$
$$R^2(x_2, x_1) = R(x_2, x_1).R(x_2, x_1)^*. \quad [5]$$

After removing the influence of x_2, (Mihanović, Orlić, and Pasarić 2009) proposed that an equation analogous to the partial correlation squared can be used to define PWC squared, as

$$RP^2(y, x_1, x_2) = \frac{|R(y, x_1) - R(y, x_2).R(y, x_1)^*|^2}{[1 - R(y, x_2)]^2[1 - R(x_2, x_1)]^2}, \quad [6]$$

This is similar to a standard WTC, with a range of 0 to 1.
Whereas in this instance, a high wavelet coherence squared was seen, a low PWC squared indicates that the time series. x_1 does not significantly affect the time series y during that specific time-frequency space, and the influence of the time series x_2 impacts the variance of y, and conversely. Both $x_1$and x_2 have a significant influence on y if both $RP^2(y, x_1, x_2)$ and $RP^2(y, x_2, x_1)$ still have significant bands.

2.1 The Copula Technique

The nature of cross-stock return dependence affects policy formation, asset pricing, and portfolio allocation using copula techniques. Diversification of a portfolio across borders is less effective when markets are erratic. Investment professionals pay particular attention to stock market co-movement because a thorough understanding of it and its assessment affects the risk-return trade-off arising from global diversification. Policymakers, on the other hand, are more concerned with the extent to which cross-market connectivity influences shock transmission, as well as its ramifications and risk management implications. (Mensah and Alagidede 2017). Copulas are mathematical functions that connect multivariate distributions to their one-dimensional boundaries. For example, we may describe the joint cumulative distribution function of two random variables. X_1 and X_2 with marginal distributions $F_1(X_1)$ and $F_2(X_2)$ as $F(X_1, X_2) = C[F_1(X_1), F_2(X_2)]$ (Sklar, 1959). We can deduce from this statement that, in addition to their separate marginal distributions, one has to know how X and Y are connected to obtain the joint distribution. The copula function C offers this additional information in this case. (Embrechts, Mcneil and Straumann 2002). The dependence between X_1 and X_2 will, for example, be the same as the dependency between $\ln(X_1)$ and $\ln(X_2)$.

Sklar (1959) was the first to propose the copula concept, which argues that a copula with n dimensions and n-univariate marginal distributions can be decomposed from an n-dimensional joint distribution: Let X = (X_1,..., X_n) indicate an unpredicted vector having F as the marginal and distributional functions as, $F_{i,} X_i \sim F_{i,} 1 \leq I \leq n$. The copula of the variable X is a distributional function C that translates $[0,1]^n$ into [0,1] such that

$$F(X_1, \dots X_n) = C[F_1(X_1), \dots, F_n(X_n)] \quad [7]$$

The function that converts the univariate marginal distribution, F_i, to the joint distribution F is called the copula C of the variable X. The "probability integral transformation" (PIT), U_i=F_i (X_i), can also be used to understand the copula function (Patton, 2012). According to Patton (2012), the variable U_i will have the Unif (0,1) distribution if F_i is continuous, regardless of the initial distribution F_i:

$$U_i = F_i(X_i) \sim Unif\ (0,1), i = 1, \dots, n \quad [8]$$

As a result, the copula C of the variable X can be viewed as the vector of probability integral transformations' joint distribution, $U_i = [U_{1,\dots} U_n]$, and therefore as a joint function with margins of $Unif$ (0,1) (Patton,2012). We get the joint probability density function by separating the above representation from all of its arguments once, as:

$$f(X_1, \dots X_n) = C[F_1(X_1), \dots, F_n(X_n)] \times \prod_{i=1}^{n} f_i\ (X_i) \quad [9]$$

Where $C(u_1, \dots u_n) = \frac{\partial^n(u_{1,\dots} u_n)}{\partial u_{1,\dots,}\partial u_n}$

The following two steps make up the estimation of the joint cdf F: (i) The marginal functions are identified and estimated; (ii) the copula functions are identified and estimated. Because the marginal distributions and the copula can be separated, multiple families of distributions can be combined and still be valid.

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The conditional copula is a useful tool for modelling this dependence, since the marginal distribution of financial series returns exhibits time-varying mean and volatility. Let $X_t=(X_{1t},\ldots,X_{nt})$ be a random procedure, $\mathcal{F}_t$ indicate a collection of information that is available at the time t, and the conditional distribution of $(X_{1t},\ldots,X_{nt})$ || $\mathcal{F}_{t-1}$ be F_t. Then

$$F_t\ (X_{1t}, \ldots X_{nt}\ |\mathcal{F}_{t-1}) = C_t[F_{1t}(X_{1t}|\mathcal{F}_{t-1}), \ldots, F_{nt}(X_{nt}\ |\mathcal{F}_{t-1})] \quad [10]$$

3.0 EMPIRICAL RESULTS

3.1 Data

Before you zoom into a discussion of the results, present some fundamental analysis of the data. It is important to see through the nuances of the data before estimating relationships. Such analysis could lend further credence to the results and should be the first step before mainstream exploration of other patterns, which could be carried out using regression analysis. This comment applies to all chapters of the thesis that are of this nature. The elegance of the wavelets and other techniques is not just in the derivations but also in the results, which ought to be thoroughly discussed and analysed.

The study employs wavelet analysis to analyse the data. This is because it does not require any pre-treatment of data, no band-pass or trend projection method is required, it further proposes robust modelling of a non-stationary process, thereby avoiding information loss, and it further provides additional information about the time horizon of the relationship; whether the studied variables present short, medium or long-term interdependences. Partial wavelet is used in this study because it extends beyond pairwise correlations and accounts for three or more assets, with one variable mediating the relationship between two variables. The copula technique is further employed in this study to assess robustness. One can demonstrate that well-known duration models are specialised versions of the copula model, thereby establishing that copula-based models constitute a diverse class.

Copulas come in a wide variety of families; they enable this flexibility in modelling dependence structures. (Nelsen 2006). Existing contributions that analyse identification and estimates include several. The data were collected monthly from January 2003 to June 30, 2022. On March 11, 2020, the World Health Organisation classified COVID-19 as a pandemic (Phan and Narayan 2020). The analysis uses available monthly EPU data for each BRICS country. The study period, from March 2020 to June 30, 2022, is relatively long given the timing of the pandemic onset. This will facilitate the effective determination of variable patterns; high precision is provided when observing changes across variables over time, while also ensuring a clear emphasis and validity. Data for the commodities market index is sourced from DataStream, EPU data except South Africa is from www.policyuncertainty.com, EPU data for South Africa is sourced from www.fred.stlouisfed.org, and COVID-19 data is sourced from https://github.com/owid/covid-19-data/tree/master/public/data.

Close-to-close is a strategy for removing data points that occur during non-trading or holiday periods across diverse marketplaces to mitigate the effects of non-synchronous trading. Specifically, the data consist of the COVID-19 death rate (COVID-19 daily confirmed, death, and recovery cases), Economic Policy Uncertainty (EPU), based on BRICS country newspapers, and Gold prices. We evaluate each asset's specific volatility and its movement in tandem with the COVID-19 epidemic using the wavelet approach. To begin, we employ the wavelet power spectrum (WPS) technique to depict the return series' local volatility in both time and frequency domains. The WPS is defined as:

$$WPS_x(\tau, s) = |W_x(\tau, s)|^2 \quad [1]$$

With

$$W_x(\tau, s) = \int_{-\infty}^{+\infty} x(t)\psi^*\left(\frac{t-t}{s}\right)dt, \quad s, \tau \in \mathbb{R}, s \neq 0 \quad [2]$$

The continuous wavelet transform of a time series for a mother wavelet, the scaling factor, the translation parameter, and an asterisk denoting complex conjugation are all represented as $W_x(\tau, s)$. The mother wavelet dilates and transforms itself over a range of values to produce wavelets of the same lineage. The WPS charts use the darkest power shades and colour-coding to denote the most volatile periods.

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Second, because we are looking for the interdependence of two time series, we adhere to Torrence & Compo, (1998), who define wavelet coherency (WSC) as:

$$WSC = R_{XY}^2(\tau, s) = \frac{|S(s^{-1}W_{XY}(\tau, s))|^2}{S(s^{-1}|W_X(\tau, s)|^2)S(s^{-1}|W_Y(\tau, s)|^2)} \quad [3]$$

where S represents a smoothing operator for scale and time, the cross-wavelet power (XWP) measures the local covariance at each scale between the two time series. With $0 \le R_{XY}^2(\tau, s) \le 1$, The WSC is quite similar to a classical correlation coefficient. This methodology cannot discriminate between positive and negative co-movement or correlation at this stage, nor between lead-lag relationships. The phase difference,, $\emptyset_{XY}$, of Torrence & Compo, (1998) can be used to solve this problem by capturing both positive and negative co-movements, which are potential. Furthermore, the graphical representation can provide information about the wavelet-squared coherence and the causal linkages between the two time series, in the spirit of Granger causality testing.

The phase difference of wavelet coherence is defined as follows:

$$\emptyset_{XY} = tan^{-1}\left(\frac{Im\{S(s^{-1}W_n^{XY}(s))\}}{Re\{S(s^{-1}W_n^{XY}(s))\}}\right) \quad with\ \emptyset_{XY} \in [-\pi, \pi] \quad [4]$$

where Im and Re are the smoothed XWP's imaginary and real components, respectively. The phases reveal the directional cause (lead-lag) linkages connecting two series, $\emptyset_{XY}$, are displayed on the WSC plots using arrows. Two time series that synchronise (desynchronise) or are positively (negatively) connected are shown by arrows pointing to the right (left). If the arrows point up-right or down-left, the first time series is ahead of the second; if not, the second time series is ahead.

We then use heatmaps, which are colour-based, two-dimensional graphical representations of data, to show well-defined factors. Heatmaps provide witnesses with a valuable visual aid and enable the rapid dissemination of statistical or data-driven material. As the heat maps progress from blue (lowest correlation) to red (highest correlation), the intensity of the correlation between the stock market indices increases (highest correlation). Theoretical literature is of little use in this regard. Market pricing should, according to the market efficiency hypothesis (EMH), reflect all information available to market players at any given time. (Fama 1970). As a result of the EMH, shock transmission owing to contagion in international financial markets should be impossible in the long run. Several articles based on these factors argue that contagion-induced shocks in international financial markets should be transmitted swiftly and die out quickly.

It would have been nice to see the results, but I suppose they are still being prepared. When you obtain the results, spend time understanding the patterns in the graphs and the basic statistics. Explain the regression output thoroughly in light of the research questions. This is where you demonstrate your grasp of economic and finance theory and the relationships that you are studying. It is important to contextualise the results to interpret the findings across the various countries and regions in the sample. Go beyond the statistical associations and explain the economics and finance behind the numbers, and the policies therefrom.

4.0 CONCLUSIONS

Scrutinising BRICS co-movement on a regional and global scale in terms of equity, commodity, and cryptocurrency markets during an era of the COVID-19 pandemic and economic policy uncertainty, which is the focus of this research, possibly has ramifications for both investors' decisions on portfolio allocation and selection, as well as policymakers' efforts to overcome the conundrums of BRICS financial markets. Together with the partial wavelet coherence and copula modelling techniques, due to their localisation in the frequency-time domains and capacity to decompose any ex-post variables on various frequencies, these techniques outperform currently available measures of co-movement and integration in terms of examining the subtleties of joint movements over a range of time horizons without losing data.

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