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The Impact of the SAR-CoV-2 Epidemic on Oil Prices and BRICS Stock Markets: Dynamic Conditional Copula Approach

Ayşe Metin KARAKAŞ[1*], Mine DOĞAN[2], Sinan ÇALIK[3]

[1]Bitlis Eren University, Art and Sciences Faculty, Statistics Department, Bitlis, Türkiye
[2,3]Fırat University, Science Faculty, Statistics Department, Elazığ, Türkiye

[1]https://orcid.org/0000-0003-3552-0105
[2]https://orcid.org/0000-0002-2745-9909
[3]https://orcid.org/0000-0002-4258-1662
Corresponding author: mined685@gmail.com

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ABSTRACT

The purpose of this study is to illustrate the impact of the Covid-19 epidemic on oil prices and the BRICS stock markets before and after the pandemic, as well as to create an example of the addiction model. Using the CD-vine copula approach, the goal is to demonstrate the dynamic nature of the conditional dependencies of data acquired from BRICS stock markets and oil prices (Opec Oil and Brent Oil). According to the findings, D vine branching and compatible copula families, copula family parameters, and Kendall tau values best represent the conditional dependency structure for the Sars-Cov-2 before-after pandemic period for Brent Oil, Opec Oil, and BRICS Countries. The results of the study are given with the support of figures and graphics.

SAR-CoV-2 Salgınının Petrol Fiyatlarına ve BRICS Hisse Senedi Piyasalarına Etkisi: Dinamik Koşullu Kopula Yaklaşımı

Araştırma Makalesi

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ÖZ

Bu çalışmanın amacı, Covid-19 pandemisinin öncesi ve sonrası alınarak Oil Prices ve BRICS Stock Marketleri üzerindeki etkisini sunmaktır ve bağımlılık modelinin bir örneğini oluşturmaktır. BRICS Hisse Senedi Piyasaları ve Petrol Fiyatlarından (Opec Petrol ve Brent Petrol) elde edilen verilerin koşullu bağımlılıklarının dinamik yapısını CD-vine copula tekniğini kullanarak göstermektir. Çalışmanın sonucunda Brent Oil, Opec Oil ve BRICS için Sars-Cov-2 pandemi öncesi ve sonrası dönem için D-vine dallanması ve uyumlu kopula aileleri, kopula ailesi parametreleri ve Kendall tau değerlerinin koşullu bağımlılık yapısını en iyi şekilde gösterdiği belirlendi. Çalışma sonuçları şekil ve grafiklerle desteklenerek verilmiştir.

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1. Introduction

According to Goldman Sachs' research (O'Neill, 2001) the future of the globe is dependent on the BRICS nations. According to the analysis, China will become the world's largest economy by 2050, followed by India, Brazil, and Russia. The analysis predicts that Turkey will hold an important place in the global economy in 2050. Türkiye has narrowed the gap between itself and the BRICS nations due to its economic performance during the past two decades. To investigate the relationship between oil prices and markets, several studies have been conducted by various researchers. Sadorsky's 1999) study researchers identified positive oil price shocks' negative and statistically significant impact on the stock market index. They used the VAR model, impulse response analysis, and variance decomposition methods. In a study, authors used the vine copula-based GARCH scheme to investigate the structural relationship between the oil, stock, and foreign exchange markets. As a result, they simulated that the increase in crude oil prices between 2000 and 2013 was coupled with the decline in the exchange rate and the appreciation of stock market prices (Aloui and Aïssa, 2016). They examined the time-frequency dynamics of joint transactions between BRICS indices, gold prices, WTI, Brent and oil prices (Mensi et al., 2018). The findings indicate that the BRICS index moves less frequently with the WTI crude oil price. Researchers calculated the dynamic hedge ratio for spot crude oil, simulated tail reliance, and assessed portfolio risk for crude oil futures markets using a newly constructed model (Gong et al., 2019). The application of typical hanging copulas in the analysis of the partner interdependence of the four major Russian Stock Exchange shares, Sberbank, Gazprom, FGC UES, and Rosneft, as demonstrated by the RTS index (Shchetinin, 2019). The researchers in (Tachibana, 2018) explore utilizing US stock returns as a proxy for changes in other stock markets and using a combination technique hanging on 21 economies from 2003 to 2017. The authors of (Dißmann et al., 2013) used this particular study technique in the financial dataset of 16-dimensional international stock, fixed income, and item indexes that were simulated throughout the past ten years, particularly during the time of the most recent financial crisis. Researchers employed a hanging copula technique to investigate the structural link between stock, energy, and foreign exchange markets (Aloui and Aïssa, 2016). The authors of (Mohammed and Barrales-Ruiz, 2020) have discovered an exogenous oil price shock caused by the pandemic, in addition to traditional demand, supply, and financial market shocks in international crude oil markets. They sought to analyze the dynamic joint movement of capital markets in ASEAN from 2012 to 2013, in (Sriboonchitta and Chaiboonsri, 2013). Researchers have focused on the relationship between significant global exchanges, including the European stock markets (the United Kingdom and German), the United States stock market (S & P 500), the Asian stock markets (Japan and China), and the ASEAN stock markets (Indonesia and Philippine) in the pre-crisis period (2000–2008) and post-crisis period (2000–2016), in (Chaiboonsri and Singvejsakul, 2017). They analyzed the composite stock price index and macroeconomic data using the grapevine method (inflation, IDR to USD interest rate and exchange rate) in (Hikmah et al., 2017). The dependent structure and combined movements of the Malaysian Ringgit (MYR) and Thai Baht (THB) currencies have been explored by authors (Chokethaworn et al., 2013), using up-to-date daily data from 2006 to 2013. The BRICS chair, which South Africa joined in April 2011, has been widely used to symbolize the shift in global economic dominance from developed to major developing economies (Haibin, 2012). The BRICS countries cover over a quarter of the world's surface, and more than 40% of the world's population lives there. The authors (Vandemoortele et al., 2013) evaluate the experiences of the four BRICS countries (Brazil, China, India, and South Africa) and identify four major elements affecting their growth patterns in this paper.

2. Materials and Method

a) Fundamentals

For an *n*-dimensional vector *U* on the unit hypercube, the well-known multivariate copula distribution having all uniform marginals over [0, 1], a copula *C* is given by.

$$C(w_1, w_2, \ldots, w_n) = Pr(U_1 \leq w_1, U_2 \leq w_2, \ldots, U_n \leq w_n) \quad (1)$$

The following result is the chief feature of Sklar's theorem (Sklar, 1959), such as the building block of the literature on copulas, specifies as:

Theorem 2.1. (Sklar's Theorem)

The Sklar theorem is a fundamental understanding of the copula idea. According to the Sklar theorem, any multivariate probability distribution may be represented using a copula and marginal distributions. That is, we may fully characterize the dependence between the variables by modeling the marginal distributions of the variables independently using a copula and then adding the copula that expresses this dependency structure. Finally, copula is an effective tool for describing the dependency of random vectors. With the basic insight offered by the Sklar theorem, we can investigate variable dependency more thoroughly and acquire more reliable results in statistical analysis.

Assume *F* be a *n*-dimensional distribution mapping with univariate margins $F_1, F_2, \ldots, F_n$. Also consider that defines the range of F_i and $A_i = [-\infty, \infty]$ where $i = 1,2, \ldots, n$. In that case, there exists a copula function C whole $(y_1, y_2, \ldots, y_n) \in [-\infty, \infty]$

$$F(y_1, y_2, \ldots, y_n) = C(F(y_1), F(y_2), \ldots, F(y_n)) \quad (2)$$

where the random variables $(Y_1, Y_2, \ldots, Y_n)$ are supposed to be continuous.

Definition 2. 2. [5] Kendall Tau and Spearman Rho

Rank correlations are specified as Kendall τ and Spearman ρ. For both correlation measures based on rank, the general term in their definitions is the rank of the examination, indicated as follows:

$$\imath nte\hat{g}rals\rho_S(Y, Z) = 12 \iint_U (C(w, v) - wv)\, dwdv \quad (3)$$

$$\imath nte\hat{g}rals\rho_\tau(Y, Z) = 4 \iint_U C(w, v) \partial C(wv) - 1 \quad (4)$$

where, $U = I^2$is the unique square.

Definition 2. 3. [18] Tail Dependence

Tail dependence case is clearly linked to being of the federation in extreme weights, primarily based on tails. Assume *Y* and *Z* are two random variables along with the distributions F_Y and F_Z serially. So, two primary asymptotic measures for tail dependence, named the coefficient of upper and lower tail dependence indicated below,

$$\lambda_l = \lim_{w\to 0} P(F_y(y) \le w | F_z(y) \le w) = \lim_{u\to 0} \frac{C(w,w)}{w}$$

(5)

$$\lambda_w = \lim_{w\to 1} P(F_y(y) > w \,|\, F_z(y) > w) = \lim_{w\to 1} \frac{1-2w-C(w,w)}{1-w}$$

(6)

where λ_l and $\lambda_w \in [0,1]$.

Definition 2. 4. [5-7] Elliptical Copulas

Let F be the multivariate cumulative distribution function (cdf) of an elliptical distribution. Let F_i be i'th margin cdf and F_i^{-1} be its inverse map for $i = 1,2,\ldots,n$, the elliptical copula established by F is;

$$C(w_1, w, \ldots, w_n) = F[F_1^{-1}(w_1) + \ldots + F_n^{-1}(w_n)] \tag{7}$$

For example, normal copulas (exemplified from unit variances, bivariate normal with zero means, and correlation ρ) and student t-copulas (exemplified by bivariate t-distribution with zero mean, association ρ, and degree of freedom ν) are two varieties of elliptical group.

Definition 2. 5. [11-12] Archimedean Copulas

An Archimedean copula is derived via a generator ϕ as;

$$C(w_1, w_2, \ldots, w_n) = \phi^{[-1]}[\phi_1(w_1) + \ldots + \phi_n(w_n)] \tag{8}$$

where, $\phi^{[-1]}$ is the pseudo-inverse of the generator, ϕ specified by,

$$\phi^{[-1]} = \begin{cases} \phi^{-1}(t) & 0 \le t \le \phi(0) \\ 0 & \phi(0) \le t \le \phi(\infty) \end{cases} \tag{9}$$

In bivariate case,

$$C(w_1, w_2) = \phi^{[-1]}(\phi(w_1) + \phi(w_2)) \tag{10}$$

defines the so-called Archimedean bivariate copula function.

Table 1. Copula Families

Elliptical Copula Family

Family No.	
1	Gaussian (Normal) Copula
2	Student's – t Copula

Arşimedyan Copula Families

	Archimedean Copula Groups of One parameter type		Archimedean Copula Groups of Two parameter type
3	Clayton Copula	7	Clayton-Gumbel (BB1) Copula
4	Gumbel Copula	8	Joe-Gumbel (BB6) Copula
5	Joe Copula	9	Joe-Clayton (BB7) Copula
6	Frank Copula	10	Joe-Frank (BB8) Copula
13	Survival Clayton Copula	17	Survival BB1Copula
14	Survival Gumbel Copula	18	Survival BB6 Copula
16	Survival Joe Copula	19	Survival BB7 Copula
23	Rotated Clayton Copula (90 degree)	20	Survival BB8 Copula
24	Rotated Gumbel Copula (90 degree)	27	Rotated BB1 Copula (90 degree)
26	Rotated Joe Copula (90 degree)	28	Rotated BB6 Copula (90 degree)

33	Rotated Clayton Copula (270 degree)	29	Rotated BB7 Copula (90 degree)
34	Rotated Gumbel Copula (270 degree)	30	Rotated BB8 Copula (90 degree)
36	Rotated Joe Copula (270 degree)	37	Rotated BB1 Copula (270 degree)
		38	Rotated BB6 Copula (270 degree)
		39	Rotated BB7 Copula (270 degree)
		40	Rotated BB8 Copula (270 degree)
		104	Tawn type 1 Copula
		114	Rotated Tawn type 1 Copula (180 degree)
		124	Rotated Tawn type 1 Copula (90 degree)
		134	Rotated Tawn type 1 Copula (270 degree)
		204	Tawn type 2 Copula
		214	Rotated Tawn type 2 Copula (180 degree)
		224	Rotated Tawn type 2 Copula (90 degree)
		234	Rotated Tawn type 2 Copula (270 degree)

Definition 2. 6. [11-13] Vine Copulas

Let $T = U_1, U_2, \ldots, U_{n-1}$denote the regular vine for *n* variables, where a connected tree U_i is specified with nodes $M_i = 1,2,\ldots,n$ and edges $E_i$for $i = 2,\ldots,n-1$. In such tree dynamics, U_i is a connected tree with nodes $M_i = E_{i-1}$. A vine with p variables is called a regular vine when two edges in tree *i* are joined by an edge in tree *i + 1*, exclusively when these edges serving a same node. Generally, there are totally $n(n-2)/2$possible edges in a regular vine for *n* variables (Kurowicka and Cooke, 2006).

Definition 2. 7. [19] Conditional Copula

Given (Kurowicka and Cooke, 2006),

$$f(y_1, y_2, \ldots, y_n) = \left(\sum_{k=2}^{n} f(y_k|y_1, y_2, \ldots, y_{k-1})\right) f_1(y_1)$$

and for isolated values of $i, j, i_1, \ldots, i_m$with i < j and $i_1 < \ldots < i_m$ and describe

$$c_{i,j|i_1,i_2,\ldots i_m} = c_{i,j|i_1,i_2,\ldots i_m}\left(F(y_i|y_{i1},\ldots,y_{im}), F(y_j|y_{i1},\ldots,y_{im})\right) \quad (11)$$

where *f* and *c* define probability density function (pdf.) of marginals and copula density mapping, serially. Then, we can write the conditional pdf

$$f(y_k|y_1, y_2, \ldots, y_{k-1}) = c_{1,k|2,\ldots,k-1} f(y_k|y_2, \ldots, y_{k-1}) = \sum_{q=1}^{k-2}\left(c_{q,k|q+1,\ldots,k-1}\right) c_{k-1,k} f_k(y_k)$$

(12)

by using equation (11) and (12) writing

$$f(y_1, y_2, \ldots, y_n) = \left(\sum_{j=1}^{n-1}\sum_{i=1}^{n-j} c_{i,i+j|i+1,\ldots,i+j-1}\right)\sum_{m=1}^{n} f_m(y_m).$$

Definition 2. 8. [11-13] CD Vine Copula

A structure vine copula is generally specified as a trees nested set defining the pairwise copula mappings un-conditionally at the first tree and conditionally for the other connected trees. This formulation is specified as follows;

Definition 2. 8.1. [11-13] C Vine Copula

This is a regular type vine distribution for which a unique node exists for every tree which is attached to the rest of all other nodes of the tree. It utilizes only star like trees and it is helpful for ordering by consequences. The relative probability density function (pdf) can be specified by

$$\prod_{k=1}^{n} f(y_k) \prod_{j=1}^{n-1} \prod_{i=1}^{n-j} c_{j,j+i|1,\dots,j-1} \{F(y_j|y_1,\dots,y_{j-1}), F(y_{j+i}|y_1,\dots,y_{j-1})\}.$$

(13)

Definition 2. 8.2. [11-13] D Vine Copula

D-vine is also a particular case of regular-type vine tree dynamics which have no node in any tree is attached to more than two edges. It utilizes only path like trees and useful for variables temporal ordering. Its density function (pdf) can be read as;

$$\prod_{k=1}^{n} f(y_k) \prod_{j=1}^{n-1} \prod_{i=1}^{n-j} c_{i,i+j|i+1,\dots,i+j-1} \{F(y_i|y_{i+1},\dots,y_{i+j-1}) F(y_{i+j}|y_{i+1},\dots,y_{i+j-1})\}. \quad (14)$$

b) Data

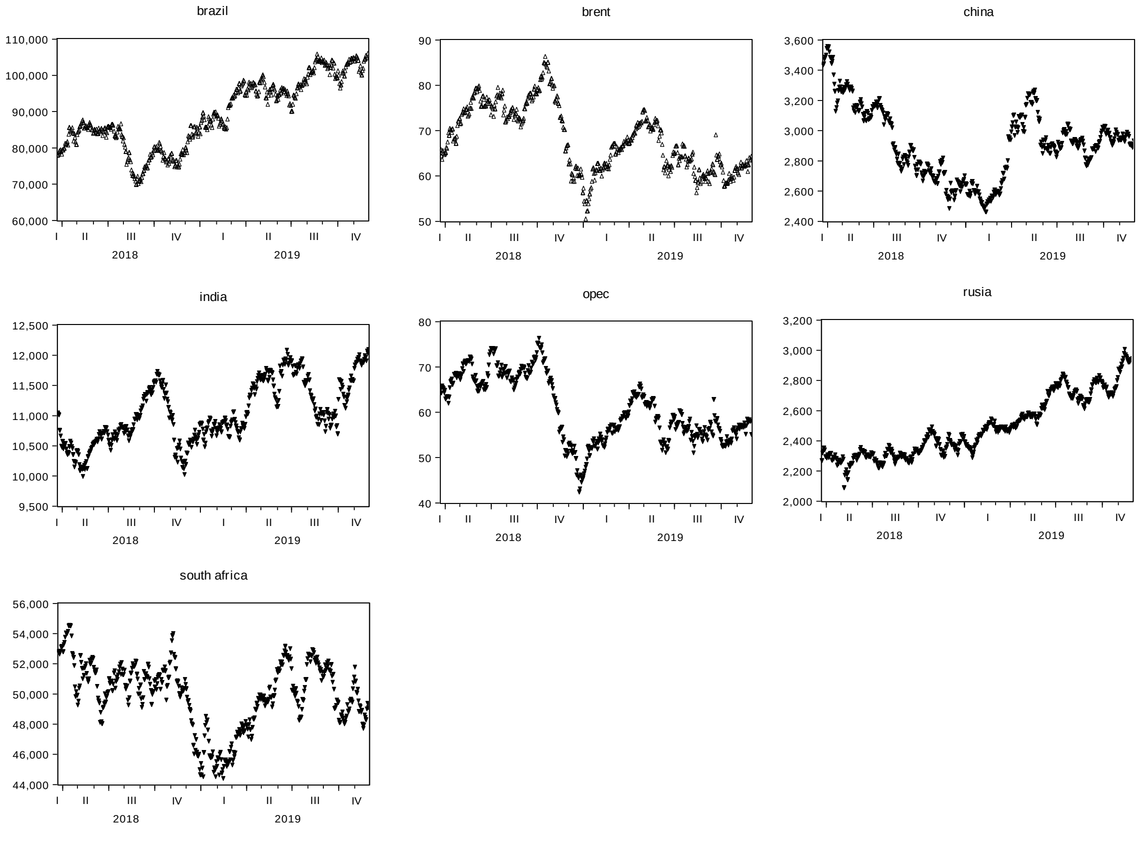
To reveal the dynamic conditional dependency structure, the dataset is taken in Pre –Sars-Cov-2 period (21.03.2018-29.11.2019) and Post –Sars-Cov-2 period (17.12.2019-19.02.2021) of Opec Oil, Brent Oil and the countries of BRICS (Russia, Brazil, China, India, and South Africa). The descriptive statistics of our data set before and after the Sars-Cov-2 pandemic are given in Table 2, Figure 1, and Figure 2. In addition, the graphs of the residual series of our data set are presented in Figure 1 and Figure 2. We obtained the dataset used in the current investigation from www.bloomberg.com.

3. Results and Discussion

Below, we go over our findings using the technique and information above. The averages and standard deviations are very different from the descriptive statistics for Opec Oil, Brent Oil, and BRICS countries before the Sars-Cov-2 pandemic, as presented in Table 2. Brazilian standard deviation is the highest. According to the metrics of skewness, Brazil and South Africa are negative and skewed to the left, whereas Brent Oil, Opec Oil, Russia, India, and China are upbeat and skewed to the right. By examining the kurtosis coefficients, it is found that all series have values lower than three, indicating that they are of the flat type. It was discovered that the series was very different from a normal distribution. Considering Jarque Bera test statistics and probability value, the normality of each return series distribution is strongly rejected at 0.05 level, indicating that all price index distributions are non-normal. Once more, it can be shown from Table 2 that the means and standard deviations varied during the time after the Sars-Cov-2 pandemic, with Brazil having the highest standard deviation. Except for China and India, all the skewness coefficients are negative and skewed to the left. Both optimistic and biased to the right are China and India. Except for South Africa and Opec Oil, the series are flat series when looking at kurtosis coefficients because their kurtosis is smaller than three. Given that they are more significant than three, South Africa and Opec Oil are pointed series. Given the Jarque Bera test statistics and probability value, it was determined that the series was very different from a normal distribution and that the normality of each return series distribution is strongly rejected at the 0.05 level, demonstrating that all price index distributions are non-normal.

Table 2. Pre –SARS-COV-2 period (21.03.2018-29.11.2019) and Post –SARS-COV-2 period (17.12.2019-19.02.2021) Descriptive Statistics of Data Sets, respectively

	Mean	Std. Dvt.	Skewness	Kurtosis	Jarquera Bera	Probability
Pre						
Brent Oil	68.1525	7.23516	0.200005	2.11800	17.47008	0.000161
Opec Oil	60.7308	7.23412	0.088910	2.065972	16.83753	0.000221
Russia	2491.88	202.740	0.566274	2.20348	35.70593	0.000000
India	11052.77	508.925	0.199508	2.011867	21.15095	0.000026
Brazil	89297.29	9571.289	-0.013474	1.865570	23.98262	0.000006
China	2919.921	236.9018	0.286998	2.648005	8.444065	0.000146
South Africa	49942.30	2230.204	-0.533446	2.728430	22.57362	0.000013
Post						
Brent Oil	46.14510	11.56108	-0.005896	2.477184	3.555188	0.00016
Opec Oil	42.19942	12.16889	-1.175352	8.144218	415.8543	0.00000
Russia	2943.488	271.3987	-0.116127	2.944119	0.741838	0.00069
India	11619.90	1676.943	0.055323	2.679665	1.481324	0.0047
Brazil	102106.1	14075.14	-0.642936	2.602282	23.55139	0.00000
China	3145.210	257.8289	0.106589	1.691235	22.85803	0.000011
South Africa	50559.46	4729.745	-0.527513	4.673833	50.89237	0.00000



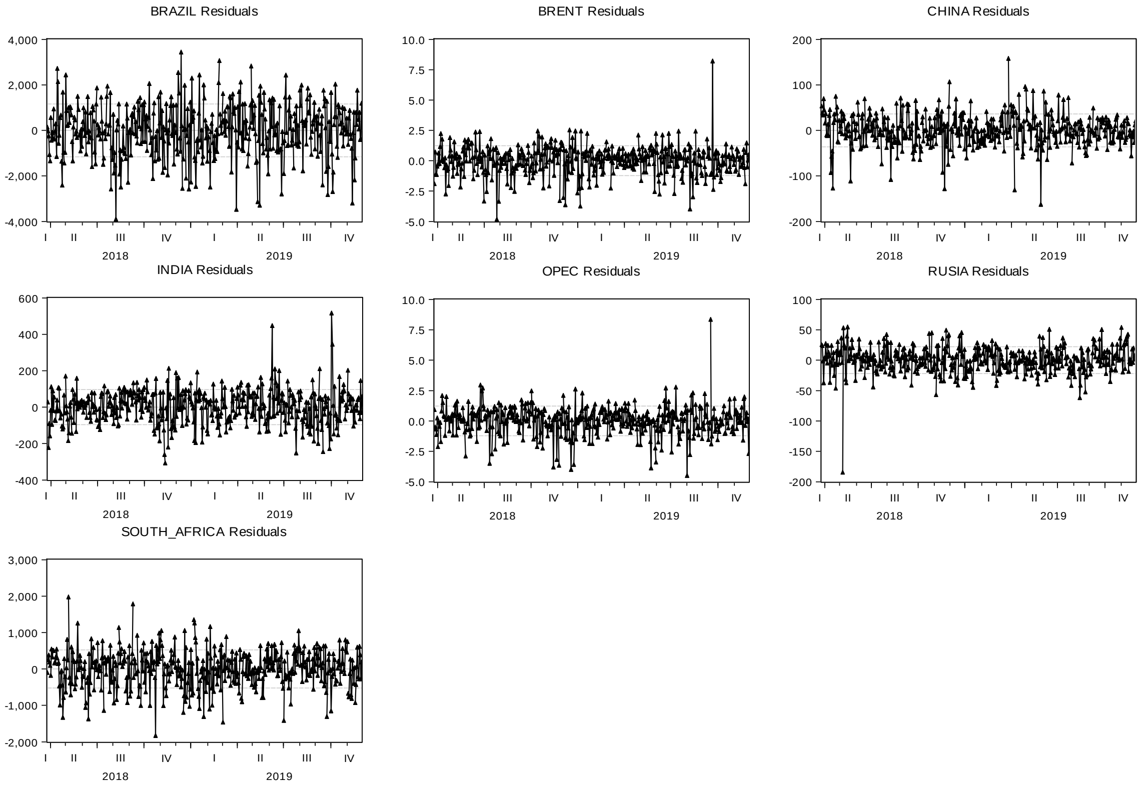
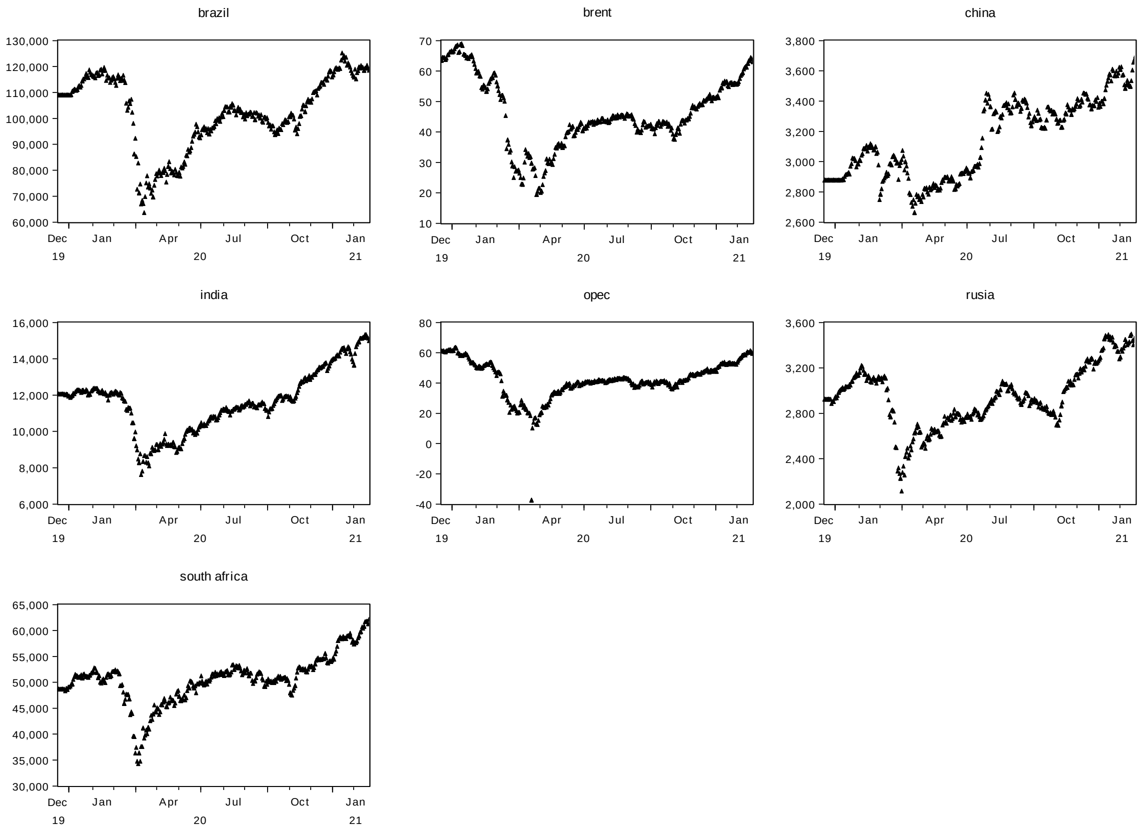


Figure 1. Pre –SARS-COV-2 period (21.03.2018-29.11.2019) Data Sets and Residuals, respectively



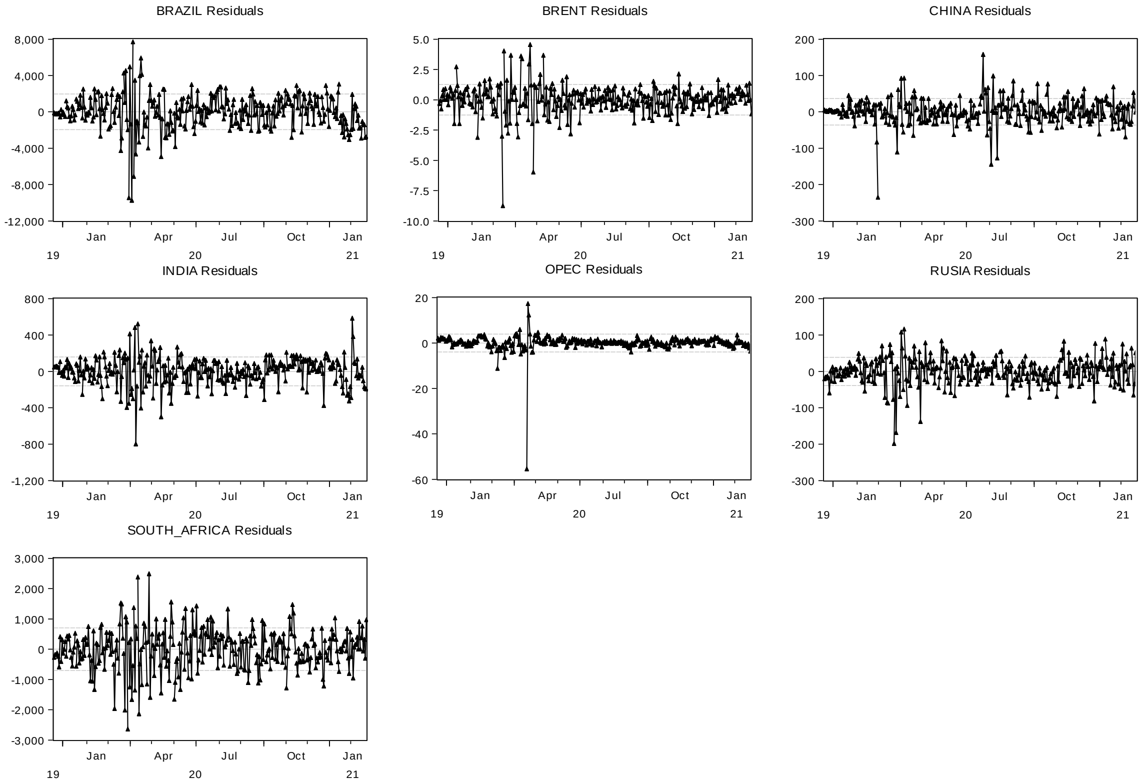
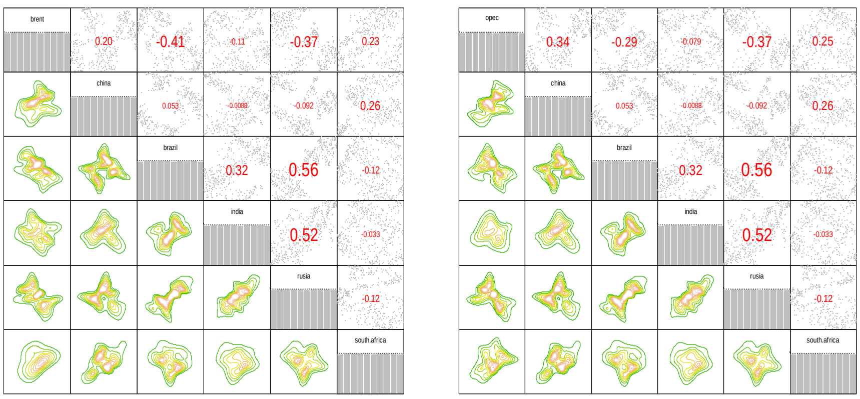


Figure 2. Post –SARS-COV-2 period (17.12.2019-19.02.2021) Data Sets and Residuals, respectively

In Figure 2, the correlation coefficient between Brent Oil and BRICS Countries, Opec Oil, and BRICS Countries of the data set taken before and after the Sars-Cov-2 pandemic was obtained. Again, as seen in Figure 2, before the Sars-Cov-2 pandemic, it was observed that Brent Oil and Opec Oil were negatively correlated with Brazil, India, and Russia and positively weakly associated with South Africa and China. Again, from Figure 2, after the Sars-Cov-2 pandemic, it was observed that Brent Oil and Opec Oil were positively strongly correlated with Brazil, India, Russia, and South Africa. It was observed that Brent Oil and Opec Oil was positively weakly. The Spearman Rho of Data Sets is given in Figure 3.



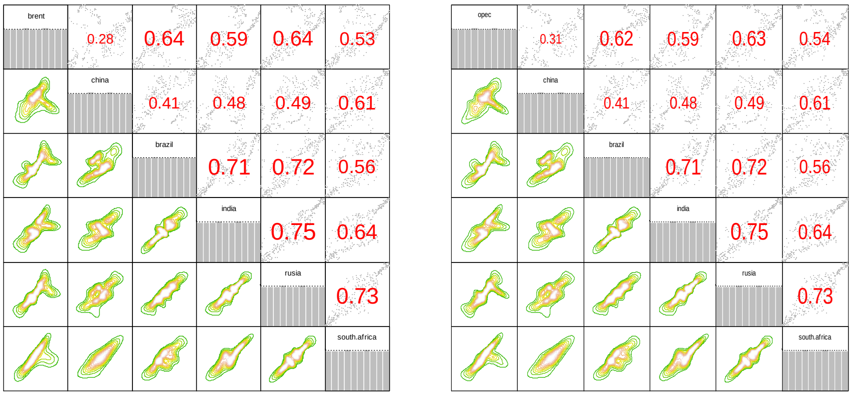


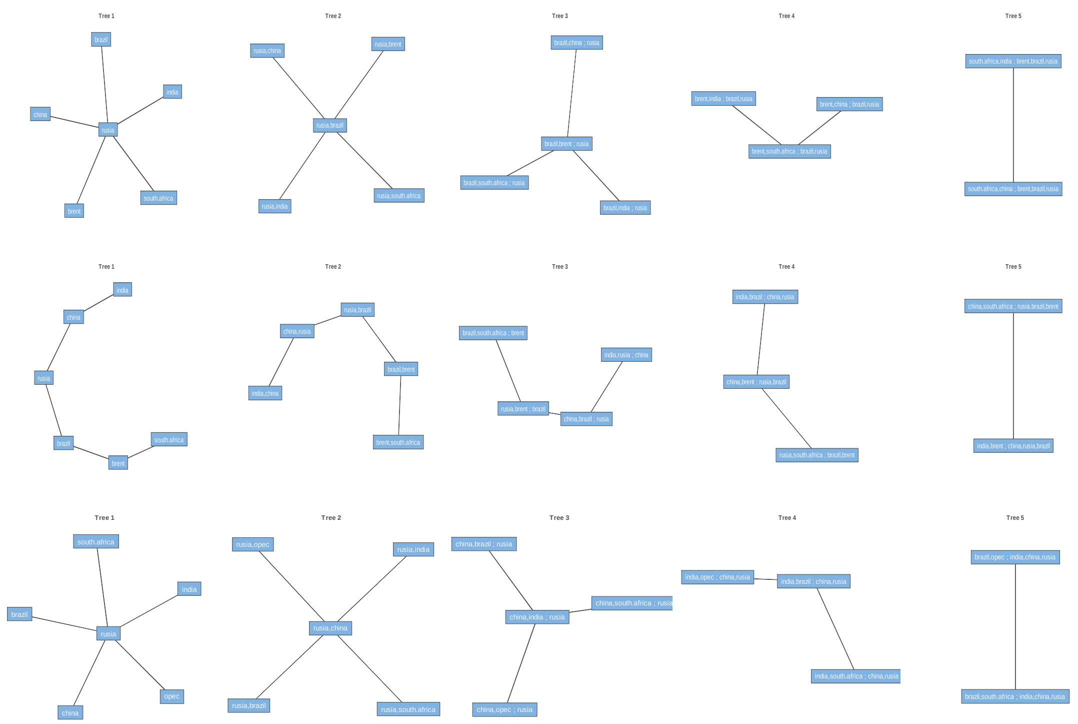
Figure 3. Pre –SARS-COV-2 period (21.03.2018-29.11.2019) and Post –SARS-COV-2 period (17.12.2019-19.02.2021) Spearman Rho of Data Sets, respectively

The conditional dependency structures between Brent Oil and BRICS Countries, Opec Oil, and BRICS countries before and after the Sars-Cov-2 pandemic are described in this section of our study. Before the Sars-Cov-2 pandemic, the conditional dependency structure between Brent Oil from the BRICS nations and Opec Oil from the BRICS countries is detailed in Tables 3, Table 4, and Figure 4. Copula families, copula family characteristics, and Kendall tau correlation coefficients for conditional dependency are derived in Table 3. For Brent Oil and Opec Oil, lower and upper tail dependency coefficients for copula groups consistent with C vine and D vine branching are derived in Table 3. Figure 4 shows the display of the figure for Opec Oil and Brant Oil. According to Table 5, D vine was the proper branching for Brent Oil and Opec Oil before the Sars-Cov-2 pandemic. In other words, it is concluded that the conditional dependency structure is best revealed by D vine branching and compatible copula families, copula family parameters, and Kendall tau values for the Sars-Cov-2 pre-pandemic period for Brent Oil, Opec Oil, and BRICS Countries. Copula families, copula family characteristics, and Kendall tau correlation coefficients for conditional dependency are now retrieved from Table 4. For Brent Oil and Opec Oil, lower and upper tail dependency coefficients for copula groups compatible with C vine and D vine branching are obtained in Table 4. Figure 5 depicts the figure for Brent Oil, Opec Oil, and the BRICS Countries. From Table 5, it was found that D vine was the proper branching for Brent Oil, Opec Oil, and BRICS Countries during the time following the Sars-Cov-2 pandemic. In other words, it is determined that D vine branching and compatible copula families, copula family parameters, and Kendall tau values best show the conditional dependency structure for the Sars-Cov-2 post-pandemic period for Brent Oil, Opec Oil, and BRICS Countries.

Table 3. Pre –SARS-COV-2 period (21.03.2018-29.11.2019), For Brent Oil and Opec Oil C and D Vine Copula

<table>
<tr><th>C vine Brent</th><th>pairs</th><th>copula</th><th>Par1</th><th>Par2</th><th>tau</th><th>utd</th><th>ltd</th></tr>
<tr><td>Tree1</td><td>China- Russia</td><td>C270</td><td>-0.46</td><td>0.00</td><td>-0.19</td><td>-</td><td>-</td></tr>
<tr><td></td><td>İndia-Russia</td><td>SBB1</td><td>0.63</td><td>1.55</td><td>0.51</td><td>0.49</td><td>0.44</td></tr>
<tr><td></td><td>Russia-South Africa</td><td>Tawn 90</td><td>-2.60</td><td>0.11</td><td>-0.09</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Russia-Brent</td><td>F</td><td>-3.78</td><td>0.00</td><td>-0.37</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Russia-Brazil</td><td>BB8</td><td>6.00</td><td>0.77</td><td>0.57</td><td>-</td><td>-</td></tr>
<tr><td>Tree2</td><td>Brazil, China| Russia</td><td>F</td><td>1.69</td><td>0.00</td><td>0.18</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Brazil, İndia| Russia</td><td>BB7270</td><td>-1.00</td><td>-0.31</td><td>-0.13</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Brazil, SAfrica| Russia</td><td>Tawn 90</td><td>-1.88</td><td>0.13</td><td>-0.10</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Brazil, Brent| Russia</td><td>C270</td><td>-0.45</td><td>0.00</td><td>-0.18</td><td>-</td><td>-</td></tr>
<tr><td>Tree3</td><td>Brent, China| Brazil, Russia</td><td>SBB8</td><td>1.90</td><td>0.92</td><td>0.26</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Brent, İndia| Brazil, Russia</td><td>BB8</td><td>2.27</td><td>0.83</td><td>0.26</td><td>-</td><td>-</td></tr>
<tr><td></td><td>Brent, S.Africa| Brazil, Russia</td><td>Tawn 180</td><td>2.17</td><td>0.21</td><td>0.17</td><td>-</td><td>0.20</td></tr>
<tr><td>Tree4</td><td>S. Africa, China |Brent, Russia Brazil,</td><td>SBB7</td><td>1.39</td><td>0.27</td><td>0.26</td><td>0.08</td><td>0.36</td></tr>
</table>

	S. Africa, İndia |Brent, Brazil, Russia	Tawn	1.78	0.12	0.09	0.11	-
Tree5	Brazil, China	Tawn2 180	1.33	0.09	0.05	-	0.06
D vine Brent							
Tree1	Brent-S. Africa	Tawn180	2.24	0.28	0.21	-	-
	Brazil-Brent	F	-4.23	0.00	-0.40	-	0.44
	Russia-Brazil	BB8	6.00	0.77	0.57	-	-
	China- Russia	C90	-0.46	0.00	-0.19	-	-
	İndia-China	J90	-1.33	0.00	-0.16	-	-
Tree2	Brazil, SAfrica| Brent	Tawn2 90	-2.25	0.05	-0.05	-	-
	Russia, Brent| Brazil	Tawn 90	-1.75	0.07	-0.05	-	-
	China, Brazil| S.Africa	F	1.69	0.00	0.18	-	-
	Russia, India, | China	BB8	3.74	0.89	0.50	-	-
Tree3	Russia, S. Africa|, Brazil, Brent	Tawn 90	-1.71	0.08	-0.06	-	-
	China, Brent| Russia, Brazil	SBB8	1.93	0.93	0.27	-	-
	India, Brazil| China, Russia	Tawn2 90	-1.77	0.29	-0.18	-	-
Tree4	China, S. Africa| Russia,Brazil, Brent	SBB7	1.53	0.17	0.28	0.02	0.43
	India, Brent |China, S.Africa,Brazil	SC	0.55	0.00	0.21	0.28	-
Tree5	India, S.Africa| Russia, China, Brazil,Brent	Tawn2	1.66	0.13	0.09	0.11	-
C vine Opec							
Tree1	Russia-Opec	BB8-90	-3.04	-0.85	-0.39	-	-
	Russia-S.Africa	Tawn 90	-2.60	0.11	-0.09	-	-
	Russia-Brazil	BB8	6.00	0.77	0.57	-	-
	Russia-India	SBB1	0.63	1.55	0.51	0.49	0.44
	Russia-Brazil	C270	-0.46	0.00	-0.19	-	-
Tree2	China, Opec| Russia	SBB8	2.00	0.93	0.28	-	-
	China, S.Africa| Russia	SBB7	1.53	0.18	0.28	0.02	0.43
	China, Brazil| Russia	F	1.69	0.00	0.18	-	-
	China, India| Russia	C	0.21	0.00	0.09	-	0.04
Tree3	India,Opec| Brazil, Russia	Tawn	1.69	0.40	0.22	0.28	-
	India, S.Africa|Brazil, Russia	Tawn2	2.19	0.12	0.10	0.12	-
	India, Brazil| Brazil, Russia	BB7-90	-1.00	-0.33	-0.14	-	-
Tree4	Brazil, Opec |India, China,Russia	Tawn90	-2.74	0.11	-0.10	-	-
	Brazil, S.Africa |India, Brent, Russia	F	-1.56	0.00	-0.17	-	-
Tree5	S.Africa, Opec| India, Brazil, China, Russia	Tawn2 180	2.57	0.11	0.10	-	0.11
D vine Opec							
Tree1	Opec-S. Africa	Tawn 180	2.82	0.23	0.20	-	0.22
	Brazil-Brent	BB8 90	-3.49	-0.66	-0.30	-	-
	Russia-Brazil	BB8	6.00	0.77	0.57	-	-
	China- Russia	C90	-0.46	0.00	0.19	-	-
	İndia-China	J90	-1.33	0.00	-0.16	-	-
Tree2	Brazil, SAfrica| Opec	N	-0.02	0.00	-0.02	-	-
	Russia, Opec| Brazil	Tawn 90	-1.81	0.34	-0.21	-	-
	China, Brazil| Russia	F	1.69	0.00	0.18	-	-
	India, Russia| China	BB8	3.74	0.89	0.50	-	-
Tree3	Russia, S.Africa| Brazil, Opec	Tawn 270	-3.52	0.02	-0.02	-	-
	China, Opec| Russia, Brazil	SBB8	2.99	0.83	0.37	-	-
	India, Brazil| China, Russia	Tawn2 90	-1.77	0.29	-0.18	-	-
Tree4	China, S. Africa|, Russia, Brazil, Opec	BB7	1.19	0.68	0.31	0.21	0.36
	India, Opec |China, Russia, Brazil	G	1.28	0.00	0.22	0.28	-
Tree5	India, S.Africa |China, Russia, Brazil, Opec	Tawn 2	1.51	0.11	0.07	0.08	-



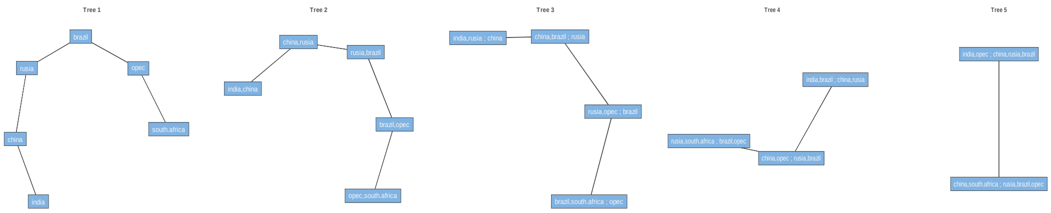


Figure 4. Pre –SARS-COV-2 period (21.03.2018-29.11.2019), For Brent Oil and Opec Oil C and D Vine Copula, respectively

Table 4. Post –SARS-COV-2 period (17.12.2019-19.02.2021), for Brent Oil and Opec Oil C and D Vine Copula

C vine Brent	pairs	copula	Par1	Par2	tau	utd	ltd
Tree1	India-China	SBB7	1.81	1.28	0.51	0.58	0.53
	India -Brazil	SG	3.46	0.00	0.71	-	0.78
	India -Russia	BB8	6.00	0.95	0.69	-	-
	India-Brent	SBB8	5.68	0.79	0.57	-	-
	India –S. Africa	SBB7	2.26	3.39	0.67	0.81	0.64
Tree2	S.Africa, China| India	BB8	3.06	0.81	0.36	-	-
	S.Africa, Brazil| India	BB8	1.48	0.78	0.09	-	-
	S.Africa, Russia| India	SG	1.69	0.00	0.41	-	0.49
	S.Africa, Brent| India	Tawn 180	2.57	0.31	0.24	-	0.29
Tree3	Brent, China| S.Africa, India	BB8 270	-3.96	-0.60	-0.30	-	-
	Brent, Russia|S.Africa, India	SBB8	2.12	0.92	0.30	-	-
	Brent S.Africa| S.Africa ,India	SBB8	1.95	0.89	0.24	-	-
Tree4	Russia, China |Brent,S.Africa, India	SC	0.08	0.00	0.04	0.00	-
	Russia, Brazil | Brent, S.Africa, India	G	1.45	0.00	0.31	0.39	-
Tree5	Brazil, China |Russia, Brent, S.Africa, India	F	0.55	0.00	0.06	-	-
D vine Brent							-
Tree1	Rusia-Brent	SBB8	5.84	0.89	0.65	-	-
	Brazil-Rusia	F	12.06	0.00	0.71	-	-
	India-Brazil	SG	3.46	0.00	0.71	-	0.78
	S.Africa- India	SBB7	2.26	3.39	0.67	0.81	0.64
	China-S.Africa	G	2.52	0.00	0.60	0.68	-
Tree2	Brazil, Brent| Russia	Tawn2 180	2.04	0.55	0.33	-	0.41
	India, Russia| Brazil	G	1.59	0.00	0.37	0.45	-
	S.Africa, Brazil| India	BB8	1.48	0.78	0.09	-	-
	China, Brazil| S.Africa	F	0.46	0.00	0.05	-	-
Tree3	India, Brent |Brazil, Russia	Tawn	1.49	0.07	0.05	0.06	-
	S.Africa, Russia| India, Brazil	SBB8	4.38	0.84	0.52	-	-
	China,Brazil |S.Africa, India	C270	-0.03	0.00	-0.01	-	-
Tree4	S. Africa, Brent| India, Brazil, Russia	F	0.41	0.00	0.05	-	-
	China, Russia| S.Africa, India, Brazil	C90	-0.12	0.00	-0.05	-	-
Tree5	China, Brent |S.Africa, India, Brazil, Russia	F	-1.77	0.00	-0.19	-	-
C vine Opec	pairs	copula	Par1	Par2	tau	utd	ltd
Tree1	India-China	SBB7	1.81	1.28	0.51	0.58	0.53
	India -Brazil	SG	3.46	0.00	0.71	-	0.78
	India -Russia	BB8	6.00	0.95	0.69	-	-
	India –S.Africa	SBB7	2.26	3.39	0.67	0.81	0.64
	India -Opec	SBB8	6.00	0.77	0.58	-	-
Tree2	Opec,China| India	J270	-1.28	0.00	-0.14	-	-
	Opec, Brazil| India	Tawn 180	1.78	0.34	0.21	-	0.26
	Opec, Russia| India	SJ	1.51	0.00	0.22	-	0.42
	Opec, S.Africa| India	Tawn2 180	2.09	0.29	0.21	-	0.26
Tree3	S.Africa,China| Opec, India	BB8	2.64	0.87	0.35	-	-
	S.Africa, Brazil| Opec, India	Tawn2	1.53	0.15	0.09	0.12	-
	S.Africa, Russia| Opec, India	SG	1.61	0.00	0.38	-	0.46
Tree4	Russia,China |S.Africa, Opec, India	N	-0.02	0.00	-0.01	-	-
	Russia, Brazil |S.Africa, Opec, India	G	1.53	0.00	0.35	0.43	-
Tree5	Brazil, China| Russia S.Africa, Opec, India	J	1.05	0.00	0.03	0.07	-
D vine Opec							
Tree1	China-Opec	Tawn2	2.69	0.43	0.33	0.40	-
	S.Africa-China	G	2.52	0.00	0.60	0.68	-
	India-S.Africa	SBB7	2.26	3.39	0.67	0.81	0.64
	Brazil- India	SG	3.46	0.00	0.71	-	0.78
	Russia-Brazil	F	12.06	0.00	0.71	-	-
Tree2	S.Africa, Opec | China	SBB8	5.01	0.75	0.50	-	-
	India, China| S.Africa	F	0.46	0.00	0.05	-	-
	Brazil, S.Africa| India	BB8	1.48	0.78	0.09	-	-
	Russia, India| Brazil	G	1.59	0.00	0.37	0.45	-
Tree3	India,Opec|S.Africa, China	BB8	2.26	0.94	0.35	-	-
	Brazil, China| India, S.Africa	C90	-0.03	0.00	-0.01	-	-
	Russia, S.Africa |Brazil, India	SBB8	4.38	0.84	0.52	-	-
Tree4	Brazil, Opec|I ndıa,S.Africa,China	SBB8	1.75	0.79	0.15	-	-
	Russia, China |Brazil, India, S.Africa	C270	-0.12	0.00	-0.05	-	-
Tree5	Russia, Opec |Brazil, India, S.Africa, China	F	0.75	0.00	0.08	-	-

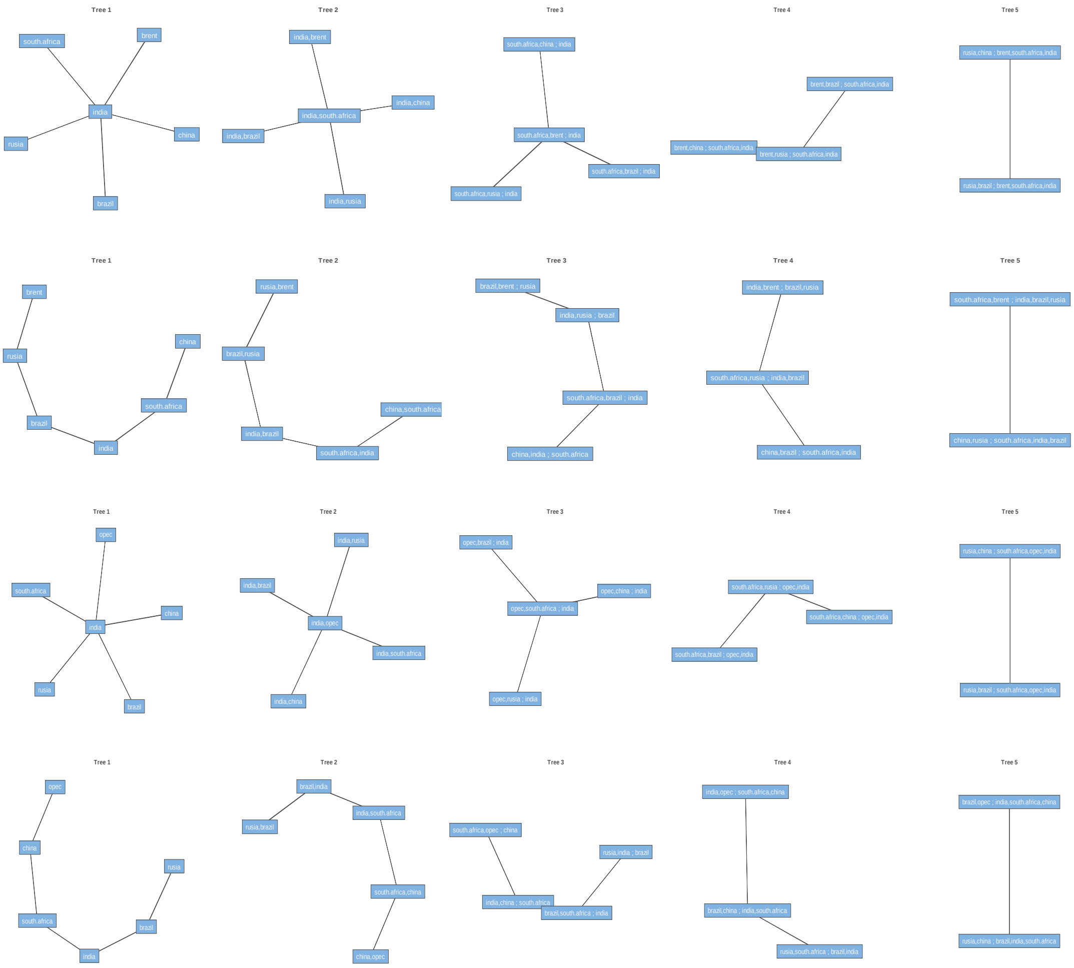


Figure 5. Post –SARS-COV-2 period (17.12.2019-19.02.2021), For Brent Oil and Opec Oil C and D Vine Copula, respectively

Table 5. Pre –SARS-COV-2 period (21.03.2018-29.11.2019) and Post –SARS-COV-2 period (17.12.2019-19.02.2021) Comparison of the C-vine and D-vine, respectively.

	C vine		D vine	
Brent Oil	Pre	Post	Pre	Post
Loglike	761.45	1349.59	780.21	1357.47
AIC	-1470.9	-2649.17	-1510.42	-2672.94
BIC	-1364.23	-2555.6	-1407.86	2594.34
Opec Oil				
Loglike	800.87	1307.75	809.07	1330.45
AIC	-1549.74	-2569.5	-1568.15	-2616.89
BIC	-1443.07	-2483.41	-1465.59	-2534.55

4. Conclusions

This article explored the dependence structure of Oil Prices and BRICS Stocks Markets before and after the SAR-CoV-2 epidemic. We have used the CD-vine copula approach to demonstrate the structure of the date of conditional dependencies of the Oil Prices and BRICS Stock Markets. The proposed CD-vine approach has provided convenience in obtaining the complex dependency structure.

We have plotted several graphs and provided tables to present the dependency structure. The given study is critical and valuable worldwide.

Data availability

The datasets generated during the current study are available in www.bloomberg.com.

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Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The contribution of the authors is equal.

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