Assessing the Impact of Renewable Energy Tokens on BRICS Stock Markets: A New Diversification Approach

Abstract

The key concern of this study is to investigate the nexus between the BRICS equity market and renewable energy tokens. Based on TVP-VAR, we examine the static and dynamic connectedness between our variables of interest. In addition to connectedness, we have also determined the diversification potential of renewable energy tokens using the DCC-GARCH model. The results infer that the connectedness between renewable energy tokens and the BRICS market remains substantial. However, it became more apmlified during COVID-19. Particularly, our findings show that BRICS equity markets act as transmitters while renewable energy tokens function as net receivers of return spillover within the system examined. Additionally, our findings infer that the inclusion of renewable energy tokens offers portfolio diversification benefits to investors in the BRICS region. However, during troublesome times, renewable energy sources provide hedging and compensate the investor's exposure to the higher level of uncertainty. Wrapping up, our findings hold indispensable guidance for investors, portfolio managers, and policy analysts.

Keywords: Static and Dynamic Connectedness, Energy tokens, BRICS, portfolio diversification, Optimal weights

JEL Classification: C40, G10, G12

1. Introduction

Environmental activism is a growing global movement that advocates for sustainable environmental practices. In the context of renewable energy, it holds immense relevance. Activists push for increased adoption of clean energy sources like wind, solar, and hydroelectric power while advocating for the reduction of fossil fuel reliance. Environmental activism plays a crucial role in shaping government policies, corporate practices, and public attitudes towards renewable energy. It serves as a driving force behind the transition to cleaner and more sustainable energy solutions to combat environmental challenges. Environmental activism aligns closely with several Sustainable Development Goals (SDGs) established by the United Nations. Primarily, it contributes to SDG 7: affordable and clean energy, by advocating for the shift towards renewable and sustainable energy sources. Furthermore, it supports SDG 13: Climate Action, by addressing climate change concerns through reduced carbon emissions. By influencing policies, practices, and public attitudes, environmental activism plays a pivotal role in advancing these SDGs and working towards a more sustainable and environmentally conscious future (Zakari et al., 2022). The confluence of environmental activism and renewable energy has far-reaching implications for society, particularly within the context of financial markets and investment. Environmental activism has propelled the concept of sustainable investing into the mainstream. Investors are increasingly seeking opportunities that align with their values, leading to a surge in sustainable and impact investments (Sinha et al., 2023). This trend has reshaped the investment landscape, encouraging companies to adopt more socially responsible and environmentally friendly practices.

The intersection of environmental activism and renewable energy holds profound implications for society, particularly within the realm of financial markets and investments. As environmental concerns take center stage, investors are increasingly drawn to sustainable and eco-conscious opportunities (Sinha et al., 2023). This surge of environment friendly investments has not only transformed investment strategies but has also driven corporations to adopt greener practices to attract such investors. Moreover, renewable energy investments have emerged as resilient assets in the face of economic volatility. These ventures offer stable, long-term returns and are seen as a hedge against market uncertainties as a result, they have become essential components of diversified investment portfolios, contributing to broader market stability.

Additionally, renewable energy holds a pivotal role in the realm of socially responsible investment (SRI). As the world grapples with the urgent need to address climate change and environmental degradation, SRI investors are increasingly drawn to renewable energy assets. These investments not only offer the potential for attractive financial returns but also align with the ethical and sustainability criteria at the core of SRI (Bai et al., 2023). Likwise, this SRI advocacy results in a transition from conventional diversification to socially responsible diversification. This leads to sustainable portfolio diversification, which not only considers the short-term gain but also the long-term implications of their investment on society and the environment. Therefore, in contrast with contemporary investment strategies, the ultimate goal of portfolio managers remains to diversify their portfolio, which not only generates positive returns but also adheres to the notion of sustainability. In light of these developments, the market capitalization of renewable energy investment recently spiked by a reomarkable $1740 billion, while fossil fuel investment hit its lowest at $1050 billion[1].

The rising surge of renewable energy is increasingly attracting the attention of various key stakeholders (Zhang et al., 2022). Particularly, the emergence of disruptive technologies has further revolutionised and transformed the landscape of the energy market by offering innovative solutions towards sustainable consumption. Blockhian technology made it possible to offer such innovative financial instruments that remain decentralised and transparent to facilitate energy trnasctions. This game-changing technology resulted in the creation of various digital assets such as cryptocurrencies and tokens, including energy tokens. Energy tokens backed by the public blockchain are digital financial instruments that facilitate energy transactions (Li et al., 2023).

The evolution of renewable energy tokens has transformed the energy landscape and offered new avenues for resource efficiency and sustainability. Accordingly, the evolution of renewable energy tokens has profound implications for the investment landscape. The energy tokens powered by blockchain offer the transition of traditional energy into a digital form of currency, which facilitates and reduces the cost of transactions. Though there are a number of renewable energy tokens that remain popular, the primary ones are termed WePower-WPR, SunContract-SNC, SunContract-

[1] Energy Statistics. For additional insight : https://www.iea.org/reports/world-energy-investment-2023/overview-and-key-findings.

SNC, and GRID. Both WePower and Power Ledger have been developed to facilitate the consumer and reduce transaction costs while making the energy landscape more decentralized[2].

The evolution of renewable energy tokens not only holds strong implications for the energy landscape but also contains implications for financial markets. However, how these newly evolved digital assets remain beneficial for investors and other stakeholders in financial markets remains unknown. Empirical evidence regarding this crucial aspect is still missing, and further examination is warranted to determine the risk and return mechanisms of these digital (Babar et al., 2023). Therefore, extending this notion, we hypothesise that to what extent do renewable energy tokens remain connected with their traditional assets? Likewise, it is also being advocated that for effective risk management practices, it is imperative to determine the linkage between these newly evolved digital assets and their traditional counterparts. Therefore, this area of research remains integral to determining the complex relationship between renewable energy tokens and other conventional assets (Billah et al., 2023). Our study is hooked up on this rationale, and the ultimate concern of our investigation is to comprehend the static and dynamic connectedness between our variables of interest in the context of BRICS economies. The studies relevant to renewable energy tokens and conventional assets remain limited; however, the literature relevant to renewable energy stocks and equity markets is well established.

Literature based on renwable energy tokens and cryptocurrencies contain two key streams that focus on the linkage between renewable energy and cryptocurrencies. The first stream of literature revolves around the nexus between fossil fuel and renewable energy stocks (Ali et al., 2022; Alkathery et al., 2022; Ghabri et al., 2022; Hu et al., 2023). As both are complementary to each other, both offer different risk and return mechanisms and also contain divergence in terms of hedging and portfolio diversification. In this vein, studies have shown the key determinants that influence their returns and volatility (Alkathery et al., 2022; Bai et al., 2023; Dawar et al., 2021; Dongna et al., 2023).

The second stream of literature is devoted to examining the linkages between conventional markets and renewable energy markets. Studies in this stream have explored the emergence of

[2] Difference between Power ledger and WePower. For details, please see: https://steemit.com/cryptocurrency/@surryhillsteemer/power-ledger-vs-wepower.

cryptocurrencies and their connectedness with traditional energy markets. These studies remain integral in providing evidence regarding the implications and rising influence of cryptocurrencies on conventional energy markets (Antonakakis & Gabauer, 2017; Bai et al., 2023; Dawar et al., 2021). The rising surge of renwable energy due to environmental activism now become a global agenda which triggered immense scholary attention. Particularly, Umar et al. (2022), carried out a detailed examination of connections between stocks of clean energy companies and fossil fuels. Their findings provide robust linkages between selected variables and also contain robust implications for investors looking to diversify their portfolios (Ghabri et al., 2022; Huynh et al., 2021; Naeem et al., 2022). Past studies have advocated mixed results about the possible link between renewable energy stocks and traditional energy stocks; however, the majority of evidence holds the view that renewable energy stocks remain beneficial for hedging and portfolio diversification (Attarzadeh & Balcilar, 2022; Bai et al., 2023; Dawar et al., 2021; Dongna et al., 2023) Likewise, studies also advocate that high volitaltiy in traditional energy market is attributed due to structural factors which remain inherited to this market. Huynh et al. (2021), Dongna et al. (2023), also advocate that high volatility in the traditional energy market is attributed to structural factors that remain inherited in this market. Their findings suggest that there is an asymmetrical and non-linear nexus between renewable energy stocks and crude oil. Accodingly, In contrast, Yousaf et al. (2022), advocate that renewable energy sources, as compared to their counterparts, show a higher degree of commutability with traditional energy sources at lower and higher ends of distribution. Based on their in-depth analysis, they have also posit that crude oil and renewable energy stocks hold safe haven properties that remain integral during uncetian times to diversify protocells effectively. Likewise, by using the quantile based regression technique Amamou and Bargaoui (2022), posit that oil market fluctuations are the key predictor of volatility in renewable energy stocks. Conclusively, the findings relevant to renewable energy stocks and their traditional counterparts remain mixed and context-specific.

Additionally, the rapid emergence of cryptocurrencies has attracted the immense attention of policymakers and investors to determine their potential in hedging and portfolio diversification. In addition to offering valuable insights, suggestive studies also offer various promising avenues for further empirical inquiry (Ali et al., 2022; Amamou & Bargaoui, 2022; Attarzadeh & Balcilar, 2022; Bai et al., 2023). The potential avanues in this particular domain are unlimited however return and risk spillover between cryptocurreines and traditional fiancial market remain dominant.

For example Xia (2022), holds the view that cryptocurrencies have a low magnitude of correlation with traditional energy markets, and this offers valuable insights for investors and portfolio managers to hedge and diversify their portfolios.

In parlell line of research, Alkathery et al. (2022), study the cohesive connections between bitcoin financial assets and cryptocurrencies, including bitcoin. Based on their analysis, they have disclosed that there is a weak correlation between include variables and cryptocurrency, which implies portfolio implications for investors. Accordingly, Attarzadeh and Balcilar (2022), conducted the volatility analysis between the energy market and cryptocurrency. Their findings indicate that adding cryptocurrency to energy stocks results in hedging and offers benefits for optimal diversification. Additionally, Bai et al. (2023) and Polemis and Tsionas (2023), used time frequency wavelet coherence analysis and advocated that for short-term horizons, cryptocurrency remains robust for hedging during troublesome times. Moreover, Polemis and Tsionas (2023), posit that global financial markets remain transmitters of return and volatility, while cryptocurrencies remain receivers of such fluctuations.

Finally, substantive literature remains devoted to COVID-19 and its potential impact on the risk and return of different financial assets, including cryptocurrency. For example, to address this, Pham et al. (2022) study the risk and return transmission between fossil fuel and clean energy crypto and determine the COVID-19 impact. Their findings hold the view that during COVID-19, clean energy crypto offers higher hedging benefits as compared to the fossil fuel market. Accordingly, Yousaf et al. (2022), conducted Q-VAR estimation and determined the static and dynamic connectedness between the crypto and energy markets during and after the COVID-19 period. Their findings advocate that during the COVID-19 pandemic there was no presence of volatility spillover between selected variables of interest. Additionally, they conclude that during COVID-19, Biticoin remains the transmitter of return spillover while their counterpart remains the receiver of intermittent spillover. Through their rigorous analysis, they identified uncertainty as a major factor shaping return and volatility attitudes, which adds to our understanding of the dynamics of markets' periodic forecasts. Additionally, study conducted by Sinha et al. (2023), investigates the connection between return and volatility dynamics in the cryptocurrency and gold markets, providing vital insights into the intricate nature of these markets. The comprehensive analysis that they conducted highlights the significance of uncertainty in terms of its ability to

influence the behaviour of returns and volatility, thereby improving our understanding of the dynamics of the market.

The rising surge of cryptos and their popularity leads to a higher connectedness between traditional financial markets and energy tokens. The causes behind the close linkage between energy tokens and equity markets are multifaceted. First, both energy tokens and their traditional counterparts are contrasting but complementary in the investment landscape. Renewable energy tokens provide new avenues and a different risk and return mechanism than their traditional counterparts. Second, renewable energy tokens, as an evolving frontier in digital assets, offer the benefits of hedging and portfolio diversification just like other traditional assets (Alkathery et al., 2022). Third, renewable tokens are largely unregulated, while traditional asset markets are highly regulated. Therefore, regulatory intervention during troublesome times can affect the risk and return mechanisms of traditional assets, but the magnitude of its effect on digital assets such as renewable energy tokens remains minimal (Amamou & Bargaoui, 2022).

This robust linkage between renewable energy tokens and traditional studies devoted to the examination of connectedness and its implications remains limited. Although the linkage between cryptos and traditional energy markets is well established, For example, Attarzadeh and Balcilar (2022) by using the optimal copyula approach, examine the connection between green energy and cryptocurrency and hold the view that clean energy and cryptos offer optimal diversification. Accoridngly, Dawar et al. (2021), holds the view that clean energy indices remain integral for hedging because cryptocurrencies remain highly volatile. Accordingly, the clen energy cryptos contain safe haven properties that remain beneficial for investors to hedge high volatility in these markets effectively.

Literature based on energy markets and cryptocurrencies during and after COVID-19 is well established; however, studies relevant to the emergence of toknes and their implied connectedness with other financial markets are limited (Attarzadeh & Balcilar, 2022; Bai et al., 2023; Dawar et al., 2021). Past studies have failed to provide evidence regarding the connectedness between recently emerged renewable energy tokens and financial markets (Alkathery et al., 2022; Amamou & Bargaoui, 2022; Xia, 2022; Yousaf et al., 2022). Particularly, the evidence regarding the static and dynamic connectedness between renewable energy tokens and traditional financial assets remains limited. Unfortunately, to what extent these renewable energy tokens provide health

benefits and diversify portfolios optimally is not known. Therefore, the possible linkage between these recently emerged renewable energy tokens as an alternative to conventional energy has gained immense attention. Both investors and policymakers remain interested in determining to what extent these tokens impact the risk and return mechanisms of conventional financial markets (Zakari et al., 2022). Accordingly, such examinations also remain profound because it is widely presumed that cryptocurrencies, particularly tokens, remain optimal in providing diversification benefits. Extending this notion our study aim to explore the connectedness between renewable energy tokens and equity markets. Contextual setting of the study is provided by BRICS economies and TVP-VAR has been utilized by following (Antonakakis & Gabauer, 2017).

Emerging trends in the financial markets due to financial technology are revolutionizing the landscape of market interconnectedness. These trends are marked by the growing prominence of digital assets, which are fostering increased interconnectedness among financial markets. As these digital assets gain popularity, they create new avenues for cross-border investment and collaboration within the BRICS bloc (Amamou & Bargaoui, 2022). This shift highlights the importance of adapting to these evolving trends for policymakers and investors alike, as they shape the future of financial markets in these markets. Additionally, the hostile market volatility of stock markets has attained significant attention from scholars examining financial market investments. The stock market, being a crucial investment focal point for BRICS nations, has drawn the interest of investors. Past studies have highlighted the long-term correlations among BRICS countries' stock markets (Amamou & Bargaoui, 2022; Attarzadeh & Balcilar, 2022; Zakari et al., 2022). However, the concept of risk dispersion suggests that diversifying investments can alter the risk-return profiles and correlations of various asset classes over time. Therefore, in the realm of digital asset such as renewable energy tokens and their connectedness with other asset classes and financial markets contain paramount significance (Umar et al., 2021). Additionally, portfolio theory advocate that lower correlation coefficients between securities and stocks reduce overall portfolio risk. Based on this premise of portfolio theory this study aims to determine the static and dynamic connectedness between renewable energy tokens and stock markets of BRICS countries. Understanding the evolving dynamics of digital assets and their interplay with traditional financial markets is essential for informed investment decisions, risk management and development of financial markets within the BRICS bloc (Xia, 2022) The existing body of literature does not offer any explicit future direction to predict the future development of energy tokens. However, it is

evident through recent developments that cryptos and tokens have evolved abruptly and are gaining the attention of investors and portfolio managers to navigate their investment landscape. Beside the investment landscape, it is also imperative for responsible and sustainable consumption of energy resources, which may be instrumental in complying with socially responsible investing. Accordingly, the future footprints of these digital assets are promising due to their wide ecosystem and wider implications (Dawar et al., 2021). Accordingly, our study's significance lies in its exploration of connectedness (static and dynamic) between equity market BRICS and renewable energy tokens. By uncovering these intricate relationships, this research aims to provide valuable insights for investors, policymakers, and financial institutions within BRICS countries.

Based on TVP-VAR approach our findings reveal that static connectedness between our varible of interest particulary, return spillover before COVID-19 and across full sample remain substantive and limited. Nevertheless, throughout the COVID-19 pandemic era, there was a sudden and remarkable surge in this degree of connectedness, attaining unprecedented peaks. Our results infer that during the COVID-19 pandemic, the connectedness between renewable energy tokens and BRICS equity markets has strengthened, which implies the robust influence of this crisis. Accordingly, during the COVID-19 crisis, risk spillover remains highly intensified, both before COVID-19 and during the full sample period. Likewise, BRICS markets function as transmitters, while energy tokens are inferred as receivers of spillover. Regarding dynamic connectedness analysis, our result infers that it remains time-varying and also weak over the entire sample period. In contrast, during COVID-19, the dynamic connectedness between our variables of interest remained high. Beside connectedness, we have also computed the optimal weights and hedge ratios of different pairs of our variables to determine the hedging effectiveness of renewable energy tokens.Conclusively, our findings exhibit that the hedge ratios are exceptionally low, signifying the cost-effectiveness of hedging portfolio risks by using energy tokens. Consequently, our results offer valuable insights for investors contemplating the inclusion of energy tokens as an alternative investment strategy to manage risks and enhance overall portfolio performance. Our finding holds significance in the context of evolving digital asset markets and highlights the need for a nuanced understanding of these assets' dynamics. Investors can leverage energy tokens to mitigate risks and enhance portfolio performance, particularly during periods of market volatility. Policymakers should consider regulatory frameworks to facilitate the responsible growth of digital asset markets.

Overall, our research underscores the growing relevance of energy tokens in the financial landscape and their potential to shape investment strategies and risk mitigation practices.

Rest of the manuscript unfolds through four distinct sections, each with its unique focus. In Section 2, we provide our chosen methodology and data sources, laying the groundwork for our study. Section 3 unveils the empirical result, shedding light on our key findings. Finally, in Section 4, we bring this study to a close, offering our conclusions and future directions.

2. Research Methodology

2.1 Data and Preliminary Analysis

This paper uses the daily returns data of four energy tokens (Powerledger-POWR, GridPlus- GRID, SunContract- SNC and WePower-WPR) for analysis. The equity market of each selected economy has been considered as: BOVESPA index for Brazil, Shanghai composite index for China, S&P BSE SENSEX for India, MOEX index for Russia and JSE all share index used for South Africa. Selected time frame of the study range from February 22, 2018, to September 15, 2023. The data for energy token and stock indices are taken from coinmarketcap.com and investing.com, respectively. Furthermore, in line with (Ali et al., 2022; Ali, Yousaf, & Vo, 2023; Nham, 2022; Rubbaniy et al., 2022; Yousaf et al., 2022) we segregate the data into two subsamples; Pre COVID-19 (February 22, 2018 to December 31, 2019) and COVID-19 (January 1, 2020, to September 15, 2023).

2.2 TVP-VAR Method

To explore the connectedness between selected variable, we used TVP-VAR model proposed by Antonakakis and Gabauer (2017). The choice of methodology is motivated by other studies (Aharon & Ali, 2024; Ali, Ijaz, & Yousaf, 2023; Ali, Ijaz, et al., 2023; Ali, Moussa, & Youssef, 2023; Cao & Xie, 2022; Yousaf et al., 2023) , they also use TVP-VAR model to examine the interlinkage among assets. In addition, it also offer several other benefits over other approached. First, there is no observation loss in TVP-VAR model. Secondly, it does not require arbitrary window size thus makes it a better choice. The basic TVP-VAR (1) model is specified as follows:

$$v_t = C_t v_{t-1} + \mu_t, \qquad \mu_t \sim N(0, \tau_t) \tag{1}$$

$$\mathrm{vec}(C_t) = \mathrm{vec}(C_{t-1}) + \gamma_t, \qquad \gamma_t \sim N(0, \varepsilon_t) \tag{2}$$

where v_t , $v_{t-1}$and μ_t is a n × 1 dimensional vector and C_t and τ_t are n × n dimensionsal matrices. vec(C_t)and γ_t are $n^2 \times 1$ dimensional vectors and ε_t is an $n^2 \times n^2$ dimensional matrix. Moreover, τ_t and ε_t are the time-varying variance-covariance matrix.

To test the pairwise directional connectedness from variable (j) to variable (i), we compute the GFEVD (generalized forecast error variance decomposition) suggested by Koop et al. (1996). This method shows the impact that variable (j) has on variable (i) regarding the share of forecast variance. The GFEVD is represented as:

$$\tilde{\theta}_{ij,t}(H) = \frac{\sum_{t=1}^{H-1} \omega_{\mathrm{ij,t}}^2}{\sum_{j=1}^{n} \sum_{t=1}^{H-1} \omega_{\mathrm{ij,t}}^2}, \tag{3}$$

where $\sum_{j=1}^{n} \tilde{\theta}_{ij,t}(H) = 1$ and $\sum_{i,j=1}^{n} \tilde{\theta}_{ij,t}(H) = n$. Following recent studies (Antonakakis & Gabauer, 2017; Yousaf et al., 2022) ,we define H=10. Moreover, the numerator denotes the combined impact of the shock to the variable (i). Using the above formulation, the total connectedness index (TCI) is computed as:

$$T_t(H) = \frac{\sum_{i,j=1,i+j}^{n} \tilde{\theta}_{ij,t}(H)}{\sum_{i,j=1}^{n} \tilde{\theta}_{ij,t}(H)} = \frac{\sum_{i,j=1,i,j}^{n} \tilde{\theta}_{ij,t}(H)}{n}. \tag{4}$$

Eq. (4) shows the total connectedness. However, to conduct a more comprehensive analysis of the directional connectedness, we break the methodology down into three distinct components: total directional connectedness TO, FROM and NET.

First, the total impact that variable (i) transmits TO all other variables (j) is defined as follows:

$$T_{i \to j,t}(H) = \frac{\sum_{i,j=1,i+j}^{n} \tilde{\theta}_{ji,t}(H)}{\sum_{i,j=1}^{n} \tilde{\theta}_{ji,t}(H)}. \tag{5}$$

Second, the total impact that variable (i) receives FROM all other variables (j) is defined as follows:

$$T_{i \leftarrow j,t}(H) = \frac{\sum_{i,j=1,i+j}^{n} \tilde{\theta}_{ijpt}(H)}{\sum_{i,j=1}^{n} \tilde{\theta}_{ij,t}(H)}. \tag{6}$$

Lastly, we calculate the NET directional connectedness between variable (i) and variable (j) as:

$$T_{i,t} = T_{i\rightarrow j,t}(H) - T_{i\leftarrow j,t}(H). \quad (7)$$

Finally, we compute the net pairwise directional connectedness (NPDC) as:

$$NPDC_{ij}(H) = \left(\tilde{\theta}_{ji}(H) - \tilde{\theta}_{ij}(H)\right). \quad (8)$$

Eq. (8) explains the bidirectional net pairwise connectedness. If it is negative, it implies that variable (i) is dominated by variable (j). However, if $\left(N\text{PDC}_{ij}\,(H) > 0\right)$, then variable (i) dominates variable (j).

Similar to (Dong et al., 2024; Liu et al., 2023; Long & Li, 2023), we utilized the AIC criterion to select the optimal lag order and established a VAR (1) model for 20 steps of forecasting. Furthermore, we incorporated the rolling window technology with the TVP-VAR connectedness index to analyze the time-varying spillover of the carbon-stock system using a 100-day rolling window.

Afterwards similar to Ali et al. (2022) and Yousaf and Ali (2020) we compute the static and dynamic optimal weights and hedge ratio between energy cryptocurrencies and stock using the variance-covariance matrix from TVP-VAR model. Taking from Kroner and Ng (1998), the optimal asset allocation decision for each possible combination of stock and energy cryptocurrencies in a portfolio can be determined as:

$$W_{xy,t} = \frac{h_{y,t} - h_{xy,t}}{h_{x,y} - 2h_{xy,t} + h_{y,t}} \quad (9)$$

$$W_{xy,t} = \begin{cases} 0, & If \;\; W_{xy,t} < 0 \\ W_{xy,t}\,, & If \;\; 0 \leq W_{xy,t} \leq 1 \\ 1, & If \;\; W_{xy,t} > 1 \end{cases} \quad (10)$$

For a portfolio worth \$1 in total, the percentage allocation to sector x (stock) at time t is denoted by $W_{xy,t}$. The hedge ratio for each pair of stock-Cryptocurrency is estimated using (Kroner & Sultan, 1993). It indicates that long position risk in security x (i.e., stock) can be hedged by shorting assuming a short position in security y (i.e., energy token):

$$\beta_{xy,t} = \frac{h_{xy,t}}{h_{y,t}} \quad (11)$$

3 Results & Discussion

3.1 Descriptive Statistics

Table 1 presents the data's descriptive statistics across three distinct sample periods. Panel A of Table 1 shows that all the renewable energy tokens (GRID POWR, SNC and WPR) exhibit negative returns, while all the BRICS markets exhibit positive results except China. In contrast, the intensity of risk annexed to observed renewable energy tokens remains extremely high as compared to the BRICS market, which adheres to the basic notion of finance, i.e., higher the risk higher the return. The results reported in Panel B which cover the time period of pre-COVID-19 exhibit the same pattern as reflected in full sample period. However, interestingly, Panel C of Table 1 reports that all renewable energy tokens carry positive returns except WPR during COVID-19. Likewise, the average return of all BRICS markets remains positive but comparatively lower than renewable energy tokens. Accordingly, the variance i.e., risk remains high for renewable energy tokens while BRICS market exhibits lower level of volatility. These results indicate the performance and risk profiles of renewable energy tokens (GRID, POWR, SNC, and WPR) and BRICS markets across different sample periods. Our results infer that renewable energy tokens may offer an alternative risk-return profile compared to traditional BRICS markets, particularly during times of crisis like the COVID-19 pandemic.

<< ***Insert Table 1: Descriptive Statistics***>>

3.2 Correlation Matrix

Table 2 presents the pairwise correlations between selected financial assets, including renewable energy tokens (GRID, POWR, SNC, WPR), and the stock markets of BRICS countries (Brazil, China, India, Russia, South Africa). The positive correlations observed within renewable energy tokens indicate some degree of comovement, while their relatively weak correlations with BRICS stock markets suggest potential diversification benefits. Additionally, variations in correlations between different BRICS countries highlight the importance of considering regional factors when analyzing financial markets. Overall, this analysis contributes to a better understanding of the interconnectedness of these digital and financial assets and offers implications for investors and policymakers.

<< ***Insert Figure 2: Correlation Matrix***>>

3.3 Static Connectedness

Table 3 state the statics relevant to static connectedness (GRID, POWR, SNC, WPR) and BRICS stock markets during three distinct sample periods: Full sample (February 22, 2018, to September 15, 2023), Pre COVID-19 (February 22, 2018, to December 31, 2019), and COVID-19 (January 1, 2020, to September 15, 2023). In the full sample period, it is evident that all renewable energy tokens (GRID, POWR, SNC, WPR) are major contributors to return spillover within the system. In the full sample period (Panel A), it is evident that all renewable energy tokens (GRID, POWR, SNC, WPR) are recipients and BRICS markets serve as transmitters to return spillover within the system. The connectedness measure indicates that before COVID-19 and the full sample, the total connectedness between selected variables ranged from 3.76% to 42.12%, respectively. The connectedness remains average between renewable energy tokens and the BRICS market. Accordingly, the contribution of the reach variable to the system has been determined through "TO" which measures the tendency of shock spillover from each variable to another variable in the system. The net spillover measures the divergence between spillover transmitted to the system and received from the system. The positive value indicates the tendency of a variable as a transmitter, while the negative value reflects the receiver of more shocks from other markets. Our results exhibit that all renewable energy tokens remain recipient while the BRICS market remains transmitters. Our results carry important implications for investors and policymakers. Firstly, the fact that all renewable energy tokens (GRID, POWR, SNC, WPR) are recipients of return spillovers suggests that these tokens tend to absorb shocks from other markets within the system. This implies that renewable energy tokens can play a role as stabilizing assets within a diversified portfolio, potentially helping to mitigate the impact of external shocks on an investor's overall holdings. Conclusively, result suggest that full sample period, pre-COVID-19 and during COVID-19 the static connectedness remain the same beside certain negligible exceptions. However, during COVID-19 the static connectedness reflected through the total connectedness index (TCI) remains 55.33%. Comparatively, static connectedness between renewable energy tokens and BRICS market increased. This increased connectedness signifies the impact of the COVID-19 pandemic on the relationship between renewable energy tokens and the BRICS equity markets. It implies that during times of crisis or extreme market volatility, the interdependence between these assets intensifies, which further implies various implications for investors, policymakers, and regulators.

<< ***Insert Table 3: Static Returns*** >>

Fig. 2 exhibits the directional returns of asset pairs during the full sample, before and during COVID-19. As per the visual depicted during the selected sample, energy tokens largely remain the receivers of return spillover, while the BRICS markets remain the transmitters of return and volatility spillover. Accordingly, the visuals indicate that the BRICS market has a lower correlation with renewable energy tokens, which implies portfolio implications. Additionally, it is evident from Fig. 3 that all selected energy tokens consistently receive return spillovers, whereas BRICS stock markets consistently transmit these return shocks during all three sub-sample periods. This consistent pattern underscores the role of energy tokens as recipients and BRICS markets as transmitters of return spillovers within the system.

In Fig. 3, we can observe the dynamic TO connectedness, which illustrates the time-varying return spillovers from each variable to the entire system. These spillover patterns reveal that the transmission of shocks from each variable to others is not static; instead, it fluctuates over time in response to various economic and financial events. Our connectedness analysis shows that return spillover from each token declined during the first quarter of 2020, indicating the impact of the CVODI-19 pandemic, and spiked during the first quarter of 2022.In contrast, the return spillovers transmitted by each stock market to others exhibited more significant variations over time, reaching their peak during the initial phase of the recent COVID-19 crisis.

Fig. 4 showcase the dynamic return spillover, showcasing how these spillovers fluctuate over time. The plots depict significant variations in the amount of return spillovers which is subject to time variaton. Notably, two prominent spikes in spillovers received occurred due to COVID-19 pandemic. These findings from the time varying TO and FROM connectedness analyses emphasize the heightened sensitivity of both energy tokens and BRICS. They infter the presence of higher connectedness during increased uncertainty, particularly when triggered by natural events like the COVID-19 pandemic.

3.4 Portfolio Implications

Table 4 presents the optimal portfolio weights, hedging effectiveness, and hedge ratios for the entire sample period, the pre-COVID-19 phase, and the COVID-19 period. For analysis purpose,in line with Ali, Naveed, Yousaf and Khattak (2024) and Ali, Naveed, Hanif and Gubareva (2024), we limit ourselves to consider a portfolio consisting of two assets onlyNotably, during the entire

sample period, the optimal weight allocation for the Brazil/GRID pair stands at 0.998. This suggests that an investor should allocate 99.8% of a $1 portfolio to the Brazil stock market, leaving only 0.2% for GRID. Generally, we observe that optimal weights are lower in the pre-COVID-19 period compared to the COVID-19 period. This indicates that, during the COVID-19 crisis, investors should consider reducing their investments in energy tokens while increasing their allocations to BRICS stocks. Accordingly, the full sample optimal hedge ratio for Brazil/GRID pair remains 0.019, reflecting that $1 long position in BRICS equity market can be hedged for 0.019, cents with a short position in GRID. Our findings contrary to Akhtaruzzaman et al. (2021), hedging is cheaper during COVID-19 period compared to full sample period suggesting hedging through energy tokens is cheaper to investors.

At the outset, we explore optimal weights and hedge ratios, along with bivariate optimal portfolio weights. Figure 5, which follows, showcases the dynamic allocation of investments over time. These weights represent the fraction of the total portfolio allocated to specific assets. The results depicted in Figure 5 indicate a reduction in energy tokens' weights during periods of heightened uncertainty, such as the COVID-19 crisis. This dynamic nature of optimal weights over time suggests that investors in the BRICS region should regularly adjust their portfolios to seize optimal diversification opportunities. Additionally, we examine the bivariate optimal portfolio weight, considering both NFTs and BRICS stock indices to gain insights into their interplay and hedging effectiveness.

Conclusively, the study offers valuable guidance to investors in the BRICS region, highlighting the dynamic nature of optimal portfolio weights and the cost-effectiveness of hedging through energy tokens. These insights can aid investors and portfolio managers in constructing resilient portfolios and managing risk efficiently, particularly during times of economic uncertainty. The results underscore the relevance of incorporating renewable energy tokens into diversified portfolios, providing opportunities for risk mitigation and enhanced portfolio performance.

4 Conclusion

The aim of our study was to examine the connectedness between BRICs stock markets and emerging renewable energy tokens. Through the application of the TVP-VAR approach, we analyze the daily returns of four key energy tokens (POWR, SNC, GRID, and WPR) alongside various BRICS stock markets (Brazil, Russia, India, China, and South Africa). Besides static and

dynamic connectedness, we also calculate optimal portfolio weights, hedging ratios, and hedging effectiveness for these renewable energy token pairs across different sub-sample periods, providing valuable empirical insights for portfolio managers.

Our findings relevant to static connectedness measurements yield interesting insights. During the selected full and subsample, we observe a moderate level of return spillovers between renewable energy tokens and BRICS stock markets. However, this interconnectedness significantly surged during the COVID-19 period, reaching unprecedented levels. This indicates that both variable are highly responsive to extreme events, such as the pandemic. Additionally, the FROM/TO connectedness measures for the COVID-19 crisis period surpass those of the full sample and the pre-crisis periods. Furthermore, our analysis shows that throughout these three sub-sample periods, energy tokens consistently receive more return spillovers than they transmit, while BRICS stock markets predominantly transmit these spillovers. This suggests that BRICS stock markets play a pivotal role in driving the overall system and can potentially serve as reliable indicators for predicting movements in renewable energy tokens markets.

The dynamic connectedness analysis shows the ever-changing nature of total connectedness among BRICS stock markets and energy tokens. This connectivity is generally weak during normal periods but experiences significant surges during times of distress, like the onset of the COVID-19 crisis. These findings suggest that these new tokens can serve as effective diversification tools for BRICS stock portfolios in typical market conditions. However, during high-uncertainty episodes, investors should consider adjusting their asset allocation between BRICS stocks and energy tokens to mitigate potential portfolio losses. Furthermore, the time-varying Net connectedness measure highlights the dynamic nature of these markets. Throughout the entire sample period, BRICS stock markets and energy tokens alternately switch between being net receivers and net transmitters. However, the overall pattern shows that BRICS markets primarily act as net emitters, while energy tokens predominantly serve as net receivers.

Finally, in terms of portfolio implications, the optimal hedge ratios for renewable energy tokens and BRICS markets exhibit fascinating findings. Our findings from optimal portfolio weights indicate that, during periods of uncertainty like the COVID-19 crisis, investors should consider reducing their investments in energy tokens to minimize risk. Furthermore, the optimal hedge ratio

results reveal that the hedge ratio tends to be higher during times of uncertainty, signifying increased hedging costs during such periods.

The outcomes of our study offer valuable insights for portfolio diversification, policymaking, and investors aiming to formulate effective investment strategies and policies. Given the limited correlation between BRICS stock markets and energy cryptocurrencies, investors have the opportunity to diversify their portfolios by incorporating energy tokens, reducing risk exposure, and maximizing potential profits. However, during periods of heightened uncertainty, many energy tokens lose their diversification benefits, underscoring the need for investors to adjust their asset allocation strategies to mitigate significant losses.

Furthermore, the dynamic nature of spillovers implies that investors interested in integrating energy tokens into their stock portfolios should be prepared to adjust their allocations in response to changing market conditions. Policymakers should also consider adapting their stabilization strategies over time to align with evolving market dynamics. Notably, our findings suggest that BRICS stock markets predominantly act as net emitters of return spillovers to energy cryptocurrencies, highlighting their pivotal role as drivers and potential predictors of energy token returns. This insight can guide investors and policymakers in making informed asset allocation decisions and formulating effective strategies in the evolving landscape of digital assets and traditional stock markets. Accordingly, our findings also infer guidance for a diversified and robust investment strategy that contains new digital assets such as renewable energy tokens alongside conventional assets such as and bond. This diversified investment strategy first includes the risk and return mechanism, correlation and connectedness along with each asset weight, and its hedging effectiveness, which remain integral before investing. Effective implementation of such an investment strategy can navigate an efficient portfolio while mitigating the associated risks.

Finally, our study's exclusive focus on BRICS region may limit its wider applicability, however, it also offer an avenue for future research to explore other regions for a comprehensive global market analysis.

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Table 1: Descriptive Statistics

Panel A: Full sample (February 22, 2018, to September 15, 2023)									
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa
Mean	-0.145	-0.145	-0.193	-0.574*	0.033	0	0.06	0.031	0.025
Variance	254.062***	74.088***	70.522***	138.708***	3.313***	1.411***	1.714***	4.133***	1.787***
Skewness	-0.540***	-0.268***	0.764***	0.097	-1.084***	-0.426***	-1.356***	-6.834***	-0.401***
Ex.Kurtosis	14.884***	12.554***	12.632***	6.818***	17.001***	4.889***	18.740***	144.304***	8.730***
JB	10661.406***	7559.458***	7751.779***	2227.546***	14062.240***	1179.095***	17164.964***	1005876.401***	3679.354***
ERS	-1.816*	-2.469**	-2.925***	-12.995***	-1.566	-1.887*	-8.984***	-1.891*	-2.254**
Q(20)	70.197***	8.274	39.404***	58.589***	45.591***	14.811	57.596***	30.519***	24.765***
Q2(20)	146.083***	22.102***	43.957***	68.082***	1152.458***	34.823***	625.845***	55.406***	990.217***
Panel B: Pre COVID-19 (February 22, 2018 to December 31, 2019)									
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa
Mean	-0.75	-0.796**	-0.709	-0.892**	0.095	-0.008	0.053	0.086	0.008
Variance	291.695***	51.161***	79.823***	69.972***	2.034***	1.667***	0.838***	1.042***	1.029***
Skewness	-0.237*	0.154	1.707***	0.016	0.416***	0.095	0.218*	-0.751***	0.076
Ex.Kurtosis	2.021***	1.459***	13.470***	1.267***	3.929***	3.511***	4.756***	13.152***	1.010***
JB	68.438***	35.312***	3065.317***	25.486***	256.069***	196.220***	362.021***	2781.895***	16.552***
ERS	-1.115	-1.46	-1.877*	-6.712***	-0.82	-1.293	-5.744***	-0.571	-1.085
Q(20)	28.410***	9.545	12.982	8.906	11.549	7.27	15.617*	18.266**	6.661
Q2(20)	13.834	24.993***	2.411	13.023	4.681	15.115	12.662	15.328	17.822**
Panel C: during COVID-19 (January 1, 2020, to September 15, 2023)									
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa
Mean	0.155	0.178	0.063	-0.416	0.003	0.003	0.064	0.004	0.033
Variance	235.476***	85.228***	65.807***	172.868***	3.949***	1.285***	2.149***	5.667***	2.165***
Skewness	-0.730***	-0.403***	0.160*	0.081	-1.301***	-0.800***	-1.476***	-6.315***	-0.472***
Ex.Kurtosis	24.384***	13.855***	12.139***	6.114***	17.086***	5.820***	17.121***	113.751***	8.531***
JB	19095.093***	6163.775***	4718.655***	1197.214***	9558.583***	1166.044***	9658.395***	419157.734***	2357.430***
ERS	-1.513	-10.913***	-13.847***	-9.768***	-5.641***	-4.419***	-9.303***	-8.181***	-11.715***
Q(20)	65.175***	10.374	40.673***	58.851***	50.669***	16.710*	56.116***	21.234***	26.654***
Q2(20)	116.203***	13.087	79.061***	37.057***	823.924***	32.035***	423.065***	36.061***	675.187***

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. D'Agostino (1970) and Anscombe and Glynn (1983) statistics are used for skewness and kurtosis. JB (Jarque and Bera 1980) is the test for Normality, ERS unit root test (Stock et al. 1996) tests for stationarity, Q(20) and Q2(20) are the weighted Ljung-Box statistic for serial correlation in the returns and squared series (Fisher and Gallagher 2012), respectively.

Table 2: Kendall rank correlation coefficients

Panel A: Full sample (February 22, 2018, to September 15, 2023)									
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa
GRID	1.000***	0.187***	0.208***	0.156***	0.081***	0.039**	0.088***	0.086***	0.110***
POWR	0.187***	1.000***	0.340***	0.265***	0.083***	0.092***	0.060***	0.085***	0.119***
SNC	0.208***	0.340***	1.000***	0.219***	0.079***	0.048**	0.034	0.054***	0.049**
WPR	0.156***	0.265***	0.219***	1.000***	0.061***	0.011	0.028	0.036	0.033
Brazil	0.081***	0.083***	0.079***	0.061***	1.000***	0.062***	0.114***	0.170***	0.193***
China	0.039**	0.092***	0.048**	0.011	0.062***	1.000***	0.147***	0.135***	0.224***
India	0.088***	0.060***	0.034	0.028	0.114***	0.147***	1.000***	0.180***	0.268***
Russia	0.086***	0.085***	0.054***	0.036	0.170***	0.135***	0.180***	1.000***	0.307***
South_Africa	0.110***	0.119***	0.049**	0.033	0.193***	0.224***	0.268***	0.307***	1.000***
Panel B: Pre COVID-19 (February 22, 2018 to December 31, 2019)									
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa
GRID	1.000***	0.164***	0.215***	0.170***	0.022	0.055	0.04	0.048	0.083**
POWR	0.164***	1.000***	0.407***	0.464***	0.045	0.067	0.013	0.073**	0.079**
SNC	0.215***	0.407***	1.000***	0.325***	0.007	0.081**	0.006	0.042	0.018
WPR	0.170***	0.464***	0.325***	1.000***	0.036	0.034	0.068**	0.055	0.03
Brazil	0.022	0.045	0.007	0.036	1.000***	0.067**	0.052	0.215***	0.173***
China	0.055	0.067	0.081**	0.034	0.067**	1.000***	0.126***	0.142***	0.248***
India	0.04	0.013	0.006	0.068**	0.052	0.126***	1.000***	0.156***	0.215***
Russia	0.048	0.073**	0.042	0.055	0.215***	0.142***	0.156***	1.000***	0.329***
South_Africa	0.083**	0.079**	0.018	0.03	0.173***	0.248***	0.215***	0.329***	1.000***
Panel C: during COVID-19 (January 1, 2020, to September 15, 2023)									
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa
GRID	1.000***	0.202***	0.203***	0.155***	0.117***	0.026	0.113***	0.110***	0.123***
POWR	0.202***	1.000***	0.305***	0.168***	0.103***	0.104***	0.080***	0.089***	0.137***
SNC	0.203***	0.305***	1.000***	0.167***	0.119***	0.028	0.044	0.060**	0.064***
WPR	0.155***	0.168***	0.167***	1.000***	0.077***	-0.003	0.006	0.033	0.037
Brazil	0.117***	0.103***	0.119***	0.077***	1.000***	0.059**	0.145***	0.153***	0.203***
China	0.026	0.104***	0.028	-0.003	0.059**	1.000***	0.161***	0.134***	0.217***
India	0.113***	0.080***	0.044	0.006	0.145***	0.161***	1.000***	0.189***	0.290***
Russia	0.110***	0.089***	0.060**	0.033	0.153***	0.134***	0.189***	1.000***	0.300***
South_Africa	0.123***	0.137***	0.064***	0.037	0.203***	0.217***	0.290***	0.300***	1.000***

This table presents the unconditional correlation between the variables.

Notes: ***, ** and * denote the rejections of the null hypothesis at the significance level of 1%, 5% and 10%, respectively.

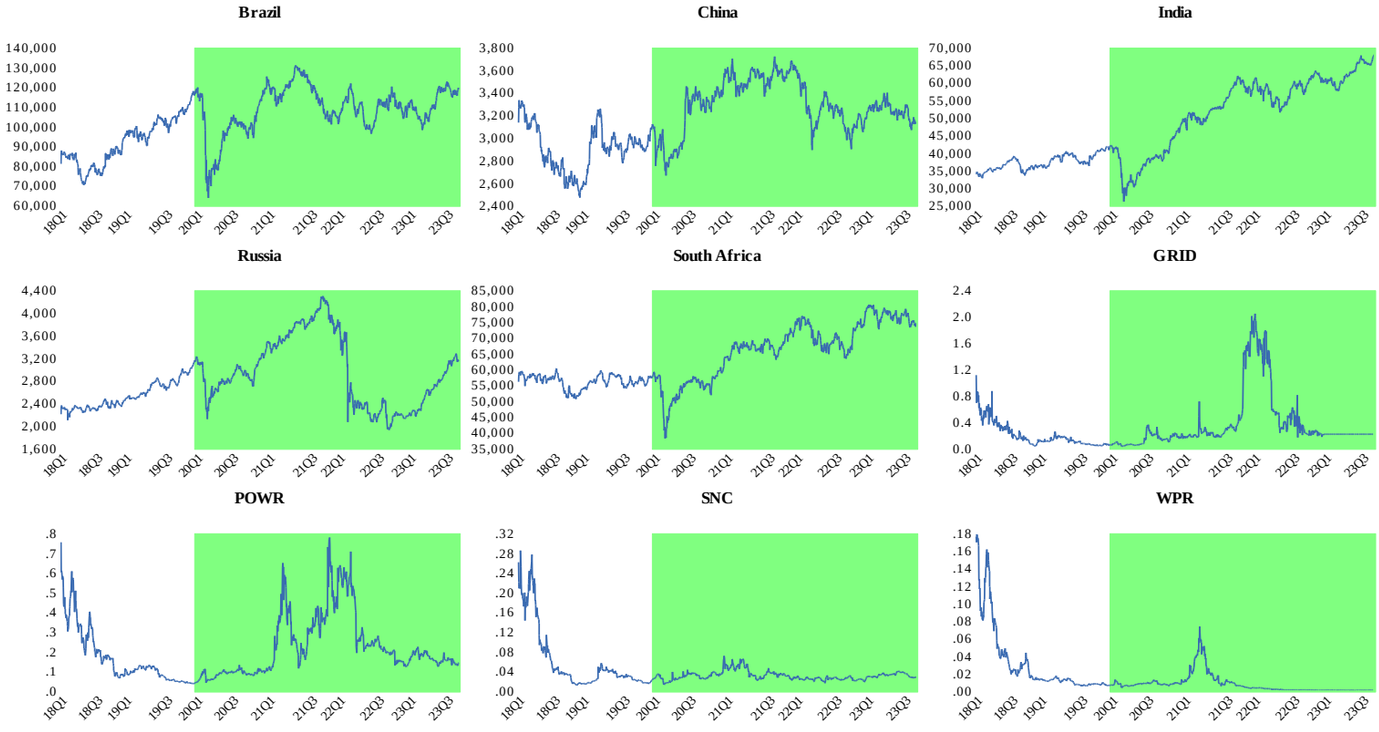


Figure 1a: Trends in the prices of BRICS stocks and energy tokens

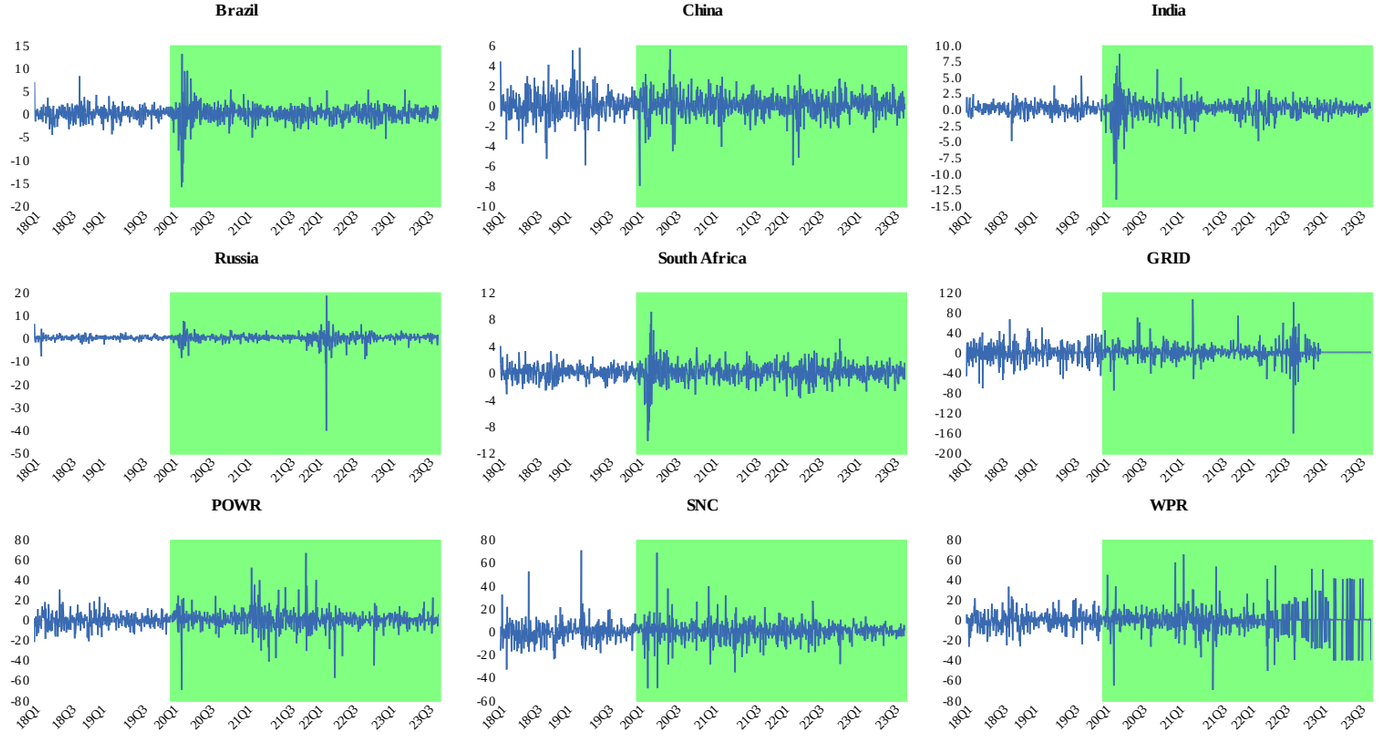


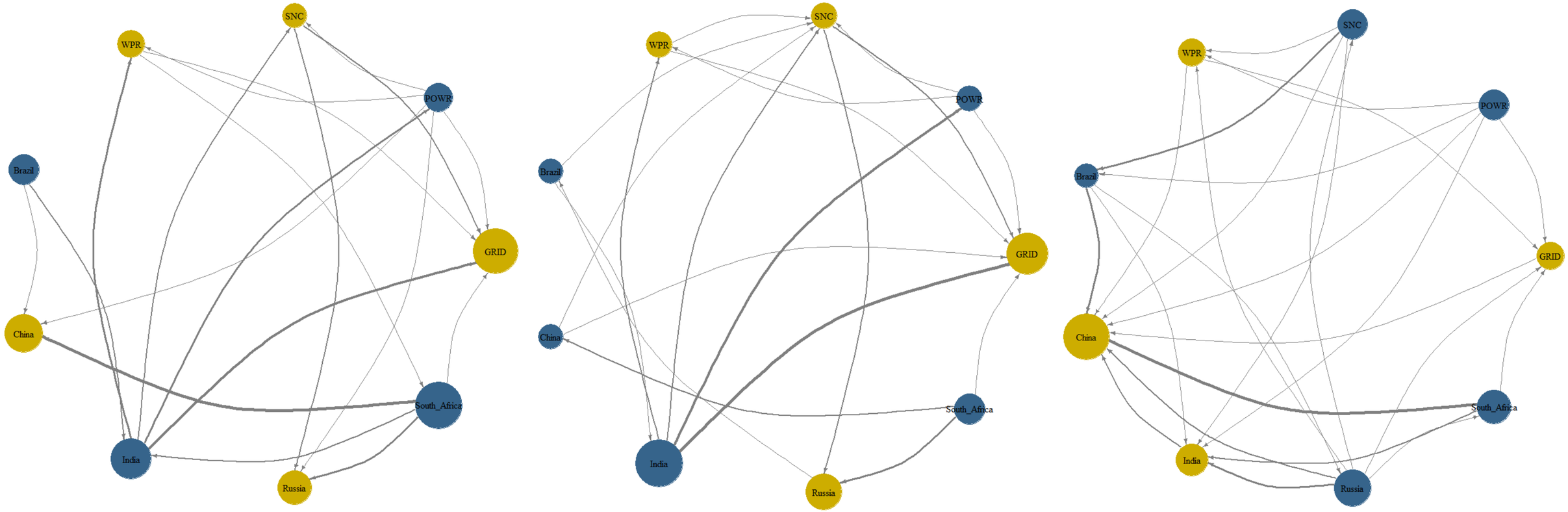
Figure 1b: Trends in the returns of BRICS stocks and energy tokens

Figure 1: Trends in the variable

Table 3: Static returns connectedness

Panel A: Full sample (February 22, 2018, to September 15, 2023)										
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa	FROM
GRID	64.21	7.39	7.45	4.7	2.69	2	5	2.32	4.25	35.79
POWR	6.36	51.05	14.06	13.06	2.83	1.87	4.24	3.04	3.49	48.95
SNC	6.18	14.54	55.71	8.29	3.47	2.33	4.59	2.18	2.7	44.29
WPR	4.02	13.95	8.2	62.77	2.04	1.43	3.14	2.64	1.81	37.23
Brazil	2.71	2.48	3.09	1.9	67.56	2.63	5.22	6.68	7.73	32.44
China	2.1	2.53	1.97	1.47	3.17	70.73	4.53	3.95	9.55	29.27
India	2.64	2.19	3.11	1.49	6.51	4.5	63.6	5.63	10.33	36.4
Russia	2.28	3.7	3.33	2.8	6.31	3.59	5.48	60.72	11.8	39.28
South_Africa	3.49	3.74	2.6	2.29	7.36	6.85	8.95	9.87	54.84	45.16
TO	29.79	50.52	43.79	35.99	34.39	25.2	41.15	36.31	51.66	348.81
Inc.Own	94	101.57	99.5	98.76	101.95	95.93	104.75	97.03	106.5	TCI
NET	-6	1.57	-0.5	-1.24	1.95	-4.07	4.75	-2.97	6.5	38.76
Panel B: Pre COVID-19 (February 22, 2018 to December 31, 2019)										
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa	FROM
GRID	57.49	7.25	9.68	5.56	1.39	3.31	7.78	2.68	4.85	42.51
POWR	5.16	40.74	14.29	22.31	2.67	1.92	6.81	3.52	2.59	59.26
SNC	6.94	15.78	46.94	12.9	2.09	3.76	7.48	1.33	2.77	53.06
WPR	4.43	24.25	11.7	46.58	2.05	1.68	5.74	2.18	1.39	53.42
Brazil	2.29	2.11	1.17	1.87	74.45	2.49	3.21	7.84	4.58	25.55
China	2.36	2.59	2.67	1.49	2.01	68.15	5.13	4.46	11.13	31.85
India	1.7	1.35	4.64	2.45	4.93	5.69	69.4	2.24	7.59	30.6
Russia	3.2	4.1	4.38	2.73	6.63	5.36	3.1	58.72	11.78	41.28
South_Africa	3.61	3.23	2.59	2.17	4.95	8.58	8.31	8.13	58.43	41.57
TO	29.69	60.67	51.12	51.48	26.74	32.78	47.56	32.38	46.68	379.1
Inc.Own	87.18	101.4	98.06	98.06	101.19	100.93	116.97	91.1	105.11	TCI
NET	-12.82	1.4	-1.94	-1.94	1.19	0.93	16.97	-8.9	5.11	42.12
Panel C: during COVID-19 (January 1, 2020, to September 15, 2023)										
	GRID	POWR	SNC	WPR	Brazil	China	India	Russia	South_Africa	FROM
GRID	46.7	9.44	8.7	7.77	8.63	1.44	4.67	6.62	6.03	53.3
POWR	8.47	37.57	15.85	8.83	8.7	2.21	5.07	7.09	6.2	62.43
SNC	8	16.58	38.3	8.62	9.31	1.6	4.81	7.22	5.56	61.7
WPR	6.86	10.46	9.91	49.18	7.52	1.29	3.47	7.13	4.18	50.82
Brazil	6.85	8.31	9.04	5.78	40.98	2.28	8.21	8.49	10.05	59.02
China	2.98	3.95	2.54	2.52	5.14	61.68	5.62	5.93	9.64	38.32
India	5.5	5.83	5.29	3.54	11.67	3.65	41.89	11.3	11.33	58.11
Russia	4.37	5.51	5.11	4.92	10.24	2.81	7.46	48.52	11.06	51.48
South_Africa	5.92	6.47	5.26	4.87	12.67	5.04	9.19	13.41	37.18	62.82
TO	48.95	66.55	61.69	46.85	73.87	20.31	48.5	67.2	64.05	497.97
Inc.Own	95.64	104.12	99.99	96.03	114.86	82	90.4	115.72	101.24	TCI
NET	-4.36	4.12	-0.01	-3.97	14.86	-18	-9.6	15.72	1.24	55.33

This table reports the static return spillover between Energy tokens and BRICS stock markets during three sample periods. Full sample (February 22, 2018, to September 15, 2023), Pre COVID-19 (February 22, 2018 to December 31, 2019) and COVID-19 (January 1, 2020, to September 15,2023) period. The optimal lag length for model specification is computed following AIC criteria.



(a) Full sample (b) Pre COVID-19 (c) COVID-19

Figure 2: Pair wise directional returns spillover

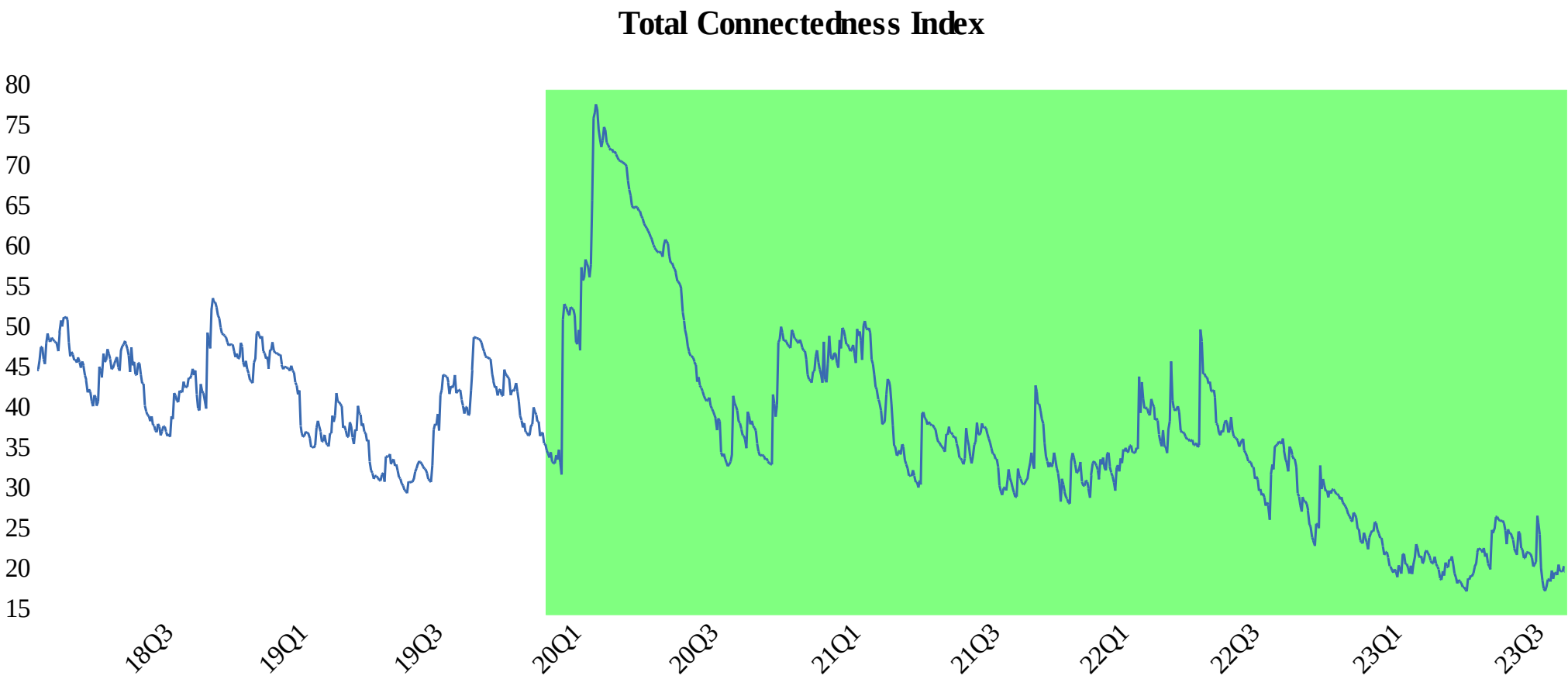
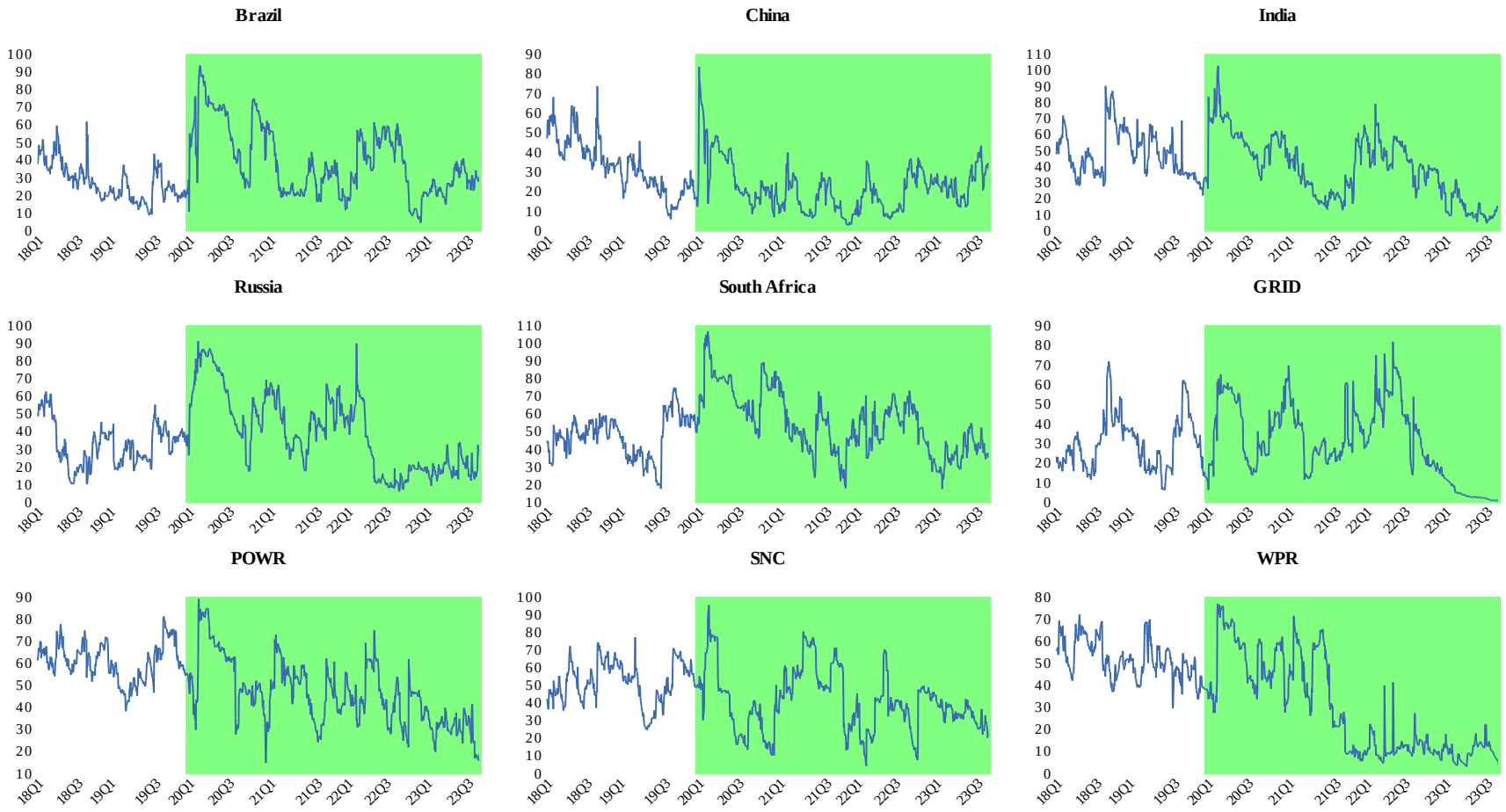
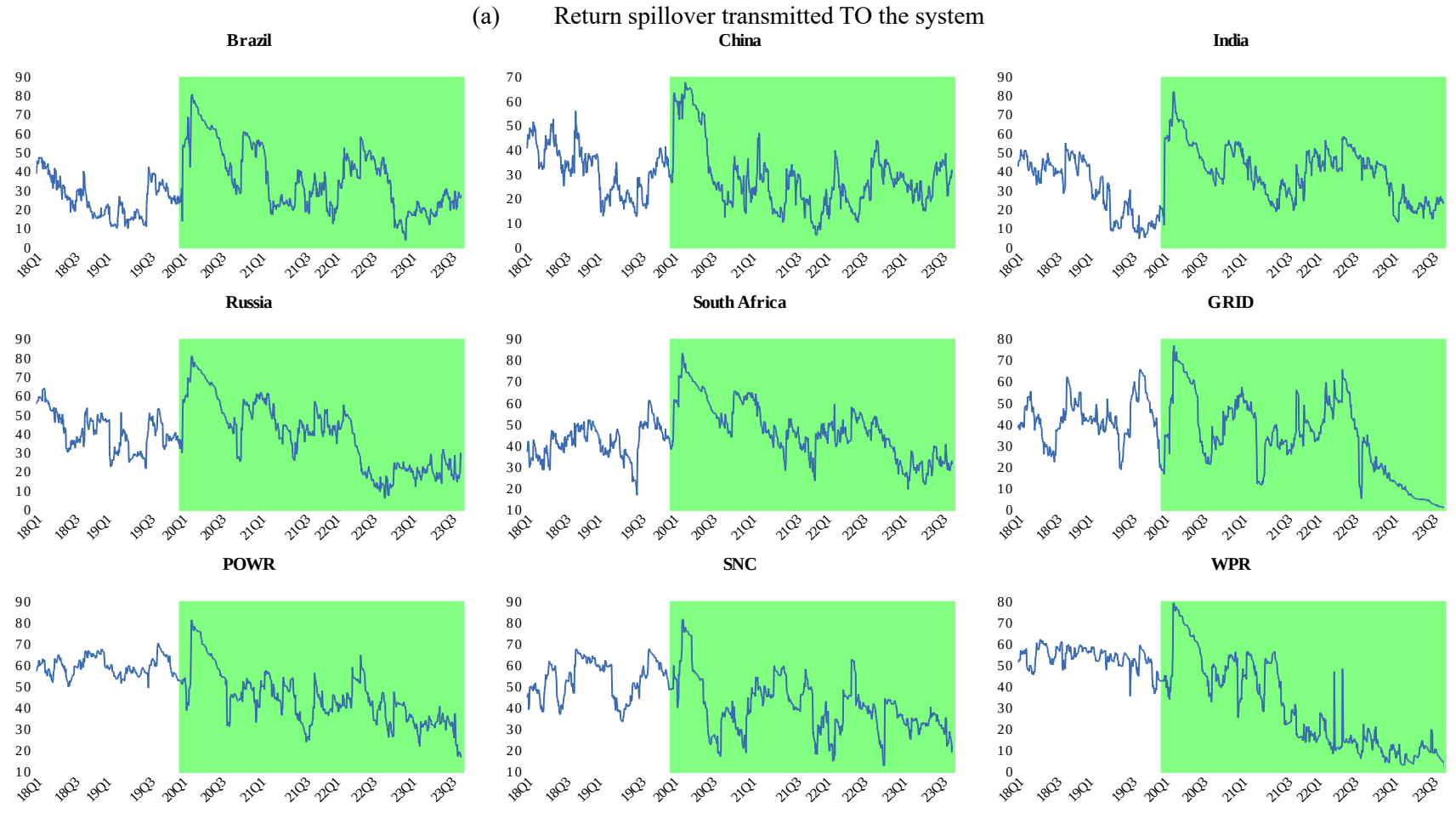


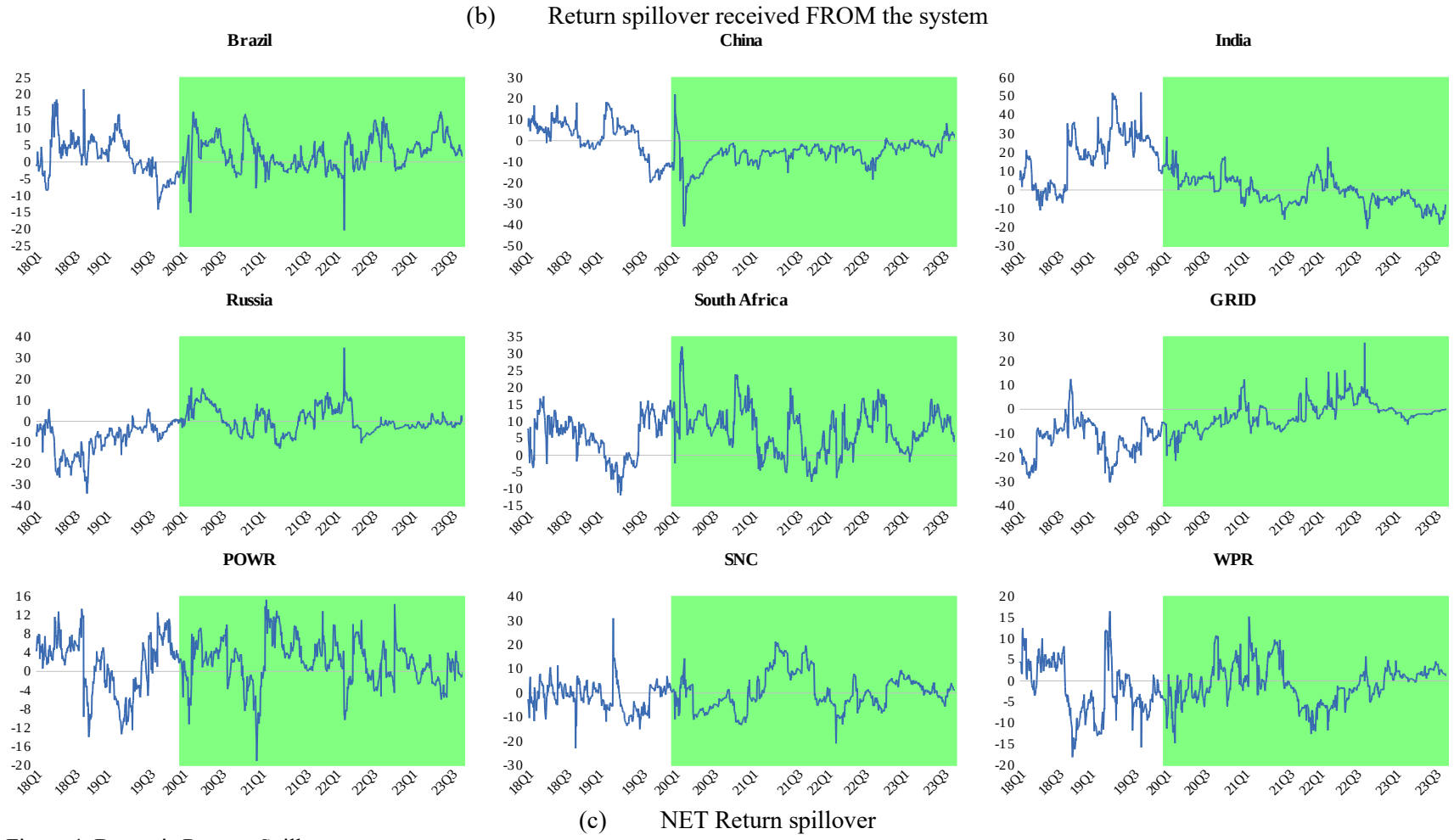
Figure 3: Total Connectedness Index



(a) Return spillover transmitted TO the system



(b) Return spillover received FROM the system



(c) NET Return spillover

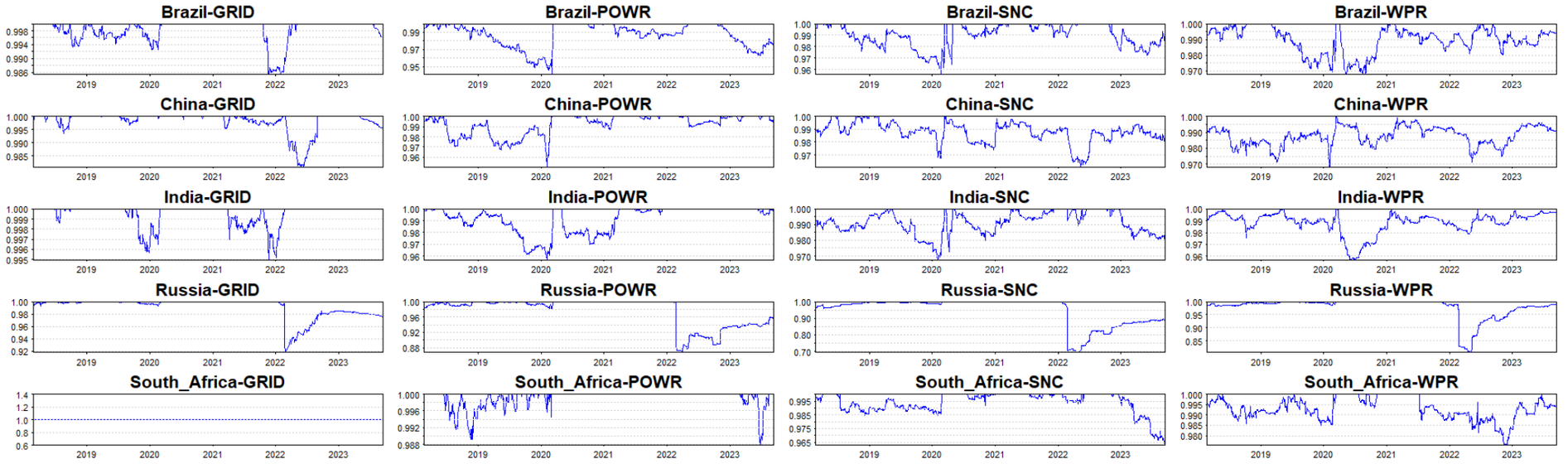
Figure 4: Dynamic Returns Spillover

Notes: This figure shows the total return spillover transmitted or received by each series from the system, along with its net impact.

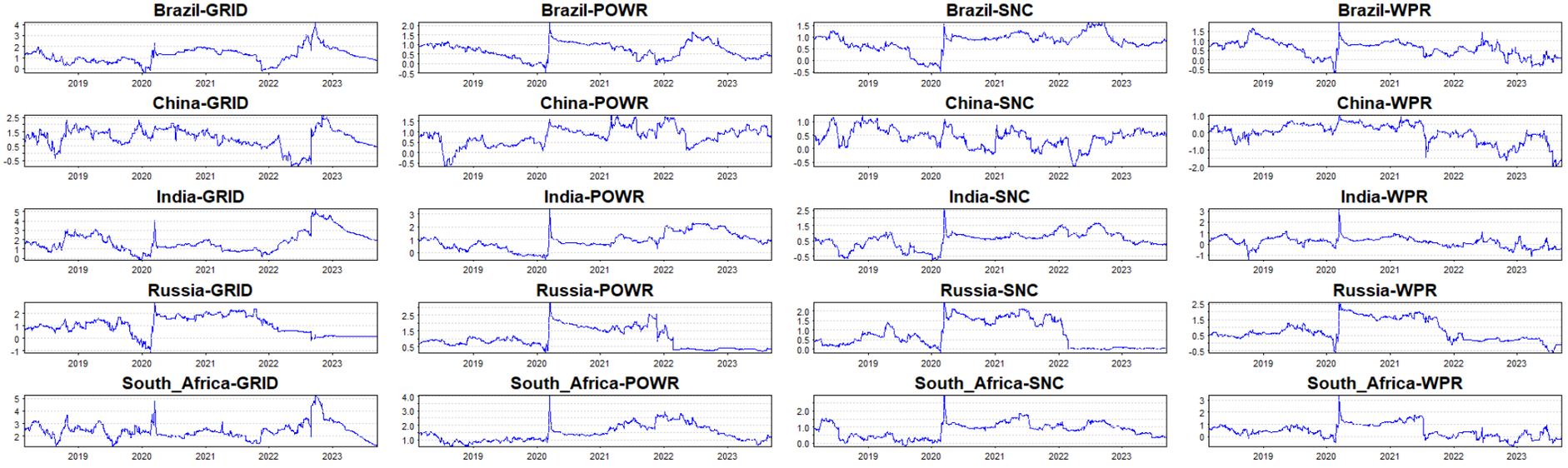
Table 4: Portfolio Implications

	Optimal weights			Hedging effective - OW			Hedge ratio			Hedging effective - HR		
	Full sample	Pre COIVD-19	COVID-19	Full sample	Pre COIVD-19	COVID-19	Full sample	Pre COIVD-19	COVID-19	Full sample	Pre COIVD-19	COVID-19
Brazil/GRID	0.998	0.997	0.999	0.003	0.012	0.001	0.019	0.005	0.03	0.069	0.004	0.113
Brazil/POWR	0.987	0.978	0.991	0.012	0.035	0.006	0.042	0.017	0.049	0.109	0.014	0.132
Brazil/SNC	0.99	0.985	0.995	0.011	0.03	0.003	0.041	0.009	0.059	0.088	0.009	0.121
Brazil/WPR	0.99	0.988	0.992	0.011	0.017	0.007	0.025	0.019	0.025	0.071	0.03	0.074
China/GRID	0.998	0.999	0.997	0.008	0.002	0.011	0.006	0.008	0.005	0.017	0.014	0.018
China/POWR	0.992	0.977	0.998	0.015	0.033	0.006	0.016	0.009	0.017	0.025	0.013	0.03
China/SNC	0.988	0.992	0.987	0.022	0.015	0.024	0.009	0.013	0.008	0.017	0.018	0.014
China/WPR	0.988	0.979	0.99	0.023	0.025	0.02	0.002	0.004	0	0.015	0.014	0.014
India/GRID	1	0.999	1	0.001	0.007	0.001	0.012	0.003	0.017	0.037	0.015	0.048
India/POWR	0.991	0.986	0.996	0.012	0.029	0.004	0.021	0.002	0.028	0.046	0.009	0.051
India/SNC	0.991	0.99	0.995	0.012	0.023	0.005	0.017	0	0.028	0.029	0.01	0.033
India/WPR	0.989	0.993	0.988	0.025	0.016	0.024	0.007	0.005	0.006	0.019	0.019	0.017
Russia/GRID	0.992	1	0.988	0.024	0.003	0.024	0.014	0.004	0.022	0.051	0.004	0.063
Russia/POWR	0.977	0.998	0.966	0.078	0.002	0.085	0.038	0.02	0.046	0.044	0.014	0.05
Russia/SNC	0.949	0.995	0.927	0.19	0.028	0.203	0.02	0.007	0.031	0.015	0.012	0.021
Russia/WPR	0.981	0.998	0.974	0.089	0.006	0.093	0.021	0.012	0.025	0.023	0.017	0.024
South_Africa/GRID	1	1	1	0	0	0	0.018	0.008	0.024	0.063	0.014	0.089
South_Africa/POWR	0.999	0.995	0.999	0.001	0.009	0	0.036	0.016	0.041	0.075	0.014	0.092
South_Africa/SNC	0.994	0.992	0.995	0.007	0.019	0.005	0.024	0.005	0.034	0.037	0.014	0.045
South_Africa/WPR	0.993	0.992	0.994	0.012	0.015	0.012	0.012	0.006	0.013	0.036	0.013	0.038

This table reports the static bivariate optimal weights, hedge ratios and hedging effectiveness for the portfolio of stock and energy token during three sample periods. Full sample (February 22, 2018, to September 15, 2023), Pre COVID-19 (February 22, 2018, to December 31, 2019) and COVID-19 (January 1, 2020, to September 15,2023) period.



(a) Bivariate optimal portfolio weight



(b) Bivariate optimal portfolio weight

Figure 5: Optimal weights and hedge ratio