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ARTICLE

Do ESG Indices across BRICS enjoy any dynamic relation: Empirical analysis using VARMA-GARCH Spillover Approach

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Abstract

The present study investigates the causal and spillover dynamics concerning ESG indices across four BRICS nations to understand the responsiveness of these nations towards Green Finance and Green Economy, a collective vision of the BRICS nations. The study covers five years, from April 2018 to March 2023, and closing price data has been collected from the MSCI ESG Leaders Index Series for four BRICS nations. Brazil, India, China, and South Africa. The model employed was the VARMA-GARCH Spillover Model, where spillover was measured through residuals. The model measures both mean and volatility spillover across BRICS for three BRICS economies, viz. South Africa, China, and Brazil, the variant used was VARMA (1,1) -GARCH (1,1), while for India, the model VARMA (1,2)-GARCH (1,1) was considered. The additional MA term for India was warranted to make the Spillover model for India free from serial correlation. The study also tested for causality, and with all variables being I(1) stationary, the model selected was Toda and Yamamoto (1995) modified 'F' causality. The model diagnostics considered for the study included ARCH effects and Serial Correlation. Amongst the study results, mean spillover was not seen. However, the volatility spillover from both India and China towards South Africa and again from India towards China was seen in the study results. No other spillover was noticed amongst any other BRICS nations. Further, ARCH and GARCH terms of all the countries in the volatility equation were added to <1, showing persistence to go away over time. All the variables were stationary at I(1), as seen from the ADF breakpoint unit root test. The causality results showed unidirectional movement from ESG India to ESG China and ESG Brazil indices. The results do not give any concrete evidence of any collective responsiveness of the four BRICS nations towards Green Finance. Leaving apart select volatility spillovers towards South Africa, the integration through spillover concerning ESG indices appears somewhat limited. These results somewhat contrast with a study by Rehman et al. (2021), where they noticed integration among ESG indices for BRICS nations.

Keywords: BRICS, ESG, VARMA-GARCH Spillover, Causality, Model Diagnostics.

1 Introduction

Several factors play an essential role in determining the selection of securities and the latest addition to this list is how a Company adheres to environmental, societal, and governance principles or ESG principles. The acronym ESG includes

issues relating to the environment (emissions, energy usage, and climate change), society (human rights and gender equality, safety, security, and fair trade practices), and governance (stakeholders protection, disclosure, independence of boards), all clubbed together into one. The term saw its first appearance in a 2004 UN report 'Who cares wins: Connecting financial markets to a changing world' (Compact, 2004) and is very closely related to other terms like sustainable investing, ethical investing, responsible investing, impact investing and so on. Thus, ESG plays a supportive role in traditional financial analysis; e.g., ESG would support business practices and ventures that do not harm the environment, and a Company may be forced to switch to a product that generates biodegradable waste rather than non-biodegradable waste. Furthermore, since ESG shows a way to include responsible and sustainable practices within organizations, investors also show a keen interest in this concept, ensuring that companies are more committed to ESG principles. (Sun et al., 2011). Today, many investors want Companies to act responsibly and not just focus on financial returns impact. A study by MSCI covering around 200 institutions showed that in 2020, 3/4th of institutions surveyed had increased investments in ESG either 'significantly' or 'moderately.'

Apart from returns, benefits which investors expects from companies following ESG principles, include transparency in reporting, greater market efficiency, and lower information asymmetry. However, much also depends upon how stringent the state implements the regulations. The efficiency of financial markets also impacts ESG investments, and there is enough evidence proving that the higher the market efficiency, the more responsible investing will be. Higher efficiency also reduces market predictability, keeps away speculative investors, and attracts responsible investors who value such a cause. (Mynhardt, et. al., 2017).

On the other hand, the initial spadework for ESG must come from companies through their CSR principles. Through proper CSR funding, Companies improve their reputation and signal the quality of their products, thereby creating a positive image amongst consumers. Further, to ensure that Companies do not shy away from their CSR responsibilities, environmental and social pressure groups now exist in many countries (Friedman & Miles, 2001; Fombrun & Shanley, 1990).

According to Hong and Scheinkman (2012), for successful CSR implementation, it is also essential that the Companies be financially strong. Most such companies also undertake a social cost-benefit analysis to determine Social IRR for any venture undertaken to meet their CSR responsibilities. Thus, it would not be incorrect to say that there are no free lunches in the mission towards 'corporate goodness'. According to McWilliams et al. (2006), the maturity of a Company's corporate responsibility, to a great extent, is linked to the stage of development of the economy. This can be seen from the nature of stakeholders' demand to implement CSR in companies, which varies substantially across economies. Bad CSR policies can sometimes result in stakeholders' loss of trust and reputation and may even lead to a boycott of the goods produced by the firm. (Bassen et al., 2006).

Investors often speak of 'ESG alpha,' an alpha built up after considering ESG Principles as against standard 'alpha,' which is independent of such 'restrictions.' Restrictions under ESG alpha would imply restricting investments in specific categories of companies, including companies involved in tobacco, arms, and ammunition and companies carrying out business that result in violation of any kind, like climate change violations, human rights violations, and so on. This restricts the universe of investments for a fund manager, and the manager is compelled to generate 'alpha' from fewer companies. Reporting results of a fund manager's survey, Kim & Li (2021) pointed out that most (72 %) of the respondents incorporated ESG principles in their investment decisions, while 90 % believed that ESG-integrated portfolios should outperform non-ESG-integrated portfolios. Many organizations like Moody's Vigeo-Eiris and Morningstar's Sustainalytics have shown interest in compiling and providing ESG Data to users. Such organizations develop parameters to evaluate companies on ESG Scales, similar to what rating agencies are known for. The data these organizations provide is now primarily used to develop ESG indices, popular ones being the Dow Jones Sustainability Index and the MSCI World ESG Leaders Index (Eccles & Stroehle, 2020; Neto & Fontgalland, 2023).

Among the BRICS, Brazil was the earliest to include an index on ethical investments in 2001. It was followed by South Africa, which launched its JSE SRI Index in 2004. Both India and China introduced ethical investments into stock indices in 2008.

2 REVIEW OF LITERATURE

ESG research is relatively recent origin as the term itself came into existence in 2004. However, there is evidence that the researchers carried out similar kinds of research in the past, focusing on socially responsible and ethical funds. Further, it was only after launching the acronym 'ESG' that investors started making explicit distinctions between ESG, Responsible Investing, and Impact Investing. Thus, whereas ESG would look at the environment from the perspective of social and governance practices, besides traditional financial measures, responsible investing would choose an investment on ethical grounds. Finally, impact investing aims to promote companies that make a social or environmental impact.

Coming to the past studies in this area, research primarily involved comparing the performance of responsible investing to conventional investing revolving around three possible hypotheses, the first being the 'no effect' hypothesis, stating that responsible funds neither perform better nor worse than conventional investments and those who have found this hypothesis to be true included Abidin & Gan (2017); Rehman et al., (2021); Junkus, & Berry (2015) amongst others. The second hypothesis, 'doing good but not well,' shows that responsible investments tend to underperform conventional investments. Finally, the third hypothesis, 'doing good while doing well,' reflects better or outperformance of responsible funds as compared to conventional investments, and contributors who agree to this hypothesis include Elaut et al. (2015);

Statman (2000); Hamilton et al., (1993) amongst others.

On the other hand, some researchers have argued against comparing the performance of responsible funds with conventional funds due to the difference in valuation methodology between the two funds. In contrast, responsible funds are valued based on the current holding methodology; the historical holdings approach is usually applied to conventional funds (Elaut et al., 2015).

Furthermore, after the entry of ESG funds, researchers too initially applied a similar approach of comparative assessment with conventional funds using risk-return dimension, and studies include Pérez-Gladish et al. (2013) and Managi et al. (2012), both studies failed to find any evidence of ESG funds performing better than the conventional funds. On the other hand, Kanamura (2022) found that the difference in performance of ESG and conventional indices was only temporary, and the two tend to converge over time. They further noticed that the ESG indices did not fully reflect the environmental aspects of ESG. Then, in their study, Ashwin Kumar et al. (2016) showed that ESG implementation differed significantly across sectors. Therefore, they suggested that a fund manager would be better off by avoiding clubbing industries in different sectors as one unit. Cornel (2021) further argued that many ESG firms were valued at higher multiples; hence, higher risk premiums were attached. According to him, this translated to lower returns than conventional firms.

Thus, several studies have also compared the performance of ESG funds with conventional funds during a crisis. A study by Leite and Cortez (2015) revealed that ESG funds outperformed conventional funds only during crises but not regular periods. This observation was made during the 2008 Crisis period. Therefore, the researchers concluded that ESG funds' performance was well below conventional funds during regular periods. Similar results were also observed by Chiappini et al. (2021); however, the crisis here was Covid 19. In yet another study focussing on the crisis period, Pástor and Vorsatz (2020) showed that not only do funds with sustainability appeal perform better during a crisis, but investors also look at these funds as a protection of their values during any major crisis. Wadhwa (2017) concluded that the global crisis was responsible for transforming the mindset of many firms, which initially considered non-financial information as a wasteful exercise, while after the crisis, such firms started considering the same as a valuable input for decision-making. Folger-Laronde et al. (2022), on the other hand, however, found the ESG index to be less transparent, especially during the COVID-19 pandemic, and the index was equally vulnerable to market downturn like any other market index. Similarly, working during the crisis period, Demers et al. (2021) showed that the returns from ESG indices were in no way superior to other broader indices. They further questioned the point raised by some researchers, who generalized that the CSR philosophy was somewhat resilient during Subprime and should be extended to ESG during COVID-19.

Some studies have found ESG funds to outperform conventional funds at all times and also generate superior returns. Neto & Fontgalland (2023) conducted one such study on BRICS economies. They showed that the profitability of ESG indices was higher than their country's broader market indices on average. They also could find risk (volatility) higher for non-ESG Companies than those included in ESG. Amongst other studies proving ESG's superior performance were Statman (2000) for US markets and Cortez et al. (2012) on European Markets. Charlo et al. (2015) found that firms listed on Spain's sustainability index performed better than those listed on conventional indices.

A report by Whelan et al. (2021) for the NYU Stern Center for Sustainable Business showed that the relationship between ESG and financial performance was generally positive. Such funds could generate positive alpha, and their Sharpe ratio was even better than that of conventional funds. Their report showed that 59 percent of such funds perform similarly or better than conventional investments. Thus, the above review of studies on returns of ESG funds reveals near consensus superior performance of such funds during crisis periods and a mixed type (better, worse, or at par) performance compared to conventional funds during regular periods. Further, despite diverse views on ESG returns, there appears to be some consensus on 'return volatility' for the ESG funds and indices, and most studies have found this to be lower than prominent broader indices. (Neto & Fontgalland, 2023; Ashwin Kumar et al., 2016; Hoang et al., 2021; Mousa et al.,2021; El Bannan,2024). Again, there is also a near consensus amongst the existing researchers that irrespective of the current performance of ESG indices; these are likely to outperform most conventional indices in the long run. It thus appears that investors seem to have realized the potential of such funds, and the same argument has been supported by the figures which reveal that investment in ESG firms has gone up exponentially during the recent past, e.g., for US Markets investment in ESG funds have increased roughly ten times in two years; from 5 billion US $ in 2018 to more than 50 billion US $ in 2020.

In their studies, the researchers have addressed a few other dimensions concerning ESG investments, including banks and financial institutions' lending policies toward companies with vital ESG records. Bassen et al., 2006 showed how lenders attach a sustainability angle while lending, which results in borrowing at lower interest rates for these companies. Another dimension explored for ESG investments is market risk and stock betas of companies with good ESG records. A study by Amel-Zadeh and Serafeim (2017) showed that ESG assets had less systematic risk and, therefore, managed to reduce the impact of negative externalities by making them less painful. Then, another dimension explored ESG policies of susceptible industries like steel, and Garcia et al. (2017), focusing on ESG analysis of environmentally sensitive industries, showed that contrary to the general belief, such industries did pose a superior performance concerning the environment. The last dimension concerns comparing the performance of ESG funds across countries, and our research could identify only two studies; first was a study by Rehman et al. (2021) where they found that ESG indices across BRICS were co-integrated with conventional indices in their own respective country and also with other ESG indices across BRICS while Neto & Fontgalland, (2023) in their study showed that profitability of ESG indices in all BRICS was higher than their broader market indices.

Research Gap Considering the above literature review, it was decided to extend the research work undertaken by two studies on ESG investments in BRICS by incorporating two new tools, viz. causality and volatility spillover across BRICS

nations; the same has not been considered in the two studies discussed above. Thus, according to our understanding, considering the growth potential of BRICS nations and with many standard features across BRICS, including a solid agrarian base, natural resources in abundance, and a fast-evolving services sector, a growth story which is although familiar to each BRICS has a separate structure, there exists a high probability of a cause-effect relation in the returns and spillover in the volatility of returns of the ESG investment across BRICS nations (Sharma & Shahani, 2018). The same was seen in a study by Latha and Kumar (2016), where they found causal and co-integrating relations between equity markets of all five BRICS nations for the entire period and the two sub-periods before and after the global financial crisis.

3 Data

The study selected four ESG indices from the MSCI ESG Leaders Index Series: MSCI Brazil, China, India, and South Africa. Russia was excluded from the study for being at war for more than two years, which could have impacted the reliability of data and the study results. For example, in 2021, the MSCI Russia index gave a positive return of 19%; this became negative 100% in 2022. Such extreme volatility in returns was not seen in any other country, and the ongoing war could be the prime reason for such extreme volatility.

Furthermore, to obtain ESG indices, the study could have employed another source: S&P Dow Jones ESG indices. However, the same was not used due to some ambiguity in South Africa's ESG index. On the other hand, MSCI ESG indices were found suitable for the current study as a similar methodology was employed in constructing all the indices, thereby facilitating ease of comparison. Moreover, since all the quotes were in the same denomination, i.e., US Dollars, inflationary pressures and currency fluctuations on index movement could be minimized, thus enabling conformity. Then, all four indices were constructed by drawing companies from their respective 'Parent Indices,' thereby ensuring that the weight of the sectors reflected in 'Parent' indices gets retained while forming ESG indices (www.msci.com). Furthermore, suppose we observe the information provided as a footnote in Table 1, which gives the beta and annualized standard deviation of each country's MSG ESG Index and the 'parent' index. In that case, we observe that these are pretty close to each other. A comparative analysis of annual performance (%) of each country's ESG index with their 'Parent Index' for the fourteen years, 2009–2022, is shown in Table 1 below:

Table 1: Comparative analysis of annual performance (%) of each BRICS's ESG index with their 'Parent Index' for the period 2009-2022

Year	Brazil		India		China		South Africa	
	MSCI ESG	MSCI 'Parent'	MSCI ESG	MSCI 'Parent'	MSCI ESG	MSCI 'Parent'	MSCI ESG	MSCI 'Parent'
2022	-7	-3.6	-9.5	-7.9	-26.5	-21.8	-5.8	-3.0
2021	-28.5	-18	21.8	26.2	-22.6	-21.6	5.9	4.3
2020	-1.4	2.1	22.8	15.6	34.9	29.6	-5.1	-3.5
2019	22.4	26.7	11.7	7.6	31.9	23.6	8.8	10.7
2018	11.5	12.3	-2.8	-7.3	-26.3	-18.8	-25	-24.3
2017	23.5	23.3	37.7	38.8	65.3	54.3	49.6	36.9
2016	23.9	32.7	-2.25	-1.4	7.6	1.1	22.6	18.4
2015	-13.7	-15.8	2.3	-6.1	3.5	-7.6	-25.2	-25.1
2014	8.1	-6.9	21.9	23.9	13.2	8.3	11.5	5.7
2013	0.1	-6.3	7.6	-3.8	15.3	3.9	-5.6	-5.8
2012	15.4	5.9	17.9	25.9	27.1	23.1	31	19
2011	-10	-15.6	-31.1	-37.2	-8.8	-18.2	-9.08	-14.4
2010	4.5	-1.2	28.7	20.9	3.8	4.3	39.44	34.2
2009	60	65.4	113.9	102.81	47.4	62.6	58.8	57.8
Beta of the Index (till date since inception)	0.98	1.0	0.9	1.0	0.95	1	1.02	1
10 yr S.D (% annualized)	23.3	22.5	18.23	19.1	25.5	23.6	25.7	25.1
Source: www.msci.com								

The analysis of annual performance across each of the BRICS nations reveals the following:

Brazil

The MSCI ESG index appears to have performed better than the 'Parent' index from 2010 to 2015. However, in 2015, the 'Parent' index delivered a superior performance, especially during the last five years (2017-2022). Furthermore, since the period (2017-2022) coincided with global turmoil in stocks due to COVID-19, if we were to assess the performance of two indices, then the 'Parent' index appears to have performed better. Then, even for 2020, the year most affected by COVID-19, the 'Parent' index performs better than the MSCI ESG Index.

India

No clear pattern is visible regarding performance. The 'Parent' Index performs better than MSCI ESG in seven out of 14

years, with reversal visible for the remaining seven years.

China

MSCI ESG performed better than the 'Parent' Index in 11 out of 14 years. However, there appears to be some indication of reversal during the last two years (2021 and 22) when the country's stock markets witnessed a fall and yielded record negative returns. Although both the 'Parent' and ESG indices showed negative returns during these two years, the 'Parent' index fell by a smaller percentage.

South Africa

For this BRICS economy, there is a clear indication that during the last five years (2018-22, except 2021), the 'Parent' Index outperformed the ESG, while the opposite held during 2009-17. Thus, the entire data period can easily be divided into two parts; the earlier period belonged to the MSCI ESG Index, while the later period saw the 'Parent' Index take over.

Table 1 also provides information about the beta of the stock index and the annualized standard deviation (a measure of systematic and total risk, respectively) for each index. The results reveal that except for South Africa, all the BRICS countries have stock in their ESG index that is lower than the 'Parent' Index. In contrast, ESG indices carry a higher risk for all BRICS countries except India regarding annualized standard deviation.

4 Methodology

The methodology under the study involves establishing a spillover and a causality model for ESG investment across BRICS nations to extend the work of two earlier studies on BRICS. Further, since BRICS enjoy many common features like a solid agrarian base, abundant natural resources, fast-evolving services sector, and unique growth story, there exists a high probability that every country reinforces every other country concerning their commitment to achieving Sustainable Development Goals (SDGs) in an integrated and holistic manner, the same being formally announced jointly by all BRICS nations at 2023 SDG Summit. Hence, the choice of tools to determine the cause-effect relation in the returns and spillover in the volatility of returns across BRICS nations for their ESG indices has been made to consider these two factors. Further design of tools also ensures the robustness of results. (Sharma and Shahani, 2018).

4.1 Spillover Model: Identification of the VARMA-GARCH Model

Spillover, which refers to an effect on a variable due to unrelated events happening elsewhere, invariably in another country, is modeled under the present study using an error term. These unrelated events in many situations are unpredictable and include the effects of natural calamities(e.g., earthquakes), political crises, etc., and can impact the variable positively or negatively. Furthermore, for the current study, the spillover across residuals of BRICS has been introduced by incorporating the same in VARMA-GARCH type models. However, before this model was selected, a simple VAR Model was established, revealing serial correlation, resulting in model improvement, and the study established a VAR-GARCH Model. This model was chosen based on the assumption that being a superior model to OLS, the serial correlation problem would be taken care of. Also, the model could capture volatility dynamics and was ideal for modeling volatility spillover. However, after running this model, the results showed that the serial correlation problem existed but was present only at later lags. It was then decided to introduce MA terms in the Model, and the model was further modified to VARMA-GARCH. This VARMA-GARCH Model was thus able to resolve the issue of serial correlation when the MA(1) term was added to our model for three BRICS countries viz. Brazil, China, and South Africa, while we had to introduce the MA(2) term to the VAR-GARCH Model for India. Thus, we could obtain the desired model free from serial correlation and the ARCH effect. We introduced the spillover terms to this optimal model, i.e., mean and variance spillover across BRICS.

Under the VARMA-GARCH approach, we have established four mean equations: eq.(1) to eq.(4), and another four as variance equations, eq.(5) to eq.(8). For three countries, Brazil, China, and South Africa, the Model considered was VARMA(1,1)-GARCH(1,1), while for India, the model under consideration was VARMA(1,2)-GARCH(1,1). We denote ESG indices of four BRICS as $ESG_{Br,t}ESG_{Ind,t}$, $ESG_{Ch,t}ESG_{SA,t}$ and develop four equations with residual terms as $u_{1,t}, u_{2,t}, u_{3,t}$ and $u_{4,t}$ respectively. These residual terms and the square of these terms are introduced as spillover in mean (eq. 1 to 4) and volatility (eq. 5 to 8) equations (Masson, 1998).

4.1.1 VARMA-GARCH Model with Mean Spillover

$$ESG_{Br,t} = \mu_1 + \beta_2 ESG_{Br,t-1} + \gamma_{3A} ESG_{Ind,t-1} + \gamma_{3B} ESG_{Ch,t-1} + \gamma_{3C} ESG_{SA,t-1} + \delta_4 u_{1,t-1} + \pi u_{2,t-1} + \theta u_{3,t-1} + \varphi u_{4,t-1} + u_{1,t}. \quad (1)$$

$$ESG_{Ind,t} = \mu_1 + \beta_2 ESG_{Ind,t-1} + \gamma_{3B} ESG_{Ch,t-1} + \gamma_{3C} ESG_{SA,t-1} + \gamma_{3D} ESG_{Br,t-1} + \delta_{4,1} u_{2,t-1} + \delta_{4,2} u_{2,t-2} + \tau u_{1,t-1} + \theta u_{3,t-1} \varphi u_{4,t-1} + u_{2,t}. \quad (2)$$

$$ESG_{Ch,t} = \mu_1 + \beta_2 ESG_{Ch,t-1} + \gamma_{3A} ESG_{Ind,t-1} + \gamma_{3C} ESG_{SA,t-1} + \gamma_{3D} ESG_{Br,t-1} + \delta_4 u_{3,t-1} + \pi u_{2,t-1}\, \tau u_{1,t-1} + \varphi u_{4,t-1} + u_{3,t}. \quad (3)$$

$$ESG_{SA,t} = \mu 1 + \beta_2 ESG_{SA,t-1} + \gamma 3A ESG_{Ind,t-1} + \gamma_{3B} ESG_{Ch,t-1} \gamma_{3D} ESG_{Br,t-1} + \delta_4 u_{4,t-1} + \tau u_{1,t-1} + \pi u_{2,t-1} + \theta u_{3,t-1} + u_{4,t}. \quad (4)$$

4.1.2 VARMA-GARCH Model with Volatility Spillover

$$h_{ESG_{Br,t}} = \pi_1 + \psi_2 u^2_{1,\,t-1} + \vartheta_3 h_{ESG_{Br,t-1}} + \xi u^2_{2,\,t-1} + \lambda u^2_{3,\,t-1} + \Omega u^2_{4,\,t-1} \quad (5)$$

$$h_{ESG_{Ind,t}} = \pi_1 + \psi_2 u^2_{2,\,t-1} + \vartheta_3 h_{ESG_{Ind,t-1}} + \phi u^2_{1,\,t-1} + \lambda u^2_{3,\,t-1} + \Omega u^2_{4,\,t-1} \quad (6)$$

$$h_{ESG_{Ch,t}} = \pi_1 + \psi_2 u^2_{3,\,t-1} + \vartheta_3 h_{ESG_{Ch,t-1}} + \xi u^2_{2,\,t-1} + \phi u^2_{1,\,t-1} + \Omega u^2_{4,\,t-1} \quad (7)$$

$$h_{ESG_{SA,t}} = \pi_1 + \psi_2 u^2_{4,\,t-1} + \vartheta_3 h_{ESG_{SA,t-1}} + \phi u^2_{1,\,t-1} + \xi u^2_{2,\,t-1} + \lambda u^2_{3,\,t-1} \quad (8)$$

4.2 The Causality Model

Besides testing for spillover across BRICS, the study also tested for the cause-effect relation amongst ESG indices across BRICS for which the tool applied was Toda and Yamamoto (1995) modified 'F' model. The choice of the model was strongly influenced by the level of integration of our variables, i.e., ESG indices, which were found to be I(1) integrated. Under the TY causality test, we developed two equations, the first being the Restricted Model(R) and the second being the Unrestricted Model(UR); the two equations are given as eq.(9) and (10), respectively. To test for causality amongst two variables, we use X_1 and X_2 as common notations. Both the models (eq. 9 and 10) are lag augmented by a higher level of integration(Ihigh) of causal variables, and the Sum of the Squared residuals of restricted and unrestricted models (SSRR and SSR UR) obtained are used to obtain statistics called Modified 'F' as given below:

$$\text{Mod F 'Wald'} = \frac{(SSR_R - \text{SSR}_{UR})/k}{\text{SSR}_{UR}/(n-k)}$$

('k' is equal to the number of parameters to be estimated, 'n' being no. of observations)

Restricted Model (R)

$$X_{1t(R)} = \mu_{0(R)} + \sum_{j=1}^{Ihigh} \alpha_{j,(R)} X_{2,(t-j)} + \sum_{i=1}^{h+Ihigh} \beta_{i,(R)} X_{1,(t-i)} + e_{1t}. \quad (9)$$

Un-Restricted Model (UR)

$$X_{1t(UR)} = \mu_{0(UR)} + \sum_{j=1}^{k+Ihigh} \alpha_{j,UR} X_{2,(t-j)} + \sum_{i=1}^{h+Ihigh} \beta_{i,(UR)} X_{1,(t-i)} + e_{2t}. \quad (10)$$

Null Hypothesis (H_0): Lagged values of X_2 do not influence X_1 or $\alpha_1, \alpha_2, \alpha_3, \ldots = 0$.

4.3 Model Diagnostics

The two models, Spillover and Causality, discussed under sections 4.1 and 4.2, will give reliable results if the model prerequisites are adequately satisfied. In this section, we discuss three prerequisites (called model diagnostics): the first is the ARCH LM test, which is applied to test the ARCH effects, which are a variant of heteroscedasticity; the second is the serial correlation using 'Q' statistics; and finally, we test for the stationarity of our variables by applying the unit root ADF test.

4.3.1 *Model for ARCH Effects*

For the ARCH test, we construct eq.(11) for each of the ESG variables, which is an AR(1) Model,

$$Y_t = \beta_1 + \beta_2 Y_{t-1} + e_t. \tag{11}$$

We collect the residuals of eq. (11) and run an auxiliary equation eq (12),

$$e_t^2 = \partial_0 + \rho_1 e_{t-1}^2 + \rho_2 e_{t-2}^2 + \cdots + \rho_m e_{t-3}^2 + \cdots v_t. \tag{12}$$

where 'm' reflects the lag order of residuals in the secondary equation and follows AIC criteria. Next, we collect the R Square of this auxiliary equation and multiply it with no. of observations. Model ARCH-LM follows ?2(m) distribution with Null Hypothesis defined as $\rho_1 = \rho_2 = \rho_3 = \cdots \rho_m = 0$ (no ARCH effect is present).

4.3.2 *Model for Serial Correlation*

Serial correlation is the second diagnostic that has been tested under the study, and the test applied is 'Q_m' Statistics where Q_m is defined as

$$Q_m = n.\sum_{i=1}^{m} \rho_{u_{i,t}}^2. \tag{13}$$

Q_m follows χ^2 Distribution with 'm' df (no. of lags). Null(H_0) for the test is given as $\rho_{u_{1t}} = \rho_{u_{2t}} = \cdots \rho_{u_{mt}} = 0$ with alt. hypothesis (H_a) being some of the $\rho_{u_{it}}$ are not equal to 0. We further define $\rho_{u_{1t}} = \frac{cov\left(u_t\,,\,u_{t-1}\right)}{\sqrt{Var_{(u_t-1)}\,Var_{(u_t)}}}$, Moreover, under the study, we compute serial correlation till lag 5.

4.3.3 *Model for Stationarity*

We have applied the Breakpoint Unit root ADF test for the stationarity test, which is similar to the famous ADF unit root test but incorporates a single breakpoint. Incorporating a breakpoint in the ADF unit root test has been considered, and the same is expected to improve the power of the test. Let us consider our first variable $ESG_{Br,t}$, we develop the Breakpoint Unit root ADF test equation as eq. (14) given as under:-

$$\Delta ESG_{Br,t} = \beta_1 + \beta_1 * D_{ESG_{Br,t}} + (\beta_2 - 1) ESG_{Br,t-1} + \sum_{i=1}^{m} \beta_{3,i} \Delta ESG_{Br,t-i} + \beta_4 t + u_t \tag{14}$$

Eq. (14) is the ADF equation with a single break point for Variable ESG of Brazil, where $\Delta ESG_{Br,t}$ is a change in ESG of Brazil in period t, β_1 represents the intercept term while $\beta_1 * D_{ESG_{Br,t}}$ is the intercept Dummy representing a single break in the intercept of the ESG of Brazil equation. This Dummy $D_{ESG_{Br,t}}$ takes the value of '1' if the observation falls after the break date (including the break date) and '0' before the break date. If the break exists (see Table 6), then the coefficient $\beta_1, *$ is expected to be statistically significant. The next term $ESG_{Br,t-1}$ reveals the stationarity of variable 'ESG' and has $(\beta_2 - 1)$ as its coefficient. The term $\sum_{i=1}^{m} \beta_{3i,} ESG_{Br,t-i}$ denotes a change in the ESG of Brazil in a period $t - i$, 'i' is the no. of lags, and this term represents the 'augmentation' for removing serial correlation. The ADF equation also takes care of trend stationarity by including a trend variable 't' with a coefficient as β_4. Finally, the random error term of this equation is given by u_t Using a similar methodology, we construct the stationary equation for our other three ESG indices of remaining BRICS countries.

5 Results of the Study

We now discuss the study results with the help of supporting tables, Tables 2-5. The first two tables (Tables 2 and 3) discuss Mean and Volatility Spillover across BRICS using VARMA(1,1) Models; Table 4 provides the causality results using the Toda and Yamamoto (1995) modified 'F' approach, and finally, table 5 gives results of Model Diagnostics which includes results of ARCH test using ARCH LM methodology, Serial Correlation using 'Q' statistics and test of stationarity using ADF unit root test.

Table 2: VARMA (1,1) Model with mean spill over

Mean Equation	$ESG_{Br,t}$	$ESG_{Ind,t}$	$ESG_{Ch,t}$	$ESG_{SA,t}$
Constant term (μ_1)	1.091(0.061)	12.33(0.002)	3.06(0.83)	23.44(0.78)
Lag 1 term (β_2)	0.994(0.000)*	0.999(0.000)*	0.998(0.000)*	0.992(0.000)*
VAR term: $ESG_{Ind,t-1}$ (γ_{3A})	-0.015(0.089)	--	-0.001(0.520)	0.006(0.305)
VAR term: $ESG_{Ch,t-1}$(γ_{3B})	-0.006(0.985)	0.003(0.549)	--	0.007(0.358)
VAR term: $ESG_{SA,t-1}$ (γ_{3C})	-0.001(0.834)	-0.000(0.956)	0.001(0.414)	--
VAR term: $ESG_{Br,t-1}$ (γ_{3D})	--	-0.001(0.944)	0.001(0.080)	-0.001(0.98)
MA(1) term(δ_4) *(For India MA(1) $\delta_{4,1}$ and MA(2) $\delta_{4,2}$)*	0.994(0.000)*	MA (1)-0.088(0.039)** MA (2) 0.073(0.0360)**	0.006(0.0367)**	-0.037(0.047)**
Spill over from India: $u_{2,t-1}$ (π)	-0.117(0.343)	--	-0.005(0.100)	-0.041(0.742)
Spill over from China: $u_{3,t-1}$ (θ)	-0.006(0.956)		--	0.124(0.098)
Spill over from South Africa: $u_{4,t-1}$ (φ)	-0.007(0.891)	0.011(0.831)	0.015(0.332)	--
Spillover-0.240(0.000) from Brazil: $u_{1,t-1}$ (τ)	--	0.005(0.811)	-0.005(0.531)	0.058(0.249)

Notes: (1) Significant at 1 %, (2) **Significant at 5 %*

Table 3: VARMA (1,1) Model with volatility spill over

Variance Equation	$ESG_{Br,t}$	$ESG_{Ind,t}$	$ESG_{Ch,t}$	$ESG_{SA,t}$
Constant (π_1)	0.334(0.002)	0.173(0.246)	0.003(0.065)	0.793(0.008)
ARCH term (ψ_2)	0.120(0.000)*	0.150(0.026)**	0.088(0.000)*	0.102(0.032)**
GARCH term (ϑ_3)	0.765(0.000)*	0.600(0.004)**	0.868(0.000)*	0.518(0.005)*
Spill over from India: $u^2_{2,t-1}$ (ξ)	-0.181(0.201)	--	0.022(0.031)**	-0.231(0.000)*
Spill over from China: $u^2_{3,t-1}$ (λ)	0.212(0.192)	0.123(0.323)	--	-0.243(0.000)*
Spill over from S Africa: $u^2_{4,t-1}$(Ω)	-0.029(0.472)	-0.054(0.421)	-0.001(0.756)	--
Spill over from Brazil: $u^2_{1,t-1}$(ϕ)	--	0.021(0.321)	0.001(0.192)	0.008(0.321)

Notes: (1) Significant at 1 %, (2) **Significant at 5 %*

The results from Tables 2 and 3 reveal that Mean Spillover from ESG indices across BRICS does not exist. At the same time, the volatility spillover, the more important spillover, is visible from India (ξ) to bBina and South Africa. Also visible was volatility spillover from China (λ) to South Africa. No other spillover was noticed in the study results. Amongst the other study results, the variance equation showed a low level of persistence for ESG indices of three of the BRICS nations, i.e., India, Brazil, and South Africa. This was evident as the ARCH and GARCH terms sum considerably below '1'. On the other hand, for China, the sum of ARCH and GARCH terms was quite close to '1', showing a tendency for shocks to persist for a longer duration; however, these shocks were expected to die in due course as the sum of ARCH and GARCH terms is less than '1'.

As far as the cause-effect relation amongst ESG indices of BRICS, we applied the Toda and Yamamoto (1995) modified 'F' causality procedure, and the results of the same are shown in Table 4. The results reveal a uni-directional causality from India towards both Brazil and China. No other causality is seen from the results of the study. The study also tested for Model Diagnostics (Tables 5 and 6); Table 5 gives the results for Serial Correlation and ARCH Effect, and these results were found to be satisfactory, while Table 6 gives the results for stationarity and all the ESG indices in all BRICS economies were found to be stationary at first difference.

Table 4: Causality Results (Toda and Yamamoto (1995) modified 'F' causality)

Direction of Relation	'F' Statistics	'p' value	Null Hypothesis (Accept / Reject)
$ESG_{IND} \rightarrow ESG_{CHINA}$	8.21086	0.0003*	*Null Rejected, Causality exists*
$ESG_{IND} \rightarrow ESG_{BRAZIL}$	4.41483	0.0123*	*Null Rejected, Causality exists*
$ESG_{IND} \rightarrow ESG_{S\ AFRICA}$	0.83019	0.4362	Null Accepted, No Causality exists
$ESG_{CHINA} \rightarrow ESG_{IND}$	0.72430	0.4849	Null Accepted, No Causality exists
$ESG_{CHINA} \rightarrow ESG_{S\ AFRICA}$	0.03859	0.9621	Null Accepted, No Causality exists
$ESG_{CHINA} \rightarrow ESG_{BRAZIL}$	0.32060	0.7258	Null Accepted, No Causality exists
$ESG_{BRAZIL} \rightarrow ESG_{CHINA}$	2.17815	0.1137	Null Accepted, No Causality exists
$ESG_{BRAZIL} \rightarrow ESG_{IND}$	0.52444	0.5920	Null Accepted, No Causality exists
$ESG_{BRAZIL} \rightarrow ESG_{S\ AFRICA}$	1.20199	0.3010	Null Accepted, No Causality exists
$ESG_{S\ AFRICA} \rightarrow ESG_{CHINA}$	2.80206	0.0611	Null Accepted, No Causality exists
$ESG_{S\ AFRICA} \rightarrow ESG_{BRAZIL}$	0.74226	0.4763	Null Accepted, No Causality exists
$ESG_{S\ AFRICA} \rightarrow ESG_{IND}$	0.64083	0.5270	Null Accepted, No Causality exists

*Notes: (1) Null : No Causality (2) * significant at 1 % level*

Table 5: Model Diagnostics I: Serial Correlation and ARCH Heteroscedasticity for ESG Indices of BRICS

	Brazil	India	China	South Africa
Observed R^2	0.964629	0.798	0.282	0..349
Probability χ^2	0.3260	0.8295	0.595	0.5554
Lag	**Brazil**	**India**	**China**	**South Africa**
1	0.0003 (0.987)	0.599 (0.43)	0.0913 (0.763)	0.1960 (0.171)
2	0.104 (0.948)	1.19 (0.55)	0.536 (0.765)	0.0875 (0.214)
3	0.135 (0.987)	1.669 (0.64)	1.81 (0.615)	0.0504 (0.429)
4	1.635 (0.802)	2.759 (0.259)	2.124 (0.713)	1.5634 (0.348)
5	1.636 (0.897)	6.777 (0.254)	2.695 (0.747)	1.763 (0.356)

Table 6: Model Diagnostics II: Breakpoint ADF Unit Root test for ESG indices

Diagnostic Tool		Brazil		India		China		South Africa	
Stationarity of Variables :		Level	1st Diff	Level	1st Diff	Level	1st Diff	Level	1st Diff
ADF Breakpoint unit root test	1	0.5253	<0.01	0.4516	<0.01	0.7356	<0.01	0.2702	<0.01
(1. 'p' values of slope coefficient	2	Unit Root	Stationary	Unit Root	Stationary	Unit Root	Stationary	Unit Root	Stationary
2. Table Result, 3. 'Break Date')	3	2/19/2020	-	10/30/2020	-	6/29/2021	-	10/29/2020	-

6 Conclusions and Discussion

To conclude, the present study attempted to understand the spillover dynamics and cause-effect relation amongst ESG indices across four BRICS nations to identify the collective responsiveness of these nations towards Green Finance and Green Economy, a joint vision of the BRICS nations. The study collected daily closing five-year data (April 01, 2018- March 31, 2023) from the MSCI ESG Leaders Index Series for four BRICS nations. Brazil, India, China, and South Africa, and the methodology included was the VARMA-GARCH Spillover Approach; spillover for the model was measured through residuals, for three BRICS economies. South Africa, China, and Brazil, the model variant used was VARMA (1,1) -GARCH (1,1), while for India, the variant VARMA (1,2)-GARCH (1,1) was considered under the study. The additional MA term for India was warranted to make a spillover model for India free from serial correlation. The study also tested for causality using Toda and Yamamoto (1995) modified 'F' causality. The model diagnostics considered for the study included ARCH effects, Serial Correlation, and Stationarity. The results showed limited unidirectional volatility spillover from India and China towards South Africa and again from India towards China, with no spillover seen amongst any other BRICS nations. Further, the results revealed unidirectional causality from India moving towards Brazil and China, with no other causality in the study. Further, ARCH and GARCH terms of all the countries in the volatility equation were added to <1, showing the tendency of shocks to die down over time.

Thus, the broad conclusion from the study is that if we leave aside one or two volatility spillovers towards South Africa, the integration through spillover and causality concerning ESG indices appears to be somewhat limited. The results, therefore, fail to provide any concrete evidence of any collective responsiveness of the four BRICS nations towards Green Finance. The study could only find limited evidence of causality across BRICS even though the study period also included the crisis period, i.e., the COVID-19 pandemic period. Such a result somewhat contrasts with another study on BRICS by Rehman et al. (2021), who could find a long-run relation (co-integration) amongst ESG indices to exist across BRICS during

this pandemic. Thus, this difference in results could be due to differences in the study period, sources of data, and tools applied, amongst others.

7 Implications and Scope for further research

The results of the study have varied implications. First, the limited evidence of spillover and also in cause-effect relation reveals that much-desired integration amongst BRICS concerning their ESG indices still has a long way to go, and BRICS are still not reinforcing each other as revealed by the independent movement shown by their respective ESG indices. Hence, it is suggested that BRICS work together more closely to monitor the progress of the existing goals as laid down in their meetings and take remedial action if things have gone out of track and are not in line with the collective vision of the BRICS towards Green Finance and Green Economy. Further, an essential step in this direction would be making a severe effort towards 'sustainable urbanization' as planned urbanization has been identified as one of the limiting factors in the majority of BRICS. This would imply shifting the growth centers from urban areas to villages and small towns, which again requires state intervention, which can alone disincentivize the starting of new businesses in big cities and provide incentives for the same in small towns and villages.

These results also impact investors and portfolio managers. The limited evidence of volatility spillover amongst BRICS ESG indices is seen as positive. It would help them construct a global portfolio of ESGs, which includes indices from different geographical locations. Such a portfolio, including ESG indices of many countries, including BRICS, is expected to have a lower risk due to global diversification than an ESG index from one country.

Finally, before we end, we would like to add some directions for future researchers interested in this area. Such researchers could compare the present study's results with those obtained by studying other regional blocs like EU, ASEAN, or QUAD. The researchers may extend this sample by adding new countries to the BRICS Block. Researchers can further employ some more alternate spillover tools like BEKK proposed by Engle and Kroner (1995) or Diebold & Yilmaz (2015) connectedness model in addition to the current spillover model given by Masson (1998) to study the relation. Further, besides data from MSCI, researchers can go for other alternative sources for ESG indices like Dow Jones ESG Indices, which are considered more rigid in their methodology, or they can make their study enjoyable by a comparative assessment of results obtained for ESG indices of BRICS by collecting data from both the sources; MSCI and Dow Jones and compare the results obtained on different parameters.

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