Market efficiency and Volatility persistence of green investments before and during COVID-19 pandemic

Yaya, OlaOluwa S and Akano, Rafiu O and Adekoya, Oluwasegun B.

University of Ibadan, University of Abuja, Federal University of Agriculture, Abeokuta

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OlaOluwa S. Yaya
Economic and Financial Statistics Unit, Department of Statistics, University of Ibadan, Ibadan, Nigeria &
Centre for Econometrics and Applied Research, Ibadan, Nigeria &
ILMA University Karachi, Pakistan
Email: os.yaya@ui.edu.ng

Rafiu O. Akano
Department of Statistics, University of Abuja, Abuja, Nigeria
Email address: rafiu.akano@uniabuja.edu.ng

Oluwasegun B. Adekoya
Department of Economics, Federal University of Agriculture, Abeokuta, Nigeria & ILMA University Karachi, Pakistan
Email address: adekoyaob@gmail.com

Abstract

Market efficiency and volatility persistence of five green investments, before and during the COVID-19 pandemic, are investigated by employing a nonlinear I(d) framework with Chebyshev polynomial in time. Results show that green investments are more efficient before the crisis, and also volatility persists more, when compared to the period during the crisis, except in MSCI global green building index. Thus, green investors are likely to make arbitrage profits during the pandemic.

Keywords: Green investment; volatility persistence; COVID-19 pandemic

JEL Classifications: C22, Q47

1. Introduction

Due to clamor for a low carbon economy to support friendly environmental projects in alleviating the negative effects of climate change, green investments were introduced and since 2007, their markets have grown from $0.8 billion to $257.7 billion in 2019 (Climate bonds initiative, 2019; Hammoudeh et al., 2020). The launch of "Principles of Green Bond" by the International Capital Markets Association (ICMA) in 2014 further created more awareness of green bonds and green stocks among scholars, investors, and policymakers. Green investments are known to be useful in rating a low carbon economy (Larcker and Watts, 2020), and reducing global coal consumption leading to low CO_2 emissions (Glomsrod and Wei, 2018). With a focus on a green environment leading to a more developed economy, green investments are expected to thrive well.

Green finance is a future-oriented type of finance that targets the financial industry by improving the environment, leading to economic growth. The current COVID-19 pandemic has affected global finance, quite more than the global financial crisis of 2008/09 with the market fearing more during the health crisis (Yaya, Gil-Alana, Vo, and Adekoya, 2021). The pandemic led to the further disentanglement of international financial markets which affected the level of market integration. Quite a number of papers has investigated the impact of the pandemic on financial markets (Salisu and Sikiru, 2020; Darjana, Wiryono and Koesrindartoto, 2022); on energy and oil (Narayan, 2020), among others. While there is a global concern for green finance for global economic growth, particularly how the current global health concern is imparting on the green investments.

The present paper, therefore investigated the level of market efficiency and persistence of green investments before and during the COVID-19 pandemic, using a 2-year daily data window in each case. While the determination of market efficiency will render useful information for market players in terms of the possibility of trading for excess gains (Gil-Alana, et al, 2018; Yaya, et al., 2021), the assessment of persistence will help policy makers to know how best to tackle market disruptions caused by a one-time shock in order to keep the green investment market in shape towards the fulfilment of its environmental sustainability objective. The fractional integration techniques were employed on the datasets to test for white noise hypothesis in prices and returns and as well test for persistence in absolute returns used as a proxy for volatility in the series. Thus, market efficiency in price series requires that price series are I(d = 1) as in the case of random walk, which further implies that the first series differences of price series (i.e. the log-returns) are I(d = 0). Evidence of market inefficiency thus means that I(d < 1) which is the case of long-range dependency of the series.

2. The I(d) model for testing market efficiency

Persistence analysis conducted in this paper is based on Cuestas and Gil-Alana's (2016) nonlinear I(d) framework. The authors introduced the Chebyshev polynomials in time to the fractionally integrated model of Robinson (1994) to form a non-linear deterministic test for testing non-linearity in I(d) processes. The set-up of the test is as follows: considering a general model,

$$y_t = f\left(\theta; z_t\right) + x_t, \quad t = 1, 2, \ldots \ , \tag{2}$$

where y_t is the observed time series and x_t follows an $I\left(d\right)$ process of the form as in (10), with $x_t = 0$ for $t \leq 0$, and $d > 0$, where L is the lag-operator $(Lx_t = x_{t-1})$ and u_t is $I\left(0\right)$ series. The function $f\left(.\right)$ is a non-linear function that depends on the unknown parameter vector of dimension m, θ, z_t which is a vector of deterministic terms. Then, re-writing (3) as,

$$y_t = \sum_{i=0}^{m} \theta_i P_{i,N}\left(t\right) + x_t, \quad t = 0, \pm 1, \ldots, \tag{3}$$

where the order of the Chebyshev polynomial is *m*. The Chebyshev polynomial $P_{i,N}(t)$ in (3) is defined as,

$$P_{i,N}(t) = \sqrt{2}\cos\left[i\pi(t-0.5)/N\right], \qquad t = 1,2,...,N; i = 1,2,..., \tag{4}$$

with $P_{0,N}(t) = 1$. From the polynomial, whenever $m = 0$, the model is expressed with an intercept only; if $m = 1$, it contains an intercept and a linear trend, and when $m > 1$, it becomes non-linear, and the higher *m* is the less linear the approximated deterministic component becomes. The choice of value for *m* then depends on the significance of the Chebyshev coefficients.

The non-linear deterministic approach of LRD by Chebyshev polynomials is a modification and improvement over Robinson's (1994) FI technique. Robinson (1994) considers the same setup as in (1) and (2) with $f(.)$ in (2) of the linear form, $\theta' z_t$, testing the null hypothesis,

$$H_0 : d = d_0, \tag{5}$$

for any real value d_0. Under H_0 and using the two equations,

$$y_t^* = \theta' z_t^* + u_t, \quad t = 1,2,..., \tag{6}$$

where $y_t^* = (1-L)^{d_0} y_t$ and $z_t^* = (1-L)^{d_0} z_t$. Then, given the linear nature of the above relationship and the $I(0)$ nature of the error term u_t, the coefficients in (6) can be estimated by standard Ordinary Least Square (OLS) or Generalized Least Squares (GLS) method. The same applies to the case of $f(.)$ containing the Chebyshev polynomials, noting that the relationship is linear in parameters. Thus, combining (1) and (3), we obtain,

$$y_t^* = \sum_{i=0}^{m} \theta_i P_{i,N}^*(t) + u_t, \quad t = 0, \pm 1, \ldots, \tag{7}$$

where $P_{i,N}^*(t) = (1-L)^{d_0} P_{i,N}(t)$, and using OLS/GLS methods, under the null hypothesis in (5), the residuals $\hat{u}_t$ are,

$$\hat{u}_t = y_t^* - \sum_{i=0}^{m} \theta_i P_{i,N}^*(t); \ \hat{\theta} = \left(\sum_{t=1}^{N} P_t P_t' \right)^{-1} \left(\sum_{t=1}^{N} P_t y_t^* \right), \tag{8}$$

and P_t is the $(m \times 1)$ vector of Chebyshev polynomials. Based on the above residuals $\hat{u}_t$, we estimate the variance,

$$\hat{\sigma}^2(\tau) = \frac{2\pi}{N} \sum_{j=1}^{N} g(\lambda_j; \hat{\tau})^{-1} I_{\hat{u}}(\lambda_j); \quad \lambda_j = \frac{2\pi j}{N}, \tag{9}$$

where $I_{\hat{u}}(\lambda_j)$ is the periodogram of $\hat{u}_t$; g is a function related to the spectral density function of u_t; and the nuisance parameter τ is estimated by $\hat{\tau} = \arg\min_{\tau \in N^*} \sigma^2(\tau)$, where N^* is a suitable subset of the R^q Euclidean space.

3. Data and Empirical Results

Daily data on green investments were obtained from Datastream. We considered a 2-year data window before the COVID-19 pandemic World Health Organization (WHO) date of 11 March 2020, and another 2-year data window after this date. Thus, the entire sample analyzed spans 1 March 2018 to 13 January 2022. Five indices of green investments, i.e. bonds and stocks were analyzed. The green bonds indices are the Standards and Poors (S&P) Green bond select index (SPGRSLL), and the S&P Green bond index (SPGRBND)), while the green stock indices are the Morgan Stanley Capital International (MSCI) global alternative energy index (MSGLAEL), MSCI global pollution prevention index (MSGLPPL), and the MSCI global green building index (MSGLGBL). The MSCI indices for green investments take up about half of the revenue from securities on environmental-friendly projects such as those of green building, alternative energy, clean water, or pollution prevention. Thus, the five variables analyzed in this paper represent global green investments.

Plots of prices of these green investments are given in Figure 1 with the corresponding log-returns superimposed. The green assets are seen to exhibit significant volatility in both prices and returns, with stronger evidence since 2020. The relative stable trend enjoyed by the assets at the beginning of the sampled period became halted with a sharp drop in their prices around the first quarter of 2020, coinciding with the period when the news about the outbreak of the pandemic seemed to be reaching the peak (Umar et al., 2021).

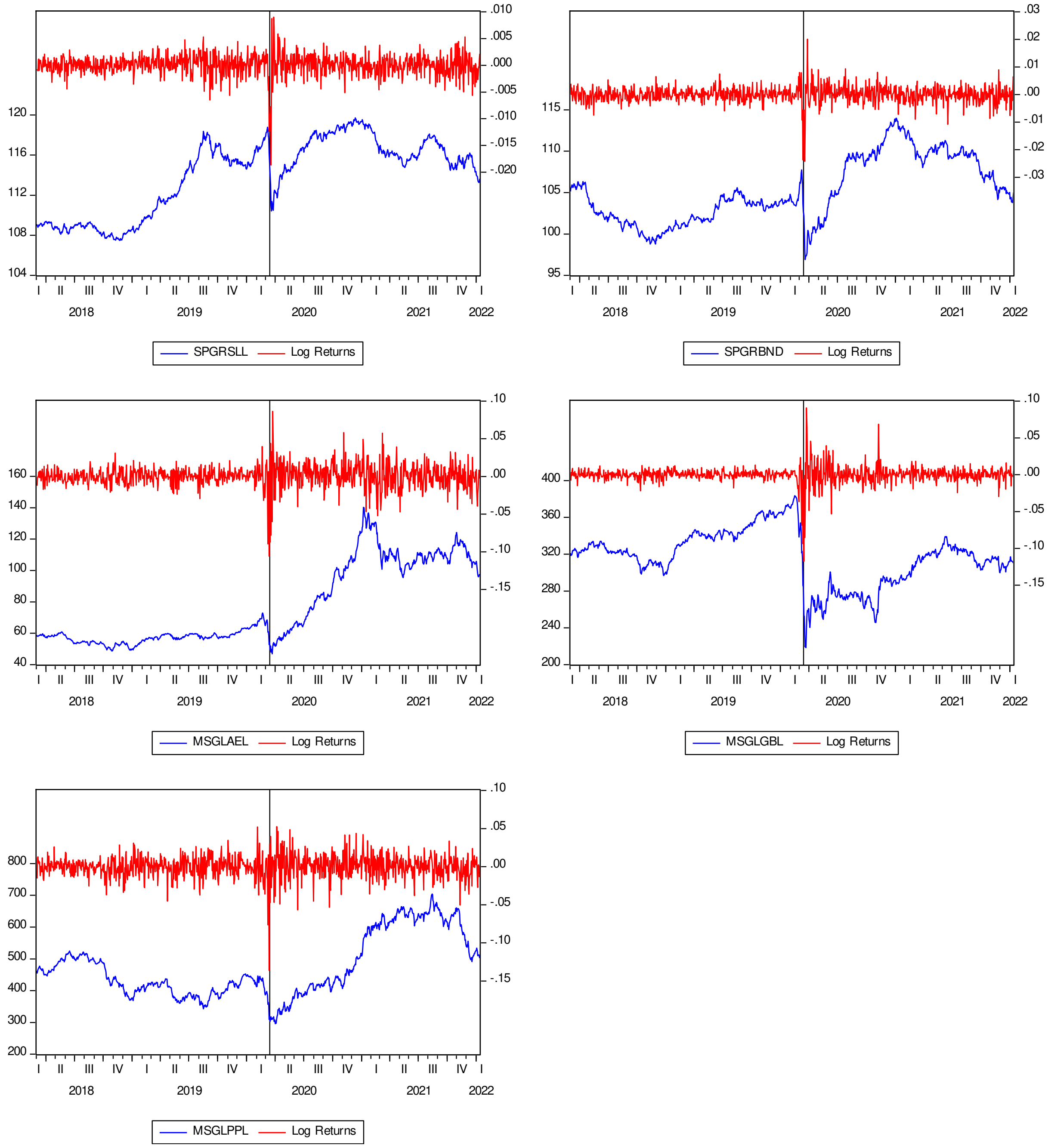

Figure 1: Plots of price and log-returns of Green investments

We start the main results with the logged prices, as reported in Table 1. the *d* estimates for both green bonds indices, SPGRSLL (1.0117) and SPGRBND (0.9943), are not significantly different from unity before the COVID-19 pandemic, implying that the null hypothesis of random walk, which is consequently associated with market efficiency, cannot be rejected. This is unlike other green assets whose *d* estimates exceed one. During the pandemic, however, the green bonds market tends to lose its efficiency, in favour of persistence, following an increase in the *d* estimates of both green bonds indices beyond the region of $d = 1$. Other green assets still maintain their initial status, except the global green building index (MSGLGBL) which is now demonstrating a random walk, given its *d* estimate to be 1.0123.

Table 1: Results of I(d) based on Chebyshev polynomial in time

Before COVID-19 pandemic					
Series	*d* (95% CI)	*c*	cos 1	cos 2	cos 3
SPGRSLL	**1.0117** (0.9409, 1.0825)	5.2709 (0.246)	**-3.0474 (-2.22)**	0.9282 (1.37)	0.7049 (1.57)
SPGRBND	**0.9943** (0.9149, 1.0737)	51.2094 (0.140)	-0.2556 (-0.175)	**1.3346 (1.82)**	**1.1062 (2.25)**
MSGLAEL	**1.0687** (0.9928, 1.1446)	6.6794 (0.616)	-1.8597 (-0.374)	1.7043 (0.743)	0.9613 (0.646)
MSGLPPL	**1.0732** (0.9942, 1.1522)	0.7738 (0.022)	-13.7793 (-0.786)	8.4307 (1.05)	2.5816 (0.495)
MSGLGBL	**1.0773** (1.0003, 1.1543)	-0.4082 (-0.004)	31.4861 (0.589)	19.4720 (0.780)	-12.8924 (-0.803)
During COVID-19 pandemic					
Series	*d* (95% CI)	*c*	cos 1	cos 2	cos 3
SPGRSLL	**1.0551** (0.9740, 1.1362)	31.2183 (1.57)	-1.3711 (-0.587)	-1.6601 (-1.53)	**-1.3421 (-1.89)**
SPGRBND	**1.1017** (1.1025, 1.1909)	19.0211 (-0.650)	-2.7753 (-0.650)	**-3.5621 (-1.88)**	-1.2852 (-1.06)
MSGLAEL	**1.0884** (1.0073, 1.1695)	0.7857 (0.212)	-14.9441 (-0.761)	-10.9694 (-1.24)	-5.4803 (-0.962)
MSGLPPL	**1.0643** (0.9779, 1.1505)	233.903 (1.57)	-32.8907 (-0.897)	-10.2176 (-0.593)	3.0883 (0.276)
MSGLGBL	**1.0123** (0.9660, 1.1086)	**-390.537 (42.8)**	-95.7030 (-1.62)	-42.8160 (-1.49)	24.8326 (1.30)

Note, significant parameter estimates of d and Chebyshev polynomial at 5% level are in bold

We turn to the results of the log-returns and volatility (absolute returns) next. The consideration of volatility persistence is an extension to the conventional weak-form efficiency hypothesis that merely relies on the asset prices or returns. Volatility persistence is important in determining how long-lasting the effect of shocks that increase the riskiness of a financial asset would be. As shown in Tables 2 and 3 for the log-returns and volatility results, respectively, the significance of the fractional parameter, *d*, tends to vary for some assets both across the series (returns and volatility) and periods (before and during the pandemic). Nonetheless, significance is established in most cases, and there is clear evidence that the estimates of *d* fall in the $0<d<0.5$ range. This suggests that the green assets' returns and volatilities demonstrate long memory and mean-reverting feature. Therefore, the effect of shocks will only be transitory, dying out in no distant time. Besides, the values of *d* seem to be greater during the pandemic, as an indication that the rate at which it will die out will be slower in this period. This is consistent with the report of Adekoya et al. (2021) that the green bond market shows evidence of stronger persistence during the pandemic. One probable reason for this is that, apart from the pandemic affecting the individual financial market, it resulted in significant risk transmissions, induced high fear and pessimism in investors (Umar et al., 2021), and erratic speculative behaviour. Based on these factors, adjusting to a normal market state could require a longer recovery time.

Table 2: Results of persistence of Log-returns based on Robinson (1994) linear models

Before COVID-19 pandemic			
Series	*d* (95% CI)	*c*	*t*
SPGRSLL	0.0352 (-0.0314, 0.1018)	-0.0066 (-0.948)	2.60E-05 (0.993)
SPGRBND	0.0211 (-0.0526, 0.0948)	-0.0097 (-1.12)	3.79E-05 (1.20)
MSGLAEL	**0.0687** (-0.0087, 0.1461)	-0.0549 (-1.23)	0.0002 (1.46)
MSGLPPL	**0.0721** (-0.0057, 0.1499)	-0.0198 (-0.741)	7.91E-05 (0.883)
MSGLGBL	**0.0825** (0.0070, 0.1580)	-0.0162 (-0.239)	6.87E-05 (0.306)
During COVID-19 pandemic			
Series	*d* (95% CI)	*c*	*t*
SPGRSLL	**0.1485** (0.0646, 0.2324)	-0.0030 (-0.163)	-1.97E-05 (-0.0311)
SPGRBND	**0.1762** (0.0872, 0.2652)	-0.0012 (-0.038)	-1.60E-05 (-0.150)
MSGLAEL	**0.0155** (-0.0609, 0.0919)	0.1539 (2.00)	-0.0006 (-2.32)

MSGLPPL	**0.1281** (0.0379, 0.2183)	-0.0432 (-0.416)	0.0001 (0.372)
MSGLGBL	-0.0197 (-0.0956, 0.0562)	0.1389 (2.42)	-0.0006 (-2.75)

Note, significant parameter estimates of d are in bold

Table 3: Results on absolute returns

Before COVID-19 pandemic			
Series	*d* (95% CI)	*c*	*t*
SPGRSLL	**0.0986** (0.0318, 0.1654)	-0.0202 (-3.45)	8.03E-05 (3.65)
SPGRBND	0.0325 (-0.0371, 0.1021)	0.0057 (1.06)	-2.17E-05 (-1.02)
MSGLAEL	**0.1418** (0.0742, 0.2094)	0.0044 (0.110)	-1.86E-05 (-0.143)
MSGLPPL	**0.0647** (-0.0029, 0.1323)	0.0162 (0.959)	-6.34E-05 (-1.10)
MSGLGBL	**0.1145** (0.0473, 0.1817)	-0.0974 (-1.91)	0.0004 (2.33)
During COVID-19 pandemic			
Series	*d* (95% CI)	*c*	*t*
SPGRSLL	**0.2539** (0.1871, 0.3207)	0.0566 (2.61)	-0.0002 (-2.35)
SPGRBND	**0.1687** (0.0966, 0.2408)	0.0489 (2.23)	-0.0002 (-2.22)
MSGLAEL	**0.1615** (0.0935, 0.2295)	0.2232 (2.14)	-0.0008 (-2.26)
MSGLPPL	**0.1895** (0.1264, 0.2526)	0.4445 (4.28)	-0.0016 (-4.70)
MSGLGBL	0.0480 (-0.0173, 0.1133)	0.1624 (3.13)	-0.0007 (-3.56)

Note, significant parameter estimates of d are in bold

4. Conclusion

This study puts the market efficiency and volatility of green investments into consideration before and after the COVID-19 pandemic. Using the fractional integration methods, we find that the green bonds market which was efficient before the pandemic demonstrates inefficiency during the crisis. However, other green markets are inefficient in both periods, except

MSGLGBL. In addition, the green assets' returns and volatilities are found to observe mean-reverting behaviour, indicating that the effect of shocks will be temporary, although will die out more slowly during the health crisis.

Green investors can glean from these findings that they can make abnormal profits following the inefficient states of the markets, except in the case of green bonds during tranquil periods. However, they should be aware that any shock that adversely affects returns during a similar crisis will have a relatively slower time of disappearance unlike when the market is normal.

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