



Journal of Economics and Financial Analysis

Type: Double Blind Peer Reviewed Scientific Journal

Printed ISSN: 2521-6627 | Online ISSN: 2521-6619

Publisher: Tripal Publishing House | DOI:10.1991/jefa.v6i1.a51

Received: 18.07.2022 | Accepted: 08.08.2022 | Published: 08.08.2022

Journal homepage: ojs.tripaledu.com/jefa



The COVID-19 Crisis and Interaction between the JSE, Real Estate, Energy, Commodity and Cryptocurrency Markets

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Abstract

This paper examines the long-run interactions between South African stock (JSE) and real estate markets, with global asset markets such as oil, gold, platinum, and cryptocurrency markets during pre-Covid-19 tranquil period and during Covid-19 pandemic period comparatively using cointegration, causality and structural break tests. Findings of the paper shed light on the fact that cointegrations relationships between Bitcoin - JSE, Oil - JSE, and Real Estate – JSE were significant during pre-Covid period, while these significances weakened or disappeared during Covid period. On the other hand, cointegration relations show up between Oil – Platinum market and Gold – Real Estate market. It implies that JSE became volatile during Covid period comparing to Oil, Platinum, Gold markets in South Africa.

Keywords: *COVID-19 Crisis; South African Markets; Commodities; Cryptocurrency; Cointegration.*

JEL Classification: *C12, C5, G1, G15, G32, R3.*

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1. Introduction

The COVID-19 pandemic has left the world in shock, disarray, and in a state of a global crisis. Perhaps this is largely due to its unprecedented and unanticipated nature that has caught and exposed our level of unpreparedness for a global pandemic as a global community. Originating from Wuhan in China, the SARS-CoV-2 also known as the coronavirus was initially underestimated and it is allegedly believed to have emerged from the Wuhan wet market in the Wuhan area, Hubei province of China around the December of 2019. On the 11th of March 2020, the World Health Organisation (WHO) officially declared the COVID-19 as a pandemic. As expected, this declaration threw the world into a frantic state of confusion as the last global pandemic – the Spanish flu, was about a century ago. As of July 2021, the world is still grappling with the COVID-19 pandemic. This almost two-year combat has witnessed several unfamiliar combative strategies such as mask-wearing, social distancing, use of hand sanitiser, elbow greetings, quarantines, contact tracing, different levels of lockdowns and more recently mass vaccination programs. Despite these measures, the world has recorded over 196, 937,540 cases as well as over 4 million human fatalities in the fight against coronavirus.

Whilst it is much easier to record cases and human lives lost to the pandemic, the scourge of the pandemic has also adversely affected jobs, livelihoods, the global economy as well as the financial system (Roy, 2020; Dvorak et al., 2020). From the perspective of the financial system, particularly the financial markets, the COVID-19 pandemic, and its consequences have caused negative disruptions in business operations and the performance (Cepoi, 2020; Shaikh, 2021). This is because of drastic measures such as lockdowns, and travel bans that have adversely impacted both the supply and demand sides of business functioning. As a result of this, several investors in the financial markets have sought to hedge and maximise their investments by diversifying and rebalancing their portfolio with investment options from asset markets such as traditional and alternative markets that offer distinct assets (Corbet et al., 2020; Ji et al., 2020).

At times of financial and economic crisis such as the COVID-19 crisis, understanding the linkages among asset markets is critical for diverse financial-economic reasons and investment decisions. Notably, having insights on the co-movement of different asset types can improve portfolio performance during periods of economic downturns through cross-asset diversification (Ji et al., 2020). This form of diversification which is a popular risk hedging strategy among investors and portfolio managers, have been proven to be an optimal strategy that can maximise overall portfolio return performance whilst minimising the

downside risk exposures in vulnerable asset markets (Mensi et al., 2019; Jiang et al., 2019). Furthermore, an in-depth understanding of interrelationships among broad asset classes during uncertain periods like financial-economic downturns is crucial to demystifying any embedded systemic risks associated to these markets, informing swift economic recovery plans and the effective stabilisation of the overall international financial markets (Mensi et al., 2021).

Thus, an understanding of the linkages among asset markets such as stocks, real estate, cryptocurrencies, and commodities markets before and during the COVID-19 periods is novel, relevant and contributes immensely to the literature on asset pricing, financial markets, commodities markets, economic crisis and COVID-19 pandemic. The contributions of this research paper are particularly useful for investment strategy, portfolio diversification, risk management and financial-economic decisions by industry professionals, policymakers and academics. This is because we believe that the results of this study will provide insights on diversification opportunities among several financial assets during the financial crisis. More specifically, our study hopes to provide insights on how asset markets can provide an opportunity to hedge for unanticipated shocks/crises in the future.

2. Empirical Literature

Studies on asset markets co-movements and spill over effects have proven beneficial to policy makers, investors, and asset managers for diverse reasons such as portfolio allocation, diversification, risk hedging and policy formulations, especially during times of crises and uncertainties. For instance, in an inquiry on volatility spill over among commodities and financial assets during the COVID-19 crisis, Adekoya and Oliyide (2021) noted that there is strong volatility across both markets, as gold and USD were the net receivers of the macro-economic shocks. This finding implies that during times of crisis such as the COVID-19 pandemic, there is an observable spill over connectedness between the financial and commodity markets. To further understand the interconnectedness of asset markets in the purview of hedging, spill overs and diversification, this research extensively reviewed recent literatures based on bivariate relationships between the asset markets.

On the possible relationship between the stock and oil markets, several regional studies have found a positive relationship between the two asset markets. For instance, Ghosh and Kanjilal (2016) found that there is a relationship between the international oil market and the Indian stock market. This implies that a change in crude oil price has a positive effect on the Indian stock market price during the global financial crisis period. Tursoy and Faisal (2018) noted that while there is a negative relationship between prices of

gold and Turkish stocks, there is an empirically observable positive relationship between the oil prices and stock prices in Turkey. This implies that gold offers a better hedging opportunity against such stock market volatility than crude oil. Similarly, Wei et al. (2019) observed that there is a connection between the Chinese stock market and the crude oil futures market. It was further revealed that in the post-global financial crisis period, the exchange rate market played a significant role in driving the interconnectedness between oil gains and the Chinese stock market's rebound. This indicates that there is a positive relationship between the Chinese stock market and the crude oil market.

Several studies have considered the relationship between the stock market and the real estate market. Abul (2019) found that there is a positive association between the real estate market and the stock market in Kuwait. This implies that prices of real estate sector stocks, specifically for multi-apartment tend to move in the same direction with the Kuwaiti stock market index. Gokmenoglu and Hesami (2019) assert that there are no diversification benefits from the combination of German stocks and real estate assets in a portfolio. This was noted in the connectedness between residential real estate and the stock market index in Germany. Yousaf and Ali (2020) found that there is cointegration between the Pakistani stock market index and its real estate market. While this finding implies that the Pakistani real estate stocks and its index stocks are positively correlated and can serve as alternative substitutes, it however indicates that this eliminates any potential diversification benefits.

In recent times, some international studies have inquired on the relationship between the stock market and precious metals markets. Using a panel cointegration analysis, Tuna (2019) noted that while gold and palladium are negatively cointegrated with selected Islamic stock markets, other precious metals such as platinum and silver are positively cointegrated with the stock market. These findings further indicate that in the context of risk hedging and diversification, precious metals such as gold and palladium have proven benefits in comparison to metals such as platinum and silver. Lahiani et al (2021) assert that despite an observable causal relationship between the S&P 500 stock market index and precious metals, it is largely unlikely that precious metals can act as a safe haven for the index market in the long run. While the study found no long run relationship between the S&P 500 stock market index and precious metals, in the short term, symmetric effects were noted between the market index and precious metals such as platinum, gold, copper and pallidum. Uddin et al (2020) found that during extreme market volatility, there is a weak spillover between gold and the stock market. This was observed based on symmetric comovement between gold and the S&P 500 stock market index volatile scenarios, in contrast to asymmetric tail dependence between the stock market and precious metals such as platinum and silver during market downturns. The implication of this is that gold can be used as a portfolio diversifier for equities.

Likewise, some studies have considered the relationship between the stock market and the cryptocurrency market. Gil-Alana et al. (2020) found no evidence of cointegration between a set of cryptocurrencies and American stock market indices. This finding suggests that cryptocurrencies are decoupled from traditional financial assets and therefore have potential diversification benefits for portfolio optimisation and risk hedging. Caferra and Vidal-Tomas (2021) noted that there is a weak correlation between cryptocurrencies and the stock market indices in America and Europe during the COVID 19 pandemic. This weak co-movement implies that cryptocurrencies have inherent risk hedging properties during market turmoil and can be used for diversifying American and European-based equity portfolios. Wang et al. (2021) asserts that cryptocurrencies could be a plausible barometer for determining the direction of technology stocks. This finding was noted in a study that evaluated the relationship between cryptocurrencies such as Bitcoin and Ethereum, and US market indices such as S&P 500 Index, Dow Jones Industrial Average Index and NASDAQ-100 Index.

A few studies have investigated the possible relationship between the real estate market and precious metal markets. Raza et al. (2018) found that gold can effectively serve as the best hedge for American real estate stocks in both the short and long run time horizons. This empirical fact was established that the effectiveness of gold's hedging potential can be seen from the perspective that it remains the best hedge against inflation risks in the long term and can hence preserve the value of portfolio assets. Chen and Tongurai (2021) discovered that there is a positive association between the Chinese real estate market and precious metal futures in both the short and long run time periods. This implies that prices of precious metals are positively linked to the performance of the Chinese real estate market.

Similarly, some studies have questioned the association between the real estate market and energy markets. For instance, Nazlioglu et al. (2016) found co-movement interactions between the American Real Estate Investment Trusts (REITs) and West Texas Intermediate (WTI) futures. Except for mortgage REITs, empirical evidence suggests a positive linkage between other sector-specific REITs and the oil market. This implies that there is a negative relationship between the unique underlying assets of mortgage REITs and the energy market. Chau and Zou (2018) observed that energy prices in China are largely influenced by a boom in the Chinese commercial real estate market. This finding was noted based on an observable asymmetric co-movement between oil prices and demand for industrial real estate. This implies that energy is a crucial input that could affect industrial production and ultimately industrial output. Alola (2021) observed positive linkages between the Saudi Arabian Real Estate market and the Brent crude oil during the 2017-2018 Global Financial Crisis periods. The findings indicate that the Saudi Arabia real estate market is susceptible to oil market volatilities.

Empirical curiosities have further inspired the investigation between oil and cryptocurrency markets linkages. For example, Okorie and Lin (2020) found evidence of both unidirectional and bidirectional volatility spillovers between the crude oil market and the cryptocurrency market. This finding implies that investors and portfolio managers can optimise a portfolio of energy-related investments via the inclusion of cryptocurrency assets. Ji et al. (2019) noted weak interconnectedness between major cryptocurrency assets such as Bitcoin, Ethereum, Ripple and the energy market. The findings of this study negate the notion that the performance of cryptocurrencies is influenced by the performance of energy market, and further implies that notable cryptocurrencies can offer diversification and hedging potentials for energy/oil investments. Yin et al. (2021) asserts that cryptocurrencies can act as a hedge for the oil market during times of crisis and uncertainties. This assertion was based on the observation that adverse shocks in oil market tend to improve the attractiveness of cryptocurrencies.

Based on the summary of the recent empirical literature on linkages between asset markets, it is evident that there are no recent studies that have considered asset market cointegration from the perspective of African financial markets. More specifically, hitherto there is yet a scientific study on the cointegration of South African markets with other asset markets during the COVID-19 pandemic crisis.

3. Research Methodology

Hitherto, just a few studies have considered linkages among precious metals during times of economic crisis using cointegration techniques with regard to the impact of structural breaks. However, this study utilized three types of tests. These tests are; the conventional Johansen test (Johansen, 1991), the recursive Johansen test, and the Gregory-Hansen test (Gregory and Hansen, 1996). Whilst the recursive Johansen test shows how the cointegration relationship has changed over the duration under consideration, the Gregory-Hansen test evaluates the endogenous structural break in the time series data and further tests for the presence and impact of structural breaks in identified cointegrated relationships.

3.1. Data and Model

Firstly, stationarity tests were performed on the prices of all the data sets considered for the purpose of this study. This was done using unit root tests such as the Augmented Dickey-Fuller (ADF), Philips-Perron (PP), KPSS, and the Zivot Andrews tests (Nielsen, 2019; Vishwas and Patel, 2020). In addition to this, we also included the lagged augmentation terms in our stationarity tests. In the instance when the dataset for the study is not

stationary, it would be necessary to consider models that accommodate non-stationarity dataset. The proposed model should ideally be a multivariate model as we examine co-movement among the different asset markets using cointegration techniques (Aruga and Kannan, 2020).

Thus, based on these criteria, the following models were developed a Johansen test using a Vector Error Correction Model (VECM), as well as a Gregory-Hansen cointegration test model.

Application of the Cointegration models

The idea of cointegration is the following – the linear combination of non-stationary time series can be integrated. In other words, the time series may have long-run relationships, which can be determined using the VECM approach. Firstly, the VECM approach assumes that cointegration may exist in pair of assets, and the lag order can be determined using either the Bayesian Information Criterion (BIC) or Schwarz information criterion (SIC). Furthermore, the cointegration rankings are estimated using the Johansen tests statistics: trace test and maximum-eigenvalue statistics, and the subsequent causality checks are performed using the Toda-Yamamoto Granger causality test. Thereafter, tests for possible structural breaks were conducted using the Gregory-Hansen model.

The Johansen Test using a Vector Error Correction Model (VECM)

The primary objective of this study was to understand co-movements among the selected asset markets for the purpose of risk hedging and diversification. To achieve this objective, the Johansen test model using a Vector Error Correction Model (VECM) was adopted. The Vector Error Correction Model (VECM) is an extension of vector autoregressive model (VAR) which allowed to work as an integrated time series, such as a special class of non-stationary process (Johansen, 1991; Aruga and Kannan, 2020). The model is expressed in the equation below:

$$\Delta P_t = \pi P_{t-1} + \sum_{i=1}^{n-1} \Gamma_i \Delta P_{t-1} + \gamma_0 + \varepsilon_t, \quad t = 1, \dots, T,$$

where T is number of observations,

P_t is a vector for each fixed t , $P_t \in \mathbb{R}^k$, $k \geq 1$ (k is number of assets),

π – is matrix, $\pi \in \mathbb{R}^{k \times r}$, where r is cointegrating rank, $0 \leq r \leq k$,

Γ_i – is sequence of matrices, $\Gamma_i \in \mathbb{R}^{k \times k}$,

n – number of lags, $n < T$, rule of thumbs,

γ_0 – is a fixed vector, intercept, $\gamma_0 \in \mathbb{R}^k$,

ε_t – is white noise, $\varepsilon_t \in \mathbb{R}^k$ for fixed t and $\varepsilon_t \sim I(0)$.

Furthermore, the recursive Johansen cointegration test is performed by estimating the Johansen trace test over an initial sample. This is due to the limitation of the conventional Gregory-Hansen cointegration test to continuously trace cointegration structural breakpoints among the asset markets in the long run. Hence, this research paper adopts the recursive cointegration test to observe and continuously trace the dynamic co-movements among the asset markets (Mei-Se et al., 2018).

In the context of this study, the initial sample is represented as the period between the (01/05/2015 – 31/12/2019). Subsequently, additional data observations are added to this base sample, and each trace statistic is recursively re-estimated at each iteration until the final sample period of (01/05/2015 – 28/04/2021). The estimation is done using the Python Programming language Version 3, and the results of the analysis are further plotted and depicted graphically.

The Toda-Yamamoto Granger Causality Test

The causality test is a test that is relevant for identifying price causalities among different time series prices such as stocks, real estate, cryptocurrencies, and commodities markets (Toda and Yamamoto, 1995). The adoption of the modified Granger causality test is useful as there is no need to difference the price series by using the $k + d$ lags in the vector autoregressive model (VAR), in the context of this study, while k represents the optimal number of lags in the model, d represents the maximal order of integration (Aruga and Kannan, 2020). We further indicated the order of k by the Schwarz Information Criterion and d was defined based on the Johansen cointegration test.

The Gregory-Hansen Cointegration Test

As sequel to the achievement of the primary objective of this study, this study further seeks to investigate the presence of possible structural breaks in the cointegrated asset markets using the Gregory-Hansen test model. The Gregory-Hansen test model is a multivariate model which allows the model to incorporate into cointegration test structural changes, such as a model with level shift with trend (Gregory and Hansen, 1996; Aruga and Kannan, 2020). The model is expressed in the equation below:

$$Y_1(t) = \alpha_1 + \alpha_2 \phi_{tt} + \beta_1 t + \beta_2 Y_2(t) + e_t, \quad t = 1, \dots, T,$$

Where:

$Y_1(t)$ and $Y_2(t)$ are 2 multivariate processes, $Y_1(t), Y_2(t) \in \mathbb{R}^k$ and $Y_1(t), Y_2(t) \sim I(1)$

Whereby:

1. $\alpha_1, \alpha_2, \beta_1$ are fixed vectors, $\alpha_1, \alpha_2, \beta_1 \in \mathbb{R}^k$
2. $\beta_1 t$ – is deterministic trend

$$\phi_{t\tau} = \begin{cases} 0, & \text{if } t \leq [T\tau] \\ 1, & \text{if } t > [T\tau] \end{cases}$$

for any real value a , $[a]$ is integer part of the value a , $\tau \in (0,1)$.

β_2 is matrix, $\beta_2 \in \mathbb{R}^{k \times k}$

e_t is white noise, $e_t \sim I(0)$.

To effectively understand the relationships among real estate, stocks, oil and the precious metals markets, the applicable cointegration tests were considered over three study periods. The first study period covers the entire period of the study (01/01/2015 – 28/04/2021). The second study period considers the “before COVID-19” period of the study (01/01/2015 – 31/12/2020). Lastly, the study period covers the “After COVID-19” period of the study (01/01/2020 – 28/04/2021), signaling the timeframe where COVID-19 became a “buzzword” in the global community. The motive for splitting of the dataset into three study periods is to evaluate the comparative linkages among asset markets whilst assessing the performance of the asset markets in each defined period of study.

Also, this research inquiry utilised daily market data for all the assets considered. To actualise this, the study computed the daily closing prices for each asset market proxy. Whilst the study sought to evaluate linkages between the stock market, property market, cryptocurrency market and the commodity market, the assets representative of these markets were the South African stock index (JSE ALSI), South African listed property index, bitcoin, Brent crude oil, gold and platinum. The relevant datasets for this study were obtained from financial databases such as McGregor BFA, Quandl and Yahoo Finance.

4. Results and Discussions

4.1. Descriptive Analysis and Diagnostic Checks

Initially, we check for normality of the datasets. To do this, we conducted the relevant descriptive and diagnostic checks using the theoretical quantiles of the normal distribution. Figure 1 and 2 show that data appears distributed normally.



Figure 1. Logarithmic Scale of the Data

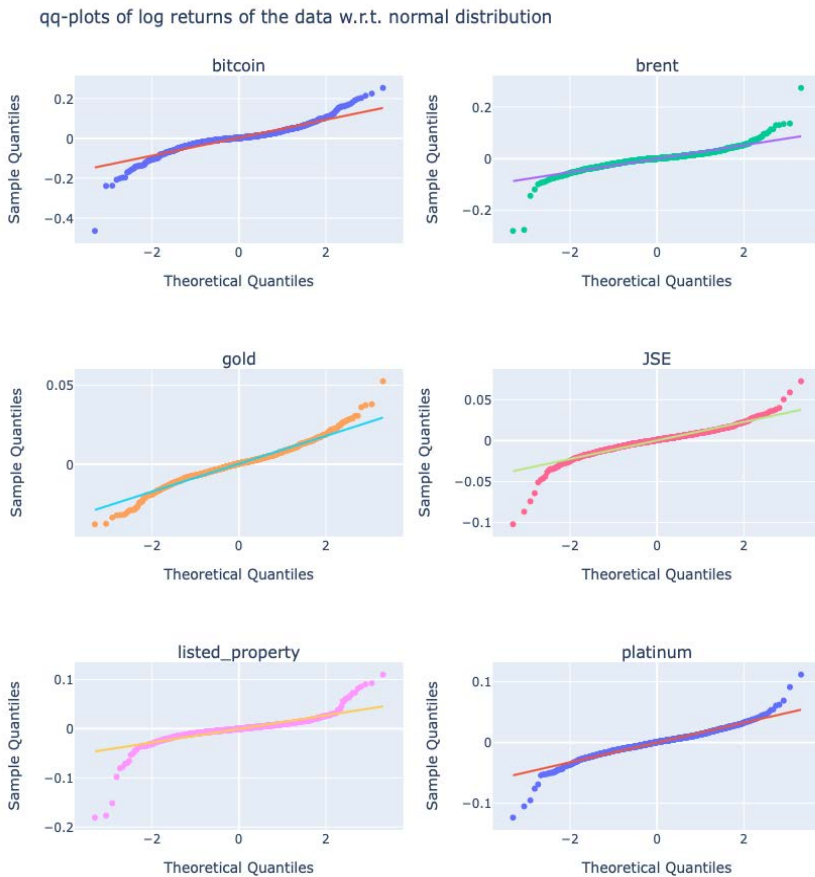


Figure 2. QQ-plot of the Data

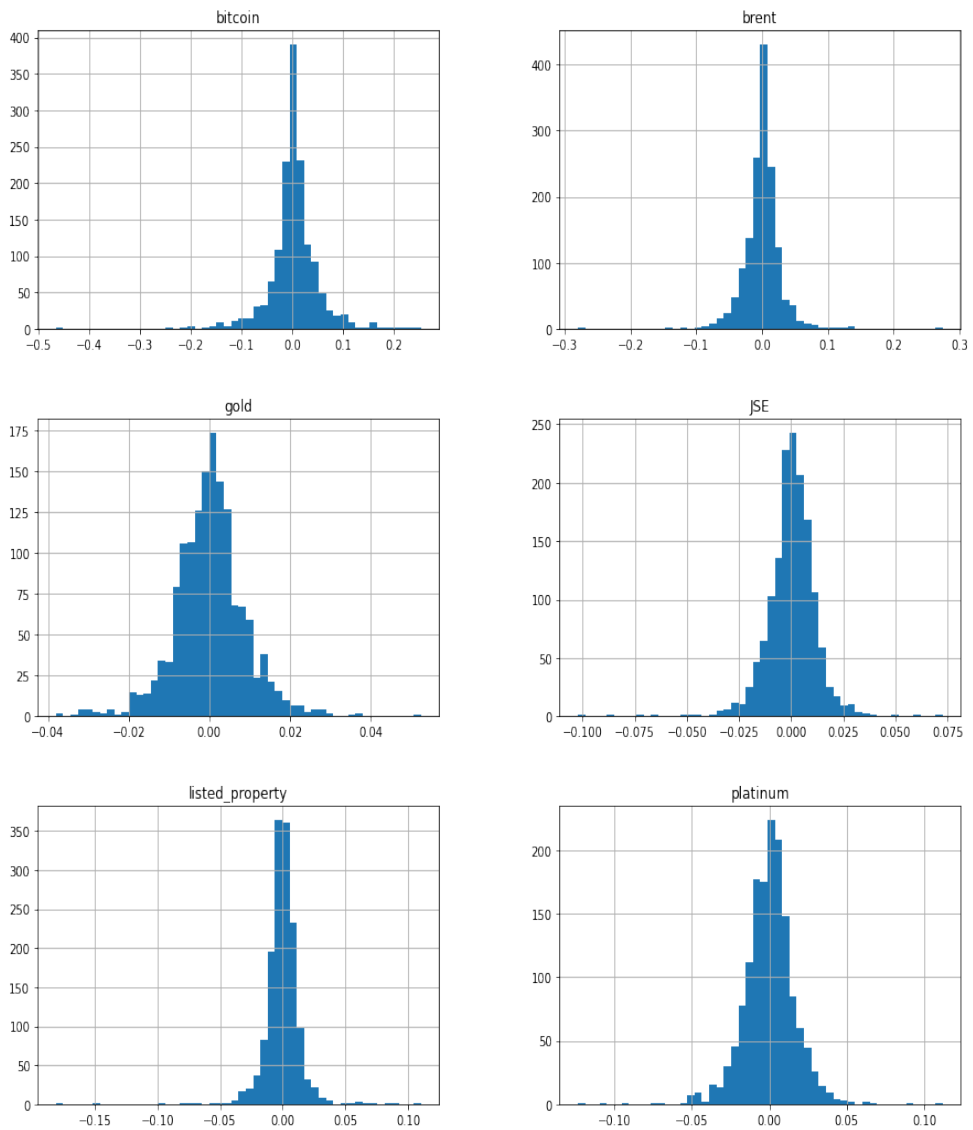


Figure 3. Graphical Illustration of the Data Distribution

Figure 3 shows empirical distributions of the log returns. As it can be seen, all distributions have fat tails. Shapiro-Wilks test reject the null hypothesis that data samples are normal with 99% significance level.

As seen in Figure 1, all assets (bitcoin, Brent crude oil, gold, stock index, listed property index and platinum) are graphically represented. As seen in Figure 2, the normal QQ-plot of the data evidence that all financial data are not normal, as there is no evidence of log-

price increments. Subsequently, the logarithmic returns distribution was calculated for all datasets to convert the financial dataset to a normal distribution. This is depicted in Figure 3. Hence, taking the logarithm of the prices allow reducing volatility.

4.2. Unit Root and Stationarity Tests

Prior to specifying the model, we shall check for healthiness of the data as well as their orders of integration. Thus, we pursue multiple stationarity tests such as Augmented Dickey Fuller (ADF), Phillips Perron (PP), KPSS as well as the Zivot Andrews test.

Table 1. Unit Root Tests

	Level				First difference			
	ADF	PP	KPSS	ZA	ADF	PP	KPSS	ZA
Entire period (2015:01 – 2021:04)								
BITCOIN	-1.58	-1.58	16.81	-2.84	-39.01***	-39.01***	0.13***	-39.60***
OIL	-2.29	-2.29	12.92	-4.66	-38.98***	-38.98***	0.06***	-39.37***
GOLD	-2.16	-2.16	21.25	-3.67	-38.28***	-38.28***	0.04***	-38.45***
JSE ALSI	-3.22*	-3.22*	4.02	-6.16***	-40.00***	-40.00***	0.04***	-40.46***
L.PROPERTY	-2.10	-2.10	26.08	-5.13**	-35.80***	-35.80***	0.08***	-36.21***
PLATINUM	-2.42	-2.42	11.15	-4.86*	-38.33***	-38.33***	0.03***	-38.53***
Before COVID - 19 occurrence (2015:01 – 2019:12)								
BITCOIN	-1.23	-1.23	14.05	-3.84	-34.09***	-34.09***	0.16***	-34.68***
OIL	-2.60	-2.60	8.68	-3.78	-38.35***	-38.35***	0.05***	-38.84***
GOLD	-2.28	-2.28	4.26	-3.80	-35.72***	-35.72***	0.04***	-35.86***
JSE ALSI	-3.97**	-3.97**	5.28	-5.23**	-35.22***	-35.22***	0.02***	-35.33***
L.PROPERTY	-2.69	-2.69	21.56	-6.62***	-33.70***	-33.70***	0.02***	-33.92***
PLATINUM	-2.44	-2.44	7.56	-4.57	-33.25***	-33.28***	0.03***	-33.91***
After COVID - 19 occurrence (2020:01 – 2021:04)								
BITCOIN	-1.49	-1.49	6.20	-3.02	-18.90***	-18.90***	0.06***	-19.95***
OIL	-2.32	-2.32	3.43	-4.87*	-15.92***	-15.92***	0.09***	-16.79***
GOLD	-1.68	-1.68	6.21	-5.19**	-15.78***	-15.78***	0.03***	-16.11***
JSE ALSI	-2.44	-2.44	2.52	-3.88	-18.34***	-18.34***	0.06***	-20.57***
L.PROPERTY	-1.64	-1.64	4.58	-4.76	-15.93***	-15.93***	0.06***	-17.44***
PLATINUM	-2.47	-2.47	3.56	-4.33	-16.78***	-16.78***	0.04***	-17.91***

Note: The ADF, PP, and KPSS unit root tests include only a constant. The Zivot Andrews (ZA) test has both constant and trend with one structural break in the test model. ***, **, * denote significance at 1%, 5%, 10%.

As presented in the Table 1, the unit root test results show that the log prices are not stationary at levels but become stationary the first difference with 99% confidence level. Therefore, we found that the log prices are $I(1)$ processes. Although the ZA test had shown that JSE ALSI and the SA Listed property data are stationary before first differencing, however, to effect stationarity across all datasets, it was necessary to perform first differencing ($I(1)$) on all datasets.

Thus, based on the unit root results, it is appropriate to check which asset markets are cointegrated and further confirm the possibility of structural breaks among the cointegrated markets. This was done using the Johansen cointegration trace and max tests as well as the Gregory-Hanson test, respectively.

4.3. Johansen Cointegration Test

To determine the existence of linkages among the asset markets, the Johansen cointegration trace and max tests were applied to find cointegration among the data sets. Tables 2, 3 and Figure 4 present the results of the statistical tests using the Johansen cointegration tests and Toda-Yamamoto Granger Causality test as well as the recursive plots of Johansen's trace statistic.

Based on the full period (2015:01-2021:04), there are two significant cointegration relationships that can be seen from the results of the datasets. Firstly, the Brent crude oil vs JSE ALSI index– trace and max eigenvalue tests statistics shows the cointegration with 99% confidence level. More so, the Granger causality test shows that Δ JSE ALSI index caused on Δ Brent crude oil with 99% confidence level. Likewise, the JSE ALSI index vs Platinum – trace and max eigenvalue tests statistics shows the cointegration with 99% confidence level. Similarly, the Granger causality test shows that Δ Platinum caused on Δ JSE ALSI index with 95% confidence level.

In the Pre-COVID period, Johansen cointegration test finds two significant cointegrations. Firstly, the Brent crude oil vs JSE ALSI index– trace and max eigenvalue tests statistics shows the cointegration with 95% confidence level. Also, the Granger causality test shows that Δ JSE ALSI index caused on Δ Brent crude oil with 95% confidence level. Secondly, JSE ALSI index vs Platinum - trace and max eigenvalue tests statistics shows the cointegration with 95% confidence level. However, the Granger causality test did not show any significant causality of data.

These findings are supported by studies such as Ghosh and Kanjilal (2016), Tursoy and Faisal (2018) and Wei et al. (2019) who found cointegration between energy and stock markets during times of crisis. Likewise, studies such as Tuna (2019), Uddin et al. (2020) and Lahiani et al. (2021) also reported interconnectedness between stock and platinum markets.

Table 2. Results of Cointegration and Trace Tests

Variables	H ₀ : rank=r	FULL PERIOD		PRE COVID PERIOD		COVID PERIOD	
		Trace	Max	Trace	Max	Trace	Max
BITCOIN - OIL	r = 0	7.43	7.38	7.20	6.35	12.16	12.15
	r ≤ 1	0.05	0.05	0.85	0.85	0.01	0.01
BITCOIN - GOLD	r = 0	3.44	3.35	5.04	4.01	5.77	5.74
	r ≤ 1	0.09	0.09	1.02	1.02	0.03	0.03
BITCOIN - JSE ALSI	r = 0	16.03**	16.02**	29.56***	28.47***	9.17	9.06
	r ≤ 1	0.01	0.01	1.09	1.09	0.11	0.11
BITCOIN - L.PROPERTY	r = 0	2.97	2.85	9.05	6.86	11.38	11.1
	r ≤ 1	0.12	0.12	2.20	2.20	0.28	0.28
BITCOIN - PLATINIUM	r = 0	8.00	7.97	11.23	9.74	14.22*	14.15*
	r ≤ 1	0.03	0.03	1.49	1.49	0.06	0.06
OIL - GOLD	r = 0	8.85	7.53	14.01*	11.33	9.60	6.94
	r ≤ 1	1.32	1.32	2.68	2.68	2.66	2.66
OIL - JSE ALSI	r = 0	26.54***	19.77***	30.10***	26.11***	24.01***	22.78***
	r ≤ 1	6.76***	6.76***	3.99**	3.99**	1.24	1.24
OIL - L.PROPERTY	r = 0	5.76	5.67	8.24	7.99	12.05	8.73
	r ≤ 1	0.09	0.09	0.25	0.25	3.32*	3.32*
OIL - PLATINIUM	r = 0	15.48*	9.87	14.05*	11.36	21.82***	20.98***
	r ≤ 1	5.61**	5.61**	2.69	2.69	0.84	0.84
GOLD - JSE ALSI	r = 0	11.91	11.13	19.84**	18.84***	7.01	5.93
	r ≤ 1	0.78	0.78	1.00	1.00	1.08	1.08
GOLD - L.PROPERTY	r = 0	12.36	12.36*	5.51	5.51	13.76*	8.02
	r ≤ 1	0.00	0.00	0.00	0.00	5.74**	5.74**
GOLD - PLATINIUM	r = 0	15.38*	12.47*	12.40	9.33	10.26	8.85
	r ≤ 1	2.91*	2.91*	3.07*	3.07*	1.42	1.42
JSE ALSI - L.PROPERTY	r = 0	20.61***	20.03***	16.56**	16.47**	20.84***	12.26
	r ≤ 1	0.57	0.57	0.09	0.09	8.58***	8.58***
JSE ALSI - PLATINIUM	r = 0	19.10**	11.73	19.98***	11.96	20.04***	18.8***
	r ≤ 1	7.37***	7.37***	8.03***	8.03***	1.24	1.24
L.PROPERTY - PLATINIUM	r = 0	17.48**	15.81**	11.34	10.61	14.83*	10.35
	r ≤ 1	1.67	1.67	0.73	0.73	4.48**	4.48**

Note: The test is performed with the level data having no deterministic trends but the cointegrating equations have intercepts. ***, **, * denotes significance at 1%, 5%, and 10%. The Full period is 2015:01–2021:04, Pre-Covid period is 2015:01–2019:12, and Covid period is 2020:01–2021:04.

During the COVID period, Johansen cointegration test finds significant cointegration relationships between JSE ALSI index vs South African listed property Index - trace and max eigenvalue tests statistics shows the cointegration with 95% confidence level. However, the Granger causality test did not show any significant causality of data. Likewise, we observed a linkage between the South African listed property Index vs Platinum - trace and max eigenvalue tests statistics shows the cointegration with 95% confidence level. Herein, the Granger causality test shows that Δ Platinum is impacted by a Δ Listed property with 90% confidence level.

These findings are in line with studies such as Abul (2019), Gokmenoglu and Hesami (2019) and Yousaf and Ali (2020) who observed cointegration between stocks and real estate markets during times of crisis. In addition, our finding also support studies such as Raza et al (2018) and Chen and Tongurai (2021) who have reported interconnectedness between real estate and precious metals like platinum markets.

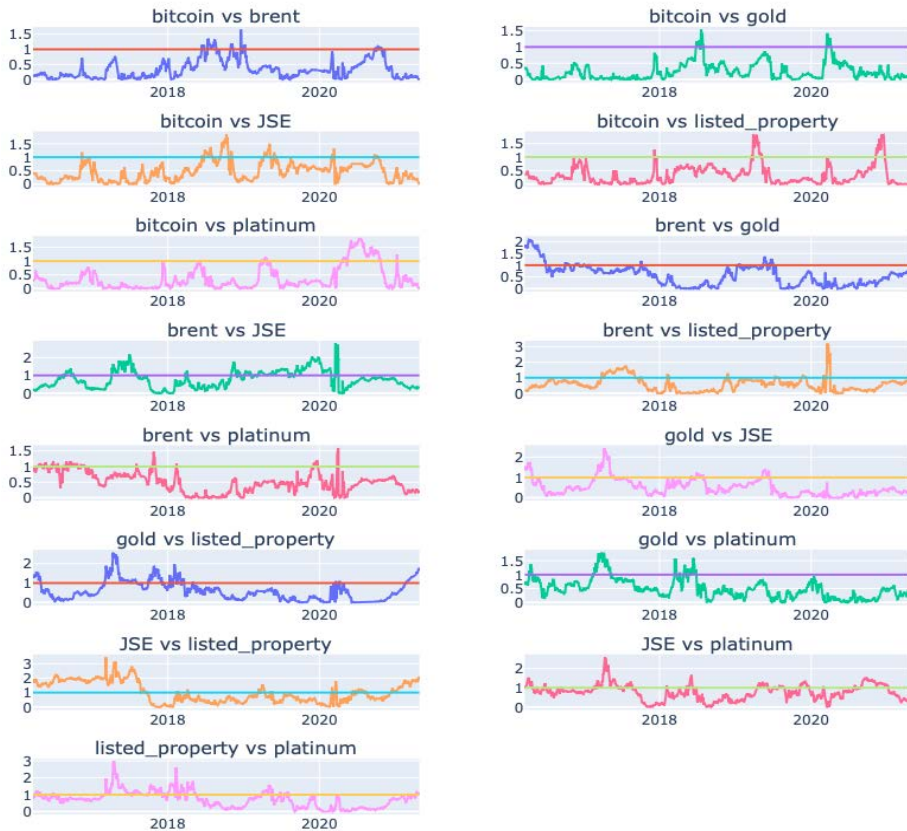


Figure 4. Recursive Plots of Johansen's Trace Statistic

Table 3. Results of Causality Tests

	FULL PERIOD	PRE COVID PERIOD	COVID PERIOD
T-Y Granger Causality tests	Chi-sq test	Chi-sq test	Chi-sq test
Δ BITCOIN \nrightarrow Δ OIL	2.24	2.32	0.02
Δ OIL \nrightarrow Δ BITCOIN	0.51	0.86	0.08
Δ BITCOIN \nrightarrow Δ GOLD	5.39**	0.27	9.48***
Δ GOLD \nrightarrow Δ BITCOIN	0.00	0.12	0.13
Δ BITCOIN \nrightarrow Δ JSE	2.47	0.49	2.73*
Δ JSE \nrightarrow Δ BITCOIN	2.87*	0.84	1.30
Δ BITCOIN \nrightarrow Δ L.PROPERTY	3.17*	2.60	0.98
Δ L.PROPERTY \nrightarrow Δ BITCOIN	0.93	1.00	2.58
Δ BITCOIN \nrightarrow Δ PLATINUM	1.01	0.01	1.72
Δ PLATINUM \nrightarrow Δ BITCOIN	0.99	0.93	0.01
Δ OIL \nrightarrow Δ GOLD	2.92*	0.09	3.44*
Δ GOLD \nrightarrow Δ OIL	0.09	0.00	0.28
Δ OIL \nrightarrow Δ JSE	14.09***	3.59*	6.70***
Δ JSE \nrightarrow Δ OIL	0.00	4.05**	1.92
Δ OIL \nrightarrow Δ L.PROPERTY	5.80**	0.01	3.82*
Δ L.PROPERTY \nrightarrow Δ OIL	0.06	0.09	0.41
Δ OIL \nrightarrow Δ PLATINUM	3.90**	2.23	1.05
Δ PLATINUM \nrightarrow Δ OIL	0.39	0.90	1.42
Δ GOLD \nrightarrow Δ JSE	0.50	1.13	0.00
Δ JSE \nrightarrow Δ GOLD	7.56***	0.08	7.06***
Δ GOLD \nrightarrow Δ L.PROPERTY	5.11**	1.27	2.35
Δ L.PROPERTY \nrightarrow Δ GOLD	0.04	0.05	0.00
Δ GOLD \nrightarrow Δ PLATINUM	7.07***	10.88***	0.81
Δ PLATINUM \nrightarrow Δ GOLD	52.13***	4.34**	44.58***
Δ JSE \nrightarrow Δ L.PROPERTY	1.13	1.15	0.31
Δ L.PROPERTY \nrightarrow Δ JSE	3.70*	0.01	2.38
Δ JSE \nrightarrow Δ PLATINUM	2.72*	1.72	0.44
Δ PLATINUM \nrightarrow Δ JSE	3.90**	0.49	3.01*
Δ L.PROPERTY \nrightarrow Δ PLATINUM	0.90	0.27	0.17
Δ PLATINUM \nrightarrow Δ L.PROPERTY	5.29**	0.02	2.98*

Note: The ***, **, * denotes significance at 1%, 5%, and 10%. The Full period is 2015:01–2021:04, Pre-Covid period is 2015:01–2019:12, and Covid period is 2020:01–2021:04.

4.4. The Gregory-Hansen Test

For further robustness, we shall check if cointegrated data contains any structural breaks or not. Thus, we conduct Gregory-Hansen test and present results at tables 4.

Table 4. Results of the Gregory-Hansen Test for Full Period

Variables	ADF		Zt		Za	
	Test Stat.	Break Point	Test Stat.	Break Point	Test Stat.	Break Point
BITCOIN - OIL	-3.85	14/06/2018	-3.85	16/07/2018	-27.90	16/07/2018
BITCOIN - GOLD	-3.40	24/07/2018	-3.44	23/07/2018	-20.77	23/07/2018
BITCOIN - JSE ALSI	-4.54	02/01/2019	-4.52	18/12/2018	-37.48	18/12/2018
BITCOIN - L.PROPERTY	-4.38	13/03/2020	-4.49	12/03/2020	-35.71	12/03/2020
BITCOIN - PLATINUM	-3.30	12/05/2017	-3.31	15/05/2017	-22.42	15/05/2017
OIL - GOLD	-3.14	06/04/2020	-3.17	03/12/2015	-20.94	03/12/2015
OIL - JSE ALSI	-5.57***	03/04/2020	-5.60***	02/04/2020	-59.67***	02/04/2020
OIL - L.PROPERTY	-4.59	03/12/2015	-4.58	03/12/2015	-39.96	03/12/2015
OIL - PLATINUM	-4.24	16/01/2020	-4.18	06/01/2020	-34.60	06/01/2020
GOLD - JSE ALSI	-3.89	16/03/2020	-3.79	16/03/2020	-28.77	16/03/2020
GOLD - L.PROPERTY	-4.45	06/06/2018	-4.20	21/05/2018	-34.93	21/05/2018
GOLD - PLATINUM	-3.30	08/01/2020	-3.16	10/01/2020	-22.39	10/01/2020
JSE ALSI - L.PROPERTY	-4.97*	30/04/2020	-4.97*	04/05/2020	-48.92**	04/05/2020
JSE ALSI - PLATINUM	-5.46***	20/08/2019	-5.40**	20/08/2019	-55.98**	20/08/2019
L.PROPERTY - PLATINUM	-5.53***	02/04/2020	-5.26**	04/03/2020	-54.18**	04/03/2020

Note: H_0 : There is no a cointegration at the break point. H_1 : There is a cointegration at the break point. The 1%, 5%, 10% critical values ADF and Zt test statistics are -5.45, -4.99, -4.72, and those for the $Z\alpha$ are -57.28, -47.96, -43.22 respectively (Gregory & Hansen, 1996). ***, **, * denote significance at 1%, 5%, and 10%.

In the Gregory-Hansen test, when absolute value of the Zt statistics is higher than the critical bound value, the null hypothesis is rejected. If H_0 is rejected, it implies that the linear combination of the series exhibits stable properties in the long-run. but with structural break. It is useful to define if there is an existence of a long-run equilibrium to which the series converge over time.

At above table, the Gregogy-Hansen test results show that there are few structural breaks in cointegration relationships. The Brent crude oil and JSE ALSI

index had a structural break in their cointegration at 1% statistical significance level. Similarly, the JSE ALSI index and Platinum cointegration also has a structural break at 1% statistical significance level. Lastly, the test detects another structural break between Listed Property and Platinum during 07/2021, but our trace and max eigenvalue statistics has not found any cointegration relationships between themselves.

To summarize, the test results show that cointegrations are stable over the full period mostly. And despite these three structural breaks, the cointegrated series converge at their long-run equilibrium point over the time. These findings and observations are supported by studies such as Ghosh and Kanjilal (2016), Tursoy and Faisal (2018) and Wei et al. (2019). Likewise, studies such as Tuna (2019), Uddin et al. (2020) and Lahiani et al. (2021) have also reported interconnectedness between stock and platinum markets.

5. Conclusion

This research aims to study long-run cointegrations among South African financial markets with energy market, precious metal market, and cryptocurrency market during pre-Covid tranquil period and during Covid period comparatively. This makes the research unique in terms of contributions in this field. And in turn, it is crucial to understand of potential cross-asset relationships and spill-over effects for the purpose of asset allocation, diversification, risk hedging and portfolio optimisation, especially during times of financial and economic crises and uncertainties.

Utilizing cointegration tests, the study first examines co-movements of series in the full period without any restrictions. As a result, it finds strong co-integrations between Bitcoin - JSE Stock Market at 5% significance level, Brent Crude Oil - JSE at 1% significance level; JSE - Real Estate market at 1% significance level; and JSE - Platinum Market at 5% significance level.

On the other hand, when we separate the full period with pre-Covid and Covid periods, we observe changes in the cointegration behaviour. The results of pre-Covid tranquil period is almost same as full period results, or at least similar with few minor increases in significance levels of cointegrated relationships. So, we can conclude that during pre-Covid period relationship between cointegrated series are more blantant and significant. However, with the Covid period unstablalities start. For instance, Bitocin - JSE cointegration relationship dissappears, JSE - Real Estate Market cointegration relationship weakens. Weirdly, during the Covid period Oil - Platinum and Gold - Real Estate Market seem to be cointegrated at 1% and 5% significance levels respectively. Moreover, the only

cointegrations that preserve during Covid period is cointegrated relationships between Oil - JSE and between JSE - Platinum Markets. From a practical standpoint, it could be said that both oil and platinum are critical inputs/commodities that affect the South African economy; while South Africa is the foremost producer of platinum in the world, it is also the second-biggest consumer of crude oil in Africa.

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