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TESTING THE RESILIENCE OF STOCK MARKETS DURING THE COVID-19 CRISIS: A CROSS-REGIONAL ANALYSIS IN AFRICA

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ABSTRACT
The objective of this study was not only to test the impact of the pandemic of COVID-19, on the dynamism of financial markets in Sub-Saharan Africa in a cross-regional context, but also on their resilience and hence their level of efficiency under the classical assumption of efficient financial markets (financial securities). The results of the coherence wavelet estimations confirm the resilience and therefore efficiency of all stock prices in our working sample to various degrees. These results reassure investors who are reluctant to invest in Africa in times of crisis that African stock markets react very weakly to the negative impact of crises. They can therefore still operate on the stock market in this continent without risk of sudden loss.

KEYWORDS: *Resilience, Stock market, COVID-19, Cross-regional Analysis.*

JEL Classification: G10; G14; G15; C14

INTRODUCTION

The coronavirus disease detected in China at the end of 2019 has spread very quickly around the world. The extent of its spread has prompted the WHO to officially declare the new coronavirus epidemic as a global pandemic on 11 March 2020, with dramatic consequences. In addition, even if the disease was slow to reach Africa, the first cases are however recorded in Morocco and South Africa respectively on 5 and 2 March 2020**.** It should be noted that the application of sanitary measures recommended by health experts and practitioners will however affect most of the economies in the world and particularly the African economies. This effect will lead many researchers to investigate the likely effects of COVID-19 on notable economic variables. Notably Kamaludin, K and al (2021) find a link between the evolution of COVID19 cases and the Asian stock markets. Our research aims to test the resilience of stocks markets (financial securities) in Africa in a cross-regional context using coherence wavelets. To our knowledge, this study is the first to consider the functioning of regional financial markets in Africa and the evolution of COVID-19 in a dynamic of highlighting not only the

impact of the pandemic on the dynamism of transregional financial markets in Africa, but also on their resilience and hence their level of efficiency. It is worth noting that work on financial markets is generally based on two main prodromes or theories, namely the classical prodrome of market efficiency on the one hand and the behavioural finance prodrome on the other. With regard to the classic hypothesis of financial markets, EUGENE FAMA (1965) postulates: "that a financial market is efficient if and only if the information available concerning each financial asset quoted on this market is immediately integrated into the price of this asset. Based on this definition by Fama, we can therefore say that in an efficient market, as soon as information about an asset exists, the price of this asset is instantly modified to integrate this information. However, with the proliferation of work on the question of market efficiency, the definition given by Fama has evolved, it is less strict and authorises a certain form of predictability: thus, from the initial efficiency synonymous with a random market in securities prices, we move on to an efficiency meaning the impossibility of obtaining a substantial gain. It is with this in mind that Jensen (1978) postulates that "markets are deemed to be efficient if the prices of listed assets incorporate information about them in such a way that an investor cannot, by buying or selling the asset, make a profit greater than the transaction costs incurred by the action". With regard to the psychological turn of rationality or behavioural finance, it should be noted that it is opposed to Eugene Fama's theory of market efficiency and recalls the flaws in behaviour and their effects on financial markets. From a definitional point of view, McGoun (2000) states that behavioural finance, born from the confrontation of the points of view of psychology and finance, endeavours to shed light on what motivates investors' decisions; it accounts for the way in which emotions interfere in their decision. It should therefore be understood that behavioural finance is the result of an alliance of two distinct theories, namely the "noise trader approach" (NTA) and a psychological theory of decision making, that of heuristics developed by Daniel Kahneman and Amos Tversky. The first theory shows that in the presence of correlated irrational investors, rational arbitrage is powerless to ensure efficiency. The second theory empirically justifies the correlation of irrationalities by drawing on research from psychology on decision heuristics. From the above, if there is one theory generally well accepted by academics as well as by many practitioners, it is that of the efficiency of financial markets, which implies that it is difficult to predict the future evolution of stock prices and therefore to "beat" the market. This hypothesis will be the basis for the present study, which argues that stocks have a medium- and long-term memory. Using a wavelet transformation, Valls Martinez, M.D.C and Martin Cervantes, P.A. (2021), tested the resilience of CSR stocks during the COVID-19 crisis on stock indices from six continents and the Dow Jones Substainability World Index (DJSWI). The empirical results show that the global impact of the sudden COVID-19 outbreak had a significantly smaller effect on sustainability-related indices compared to the other indices they considered in their study. In addition, Karamti. C, and Belhassine, O. (2021), also used the wavelet method on several stock market indices including, Nikkel 225 (Japan); SSE (China) to represent Asia, The SP500 to represent the United States; CAC40 (France) ; DAX (Germany) and FTSE (United Kingdom) to track the European market, and also WTI spot (oil) and gold as a commodity index, as well as Bitcoin and Ethereum as the two main crypto-currencies, to study the links between the COVID-19 outbreak and the main financial markets in a time-frequency framework. As a result of their investigation, it is found that wavelet coherence analysis reveals differences in perception between short-term and longer-term market reactions. Indeed, in the short term, the authors find strong movements during the first and second waves of the pandemic. During the first wave, long-term investors were driven by the belief that the pandemic would disappear in the future. As a result, they resorted to time diversification, which resulted in positive returns. During the study period, as the United States became the new epicentre of the coronavirus, it was also noted that the American fear of COVID-19 was reflected in the international markets. In short, gold, SSE and crypto-currencies seem to be the safest investments according to the conclusions of these authors' work. Furthermore, by conducting a wavelet consistency analysis to the economic policy uncertainty (EPU) data and the monthly sectoral volatility of the S&P 500 index from January 2008 to May 2020, Choi, S.Y (2020) examined the impact of economic uncertainty due to the coronavirus pandemic (COVID-19) on the industrial economy in the United States in terms of interdependence and causality. The author’s results, reveal that the UPR in terms of COVID-19 influenced

sectorial volatility more than the 2008 Global Financial Crisis (GFC) for all sectors. Furthermore, according to the author, the UPR caused the volatility of all sectors during the COVID-19 pandemic, while the volatility of some sectors caused the UPR during the 2008 GFC. Using the wavelet method and a Granger causality test on daily data of the US COVID-19, the US-EPU WTI (the news-based index), the US Geopolitical Risk Index (GPR), and the US Stock Price Index (SPI) measured by the Dow Jones 30 Index**,** Yarovaya, L et al (2020) analyse the connectivity between the spread of COVID-19, the oil price volatility shock, the stock market, geopolitical risk, and economic policy uncertainty in the United States in a time-frequency framework. The results reveal the unprecedented impact of COVID-19 and oil price shocks on the levels of geopolitical risk, economic policy uncertainty and stock market volatility in the low frequency bands. The effect of COVID-19 on geopolitical risk is significantly higher than on US economic uncertainty. COVID-19 risk is perceived differently in the short and long term and may be perceived primarily as an economic crisis. Using an AR (1)-GARCH (1,1) model, on COVID-19, S&P500, NASDAQ, DOW, DAX, CRIA, Cyprus, and GDP data, Li, W et al (2021) investigate the empirical relationship between fear of COVID-19 and stock market volatility. The results suggest that the fear of COVID-19 is the ultimate cause of public attention and stock market volatility. The results also show that stock market performance and GDP growth decreased significantly during the pandemic. Furthermore, with a 1% increase in COVID-19 cases, stock market performance and GDP decreased by 0.8% and 0.56% respectively. They note, however, that GDP growth showed a slight movement with the stock market. In addition, the public's attention to buying or selling attitude, depended strongly on the index of reported cases of the pandemic, the index of deaths and the index of global fear. For the authors, in front of such configurations, investment in the gold market, rather than in the stock markets, is recommended. Based on the wavelet consistency method applied to daily data from June 2019 to May 2020, from Bombay Stock Exchange (BSE), London Stock Exchange (LSE), NASDAQ, Tokyo Stock Exchange (Nikkei), Shanghai Stock Exchange and COVID-19, Siddiqui, T.A et al (2020) evaluate the impact of COVID-19 on the five stock markets previously mentioned. Their results show that co-movements vary in time and scale. During the crisis, the co-movement is concentrated on a short time scale, even for two days. However, the concentration of co-movement is strongest between the UK and US stock markets and is weakest between Japan and the UK. On the BSE, co-movement at shorter time scales started late. NASDAQ leads in only one case, the Shanghai Stock Exchange. The BSE does not lead in any stock index. The LES (London Stock Exchange) is in the leading position in all four cases. The authors also noted that the co-movement began to focus on a shorter time scale as soon as the impact of the crisis began to be felt. Applying a new quantile-on-quantile method on US and Chinese stock market data based on wavelets, Gao, X. et al (2020), compare the impact of COVID-19 on stock market volatility between the US and China. The wavelet decomposition shows that the impact has a stronger regularity in the low frequency domain compared to the fluctuations of the US stock market. However, unlike China, the strong growth of new daily cases, which continued for months, made the US stock market insensitive to COVID-19. In addition, the particularly loose interest rate policy effectively suppressed the volatility of the US stock market. However, unlike China, the near-zero interest rate applied by the US has reduced the volatility of the US stock market. The near zero interest rate applied by the US unfortunately makes it difficult to create money to deal with a potential new crisis. Kamaludin, K et al (2021), using wavelets on the ASEAN-5 equity markets, new daily COVID -19 cases, and the Dow Jones from February 15 to May 30, 2020, show that the stock market in Malaysia, Indonesia, and Singapore respond to Covid-19 cases beyond the pandemic phase, while Thailand and the Philippines have shown consistency in the middle of the period. As the pandemic evolved, all ASEAN-5 equity markets showed strong consistency with the Dow. However, by the end of the sample period, no coherence was observed among the ASEAN-5 equity markets, the local COVID-19 cases, and the Dow Jones index. Using wavelet-copula-GARCH methods, Alqaralleh, H. and Canepa, A. (2021) investigate the emergence of linkages among six major stock markets during the COVID-19 pandemic. The results reveal evidence of long-term interdependence among the markets considered before the onset of the COVID-19 pandemic in December 2019. However, after the onset of the health crisis, strong evidence of pure contagion between stock markets was detected. By studying the conditional dynamic correlation and asymmetric impacts

of shocks on the correlation between the U.S. and Chinese stock markets before and during the COVID-19 pandemic, Lahoued, B.B. et al. (2021) first find that the dynamic correlation approach supports the presence of volatility excess (contagion effect) between the COVID-19 pandemic and U.S. stock returns. Second, the analysis of the correlation surfaces of the impact of news (information), shows that the shocks in the US and Chinese stock markets have asymmetric effects on the correlation between the two stock markets. Finally, the authors find a persistent link between U.S. stock returns, uncertainty, and the COVID-19 pandemic during the first and second waves of the pandemic. In light of the above, and as noted above, no formal study has yet been undertaken on the resilience of financial stocks in sub-Saharan Africa in a cross-regional context following the sudden onset of the COVID-19 pandemic. To this end, this study would like to contribute to shedding light on the link between the resilience of stocks markets (financial securities) and covid-19 in sub-Saharan Africa. The remainder of this paper is organized as follows: analysis of methodology (point 1), results and their discussions (point 2), conclusion (point 3).

METHODOLOGY

Data description, descriptive statistics and data evolution

Data description

To carry out this research, we adopt a scheme similar to that of Valls Martinez and Martin Cervantes (2021), collecting two types of data related to the number of cases of COVID-19 per day, obtained from the WHO website (2022), specifically the data were selected from 5 countries in Africa in a representative way (Ivory Coast, Nigeria, Kenya, South Africa and Egypt). We also used the daily values of 5 stocks markets indices of the five countries concerned, which are an indicator of the performance of the stocks markets (financial markets) of each of the countries analysed. Based on this provision, two variables were defined: variable. I, which represents the performance of the stocks markets (financial markets) analysed, and variable II, which refers to the number of new cases of COVID-19 recorded per country.

Table 1: Description of variables

Country	Variable I : financial markets		Variable II: COVID-19
	Stock market index	Abbreviation	Abbreviation
Ivory Coast	Regional Securities Exchange "composite".	BRVMC	Ci_covid
South Africa	Johannesburg stock exchange Top 40	JSE TOP 40	Saf_covid
Nigeria	Nigerian stock Exchange	NSE 30	N_covid
Egypt	Egyptian Stock Exchange	EGX 30	E_covid
Kenya	Nairobi Stock Exchange	NSE 20	K_covid

Descriptive statistics

Table 2: Stock Market Indices

Variable	N	Average	Standard deviation	Min	Q1	Median	Q3	Max
BRVMC	553	154.970995	26.969764	122.19	133.45	144.39	175.97	219.62
JSE TOP 40	1107	56503.341861	7400.990125	34239.3	50999.61	58175.75	61616.8	71057.56
NSE 30	547	1436.667715	281.250544	871.26	1125.87	1557.65	1652.655	1822.15
EGX 30	538	11123.093903	911.160719	8756.7	10568.4875	11000.71	11456.54	14108.24
NSE 20	552	1959.402736	200.153637	1723.96	1864.545	1903.355	1974.185	2706.38

Table 3: Covid-19

Variable	N	Average	Standard deviation	Min	Q1	Median	Q3	Max
Ivory Coast	553	96.323689	178.163005	0.00	3.00	36	107	1578
South Africa	1107	2175.307136	4349.262284	-4.00	1.00	46	2001	37875
Nigeria	547	313.003656	439.372067	-47.00	35.50	155.00	436.5	4035
Egypt	538	612.808550	526.422325	0.00	149.5	587	906	2301
Kenya	552	380.570652	519.146279	0.00	36.50	180.5	511	3746

Data evolution

This sub-section of our work will focus on the evolution of the data we used to conduct our investigation. It will be a question of seeing how the financial indexes of the countries of our sample of study evolve, in relation to the new cases of daily contaminations to the pandemic of Covid-19. In other words, we will focus our attention on the mixed evolution of the stock market index and Covid-19 (Graph 1) on the one hand, and on the other hand on the respective evolution of the stock market indexes per country (Graph 2).

Graph 1: Mixed evolution of stock market index and Covid-19

Graph 2: Stock market indices evolution in 2020

Graph 1 presents the mixed evolution of the stock market index and covid-19, in the countries of our sample from 3 March 2020 to 16 March 2022. Overall, two main pieces of information emerge from a close examination of the graph. The first information concerns Nigeria, Ivory Coast and South Africa. Indeed, in these different countries, we note a drop in the stock market index from the first months of the pandemic's appearance in March, April and May 2020**.** This decline is followed by an upward trend in the stock market indexes despite the constant increase in new cases of infection. The second information concerns Kenya and Egypt. In these countries, we note a strong decline of the stock exchange indexes in a context of permanent increase of new daily cases of contamination to the pandemic and this observation seems to maintain itself from March 2020 to March 2022.

Graph 2 describes the respective evolutions of the stock market indices in our sample in the first year of the pandemic's appearance. Here again, two main pieces of information are worth noting. The first information concerns Kenya and Ivory Coast. In these countries, the stock market index fell sharply from February 2020 to November 2020 for Ivory Coast and from February 2020 to December 2020 for Kenya. The second information concerns Egypt, South Africa and Nigeria. In these countries, the decline in the stock market index is accompanied by an increase in the index (generally from April 2020 to early 2022).

Wavelet methodology

The objective of using the non-parametric wavelet method in the analysis of financials prices is to appreciate or better identify the co-movements or contagions phenomena between differents financials markets. The output or result of this method of analysis is in the form of an image that allows the direction of movements between two main variables to be appreciated. Indeed, with regard to the link between two given variables, we can appreciate the presence or absence of resilience and therefore efficiency. Moreover, if two observed variables (daily number of cases of COVID-19 and stock prices) are linked, it can be said that investors have integrated information on COVID-19 into their decisions to invest in the stock market. The wavelets can be affected by a real or complex function $\psi(.)$ defined on the real axis, assuming that the wavelet is an integrable square function, that is $\psi \in L^2(R)$.The admissibility condition applied to analysing or mother wavelets: $0 < C_\psi := \int_{-\infty}^{\infty} \frac{\psi|\omega|}{|\omega|} d\omega < \infty$ (1)

Where C_ψ is the admissibility constant. This minimal condition is often reinforced by requiring that the wavelet has zero moments: the function has ψ has m + 1 zero moments if for all k = 0, ..., m, $\int_{-\infty}^{\infty} t^k \psi(t) dt = 0$ (2). To clarify the understanding, let us' say that a wavelet oscillates for a certain time like a wave, but is then localized thanks to a damping. The number of zero moments is a measure of the oscillation of a wavelet.

From this single function ψ we build by translation and dilation, a family of functions which are the basic atoms: $\psi_{a,b}(t) = \frac{1}{\sqrt{a}} \psi\left(\frac{t-b}{a}\right), a \in R_+, b \in R$ (3)

It should be known that for an integrable square function *f*, we define its continuous wavelet transform by the function C such that: $C(a,b) = \int_{-\infty}^{\infty} f(t) \frac{1}{\sqrt{a}} \psi\left(\frac{t-b}{a}\right) dt$ (4).

Calculating this function C is to make the analysis of f by the wavelet ψ. It is worth noting that if *f* is a constant function, its wavelet coefficients are zero. The wavelet coefficients measure the fluctuations at scale a, of the function *f*. The trend at scale a, containing the slower evolutions, is essentially eliminated in C(a,b). The wavelet analysis allows a local analysis of *f* as well as the measurement of the scale effect by comparing the C(a,b) for different values of a.

As an illustration, figure 1 presents the Morlet wavelet with parameter $k_0 = 6$.

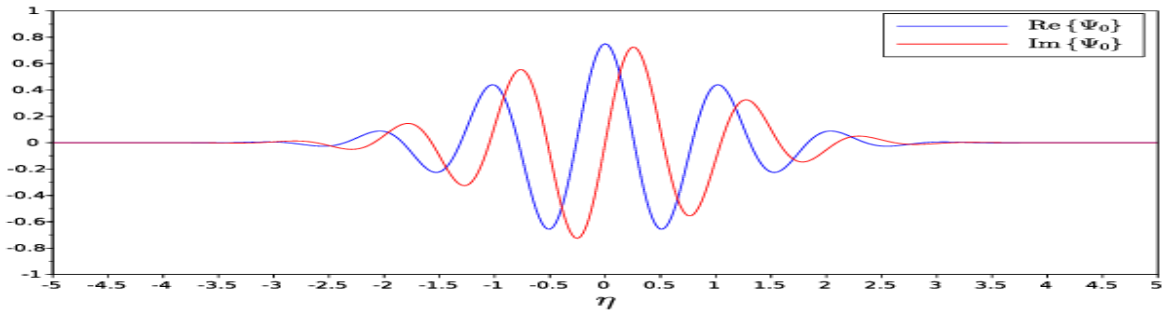

Figure 1: Prototypical example of a wavelet

RESULTS AND DISCUSSIONS

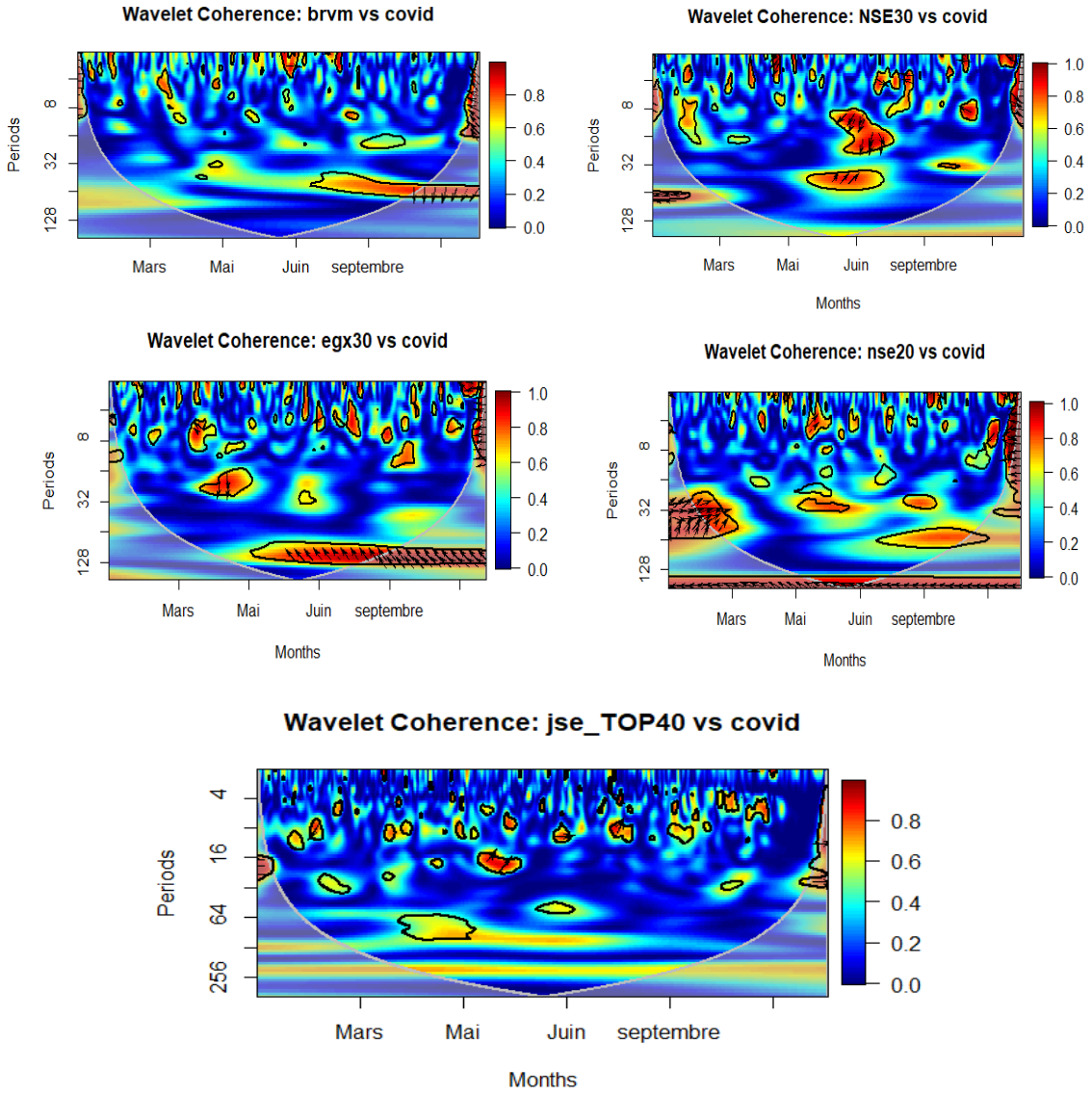

Figure 2

Figure 2 presents the results on the interrelationships between stock prices and the numbers of COVID-19 cases in the different countries in our sample. A warmer or red-coloured area indicates a significant interrelationship. A blue-coloured area shows small movements. In addition, the direction(s) of the arrows indicate(s) the phases between the variables. The arrows "top right and bottom left (↙↗)" mean that the first variable leads the second. The arrows "top left and bottom right(↖↘)" indicate that the second variable leads the first. When the arrow is pointing up and respectively down (↑↓), this indicates that the variable is leading and lagging respectively.

The pair (BRVMC and COVID number of cases), shows the existence of many small red islands that indicate a strong dependence at the beginning and end of the period between the two variables in the pair. The interrelationships are most apparent in the low frequency areas of 1 to 4 days. Towards the end of the 2020 period, we see red island zones that reflect an interrelationship between the two variables in presence. Also, in the same area we see arrows top left, which shows that the prices of the BRVM and the number of cases of COVID-19 are positively related and the waves of contamination lead the prices of the BRVM. This confirms

the contagion between the number of COVID-19 cases and BRVM stock prices. However, over the whole period, we can see that the blue islands are dominant and even more dominant in the low frequency zone, which reflects the resilience of BRVMC prices to the number of COVID-19 cases.

On the graph showing the relationship of the pair (NSE30 and COVID-19 number of cases), many small red islands indicate a strong interrelation between the two variables. The interrelationship is most noticeable between the 8th and 32nd days in mid-2020. The direction of the arrows pointing to the bottom left shows that the NSE30 prices and the number of COVID-19 cases are negatively related and the NSE30 prices lead the number of COVID-19 cases in Nigeria. This means that investors during this period were not influenced by the number of COVID-19 contamination. However, towards the end of the period, we see a small red island with arrows pointing to the top left which means that the number of COVID-19 cases is leading the NSE30 stock price movement. This shows that the two variables are positively related, which confirms the contagion of investors' fear of investing in the stock market in the face of the evolution of the number of COVID-19 cases. However, over the whole period, we note the dominance of the blue islands, which reflects the resilience of the NSE30 prices to the number of COVID-19 cases in Nigeria.

Regarding the relationship between the Egyptian stock market and the number of COVID-19 cases recorded per day (EGX30 vs. COVID), the graph shows many red areas. This finding reflects the interrelation between the two variables especially in the high frequency areas (1-4 days). However, in the low frequency area (between the 64th and 128th day), there is a red island with arrows pointing to the upper left. This reflects the fact that the two variables are positively related and that the number of recorded COVID cases leads the EGX30 prices. We can therefore infer a contagion from the number of COVID cases to the Egyptian stock market. Overall, the blue islands are in the majority which reflects the resilience of the Egyptian stock market to the COVID-19 crisis.

The graph showing the relationship between Kenya's stock prices and the number of COVID-19 cases recorded per day (NSE20 vs. COVID-19) shows some hot zones (red) reflecting the interdependence between the two variables. This interdependence became more pronounced between the 32nd and 64th day with arrows pointing to the upper right. This means that the stock market prices are in the lead. However, it is not until late 2020 that the arrows point to the upper left, highlighting the fact that the two variables are positively related and that the COVID caseload leads the NSE20 prices. Although the effect of COVID-19 cannot be ignored, it is clear that the blue areas are dominant over the entire period, confirming the resilience of the Kenyan stock market.

Finally, the graph showing the relationship of the couple (JSE_TOP40 vs COVID), shows some hot zones. However, we can see that the chart is dominated by the blue islands. This means that the South African stock market has not reacted globally to the number of COVID-19 cases recorded per day. Overall, our results are in line with those of Martinez and Cervantes (2021).

CONCLUSION

The objective of this study was to test the resilience of stocks markets in Sub-Saharan Africa in a cross-regional context under the classical assumption of efficient financial markets. The results of the coherence wavelet estimations confirm the resilience and therefore efficiency of all stock prices in our working sample to various degrees. However, we could note phenomena of contagion of the number of cases recorded per day to the stock markets of the UEMOA zone (BRVM), Nigeria (NSE 30), Kenya (NSE 20), and Egypt (EGX 30). The South African stock market did not react significantly to the number of COVID cases recorded. In other words, the South African stock market is weakly efficient, especially since the number of Covid-19 cases had no influence on the price of the securities or these two variables are independent of each other. For the other markets, UEMOA (BRVM), Nigeria (NSE 30), Kenya (NSE 20) and Egypt (EGX 30), we can speak of a semi-strong form of efficiency insofar as all the available information concerning the financial assets was integrated into the price of this security or this asset at the very moment when this information was made public, as was the case

with the Covid-19 pandemic. These results reassure investors who are reluctant to invest in Africa in times of crisis that African stock markets react very weakly to the negative impact of crises. They can therefore still operate on the stock market in this continent without risk of sudden loss. Therefore, it is up to the political authorities of the states in our sample to take appropriate measures to clean up their respective business climates in order to perpetuate the resilience of their stock markets.

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