“The effect of the COVID-19 epidemic on Moroccan sectoral indices: The entropy approach”

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THE EFFECT OF THE COVID-19 EPIDEMIC ON MOROCCAN SECTORAL INDICES: THE ENTROPY APPROACH

Abstract

The current study investigates the impact of the Coronavirus 2019 (COVID-19) pandemic on the volatility of Moroccan stock market sectoral indices. Shannon entropy with multiple estimators and Rényi entropy for different scales were calculated from February 1, 2019 to May 1, 2022, to measure volatility in the Banking, Oil and Gas, Construction and Building Materials, Beverage, Food Producers and Processors, Distributors, and Mining sector's indices. In this regard, this study uses three periods to quantify the uncertainty in Moroccan sectoral indices before, during, and after the first year of the COVID-19 pandemic in Morocco. The empirical results from Shannon and Rényi entropies indicated higher volatility during the COVID-19 pandemic for all sectoral indices except Oil and Gas. However, the consumer staples sectors have shown a form of resilience compared to other sectors. Indeed, the impact of COVID-19 on the consumer staples sectoral indices' volatilities was negligible compared to other sectors. In addition, investing in a portfolio composed of Mining or Construction and Building Materials stocks was risky due to the increased volatility before and during the epidemic. However, after the COVID-19 pandemic, the entropy level corresponding to all sectors has rearranged except the Beverage sector, which kept the lowest entropy during the three periods. Thus, it seems that the Beverage sector was a safe investment for the three periods. The findings are crucial for governments, businesses, private and public authorities, and investors to create recovery action plans for sensitive sectors and give investors trust to make smarter investment decisions.

Keywords econophysics, Rényi entropy, Shannon entropy, volatility, return time series

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INTRODUCTION

In recent years, the question of measuring financial risk has become a growing concern for academics, professionals, and regulators. Volatility, commonly used to quantify uncertainty and disorder, is particularly important in the financial world. Indeed, it is often considered to be a measure of portfolio risk. As a result, there is a large and growing literature on the study of volatility (Engle et al., 2013; Hamilton & Lin, 1996; Poterba & Summers, 1984; Schwert, 1989; Stoll & Whaley, 1990). Indeed, due to recent disasters involving derivative securities, techniques for evaluating and managing financial risks have rapidly progressed (Brooks & Persand, 2003; Pincus & Kalman, 2004). Hence, financial market volatility is crucial for risk management, asset allocation, and derivative pricing.

Several studies have demonstrated that applying physics concepts like entropy is an alternative technique to investigate stock market volatility (Bentes & Menezes, 2012; Sheraz et al., 2015). This notion is shown in a considerable body of literature to help describe financial problems (Nawrocki & Harding, 1986; Rouge & El Karoui, 2000; Zhou et

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al., 2013). However, even though there are numerous ways to interpret the concept of entropy, the most frequently used in literature is as a mirror for the disorder, ignorance, confusion, or even a lack of information (Golan, 2002). In 1948, Shannon (Shannon, 1948) provided insight into the subject, demonstrating that entropy could be used in any situation where probabilities can be determined and were not just limited to thermodynamics.

Although the pandemic's impact on the entire economy was unavoidable due to the elevated systematic risks brought on by uncertainty, theoretically, it was expected that the exposure of various sectors would differ depending on the degree of market integration and the nature of goods and services produced. For instance, while some sectors, such as tourism, air transport, and events, have experienced significant shocks, industries such as healthcare, e-commerce, and mobile payments have benefited from the COVID-19 crisis. In this regard, one pertinent research issue is identifying the sectors' response to the situation resulting from the epidemic. The results help to explain the effects of the world's s crisis on stock markets and their dispersion among different sectors. Indeed, recognizing the equity market movements is essential to stay extremely careful and vigilant, especially during times of crisis when macroeconomic variables rather than a company's fundamentals play a more significant role (Chaudhary et al., 2020; Hoshi & Kashyap, 2004).

1. LITERATURE REVIEW

Since early 2020, the COVID-19 epidemic has hurt the world economy and capital markets. As a result, the overall stock market dropped. However, while some sectors perform well throughout the crisis, some have become quite vulnerable. Consequently, health, environmental, political, economic, and financial issues have prompted financial experts to quantify the effect of the pandemic on various sectors.

Recently, a group of authors evaluated the effect of the COVID-19 epidemic on stock market sectors in different countries. For instance, the impact of COVID-19 on the sub-sector price indices of the Turkish stock exchange was measured by Öztürk et al. (2020) from January 2, 2020 to April 15, 2020. The finding suggests that the insurance, banking, transportation, tourism, sports, machinery, and metal product sectors were among the worst-hit ones. The retail trade beverage, food, beverage, retail trade, and wholesale sectors, on the other hand, were the least impacted sectors in Turkey because of the high demand for their products and the government support measures put in place to guarantee food availability in the nation. The performance of the BSE 500 and BSE indices, as well as eight sectoral indices of the Bombay stock exchange, were investigated by Chaudhary et al. (2020) to determine the effect of COVID-19 from January 2019 to May 2020. The results indicated that only the healthcare sector could maintain a positive return during the COVID-19 period. Overall, the COVID-19 period showed higher volatility in the Bombay stock exchange, and the returns deviated from non-normality. In a similar work, from March 2, 2020 to November 27, 2020, Utomo and Hanggraeni (2021) used daily stock returns of 272 stocks traded on the main board of the Jakarta stock exchange operated in eight sectors. They concluded that the COVID-19 pandemic negatively affected the property, trade, service, and investment sectors, while the performance of the Mining, Consumer goods, and Basic industry sectors is much better. Likewise, Alam et al. (2021) used a 10-day window to evaluate the effects of COVID-19's announcement on eight sectors in the Vienna stock exchange, including Real estate, Telecommunications, Energy, Food, Pharmaceuticals, Healthcare, Transportation, and Technology. The study's findings show that the indices for Healthcare, Pharmaceuticals, and Food have posted impressively favorable returns on the announcement day. However, the telecommunications, healthcare, and pharmaceutical sectors performed well after the announcement, whereas the transportation sector showed low performance. Nguyen et al. (2022) examined the effect of the COVID-19 pandemic on the Vietnam stock exchange across 13 sectors between January 23, 2020 and April 27, 2021. Their results confirm that Manufacturing, Real estate, and Construction sectors were those most severely affected by the

four waves of the COVID-19 outbreak. However, Vietnam's Information and Technology, Financial, and Insurance services sectors proved to be the most resilient during the pandemic.

As a technique to describe uncertainty and disorder, entropy is of great importance in information theory (Solomon, 1968) and statistical mechanics (Huang, 1987; Zubarev, 1974). Since Boltzmann introduced the entropy concept in thermodynamics and described it in probabilistic terms, the probabilistic description of natural systems has made entropy a central field in contemporary research. Numerous sources introduce various types of entropy, including Shannon (Shannon, 1948), Rényi (Rényi, 1961), Tallis (Tsallis, 1988), and Approximate entropy (Pincus, 1991).

In finance, entropy can be seen as an extension of probability entropy and information entropy. It could be a crucial instrument for portfolio selection and asset pricing. The notion of entropy was initially used to assist portfolio selection by Philippatos and Wilson (Philippatos & Wilson, 1972). They explored an approximation based on the concept of mean entropy. They tested the new approach against the classical methods by building every possible optimal portfolio from a random sample of monthly closing prices of 50 stocks over 14 years. They concluded that the Sharpe single-index, Markowitz full-covariance models, and mean-entropy portfolios were all consistent. Despite some limitations, their study significantly impacted the subject of portfolio selection.

Recently, a group of researchers quantified the effect of COVID-19 on stock markets worldwide based on an entropy approach. Using the Rényi entropy, Nasiri et al. (2021) reviewed the impact of the COVID-19 epidemic on 70 firms between 2016 and 2021 by evaluating the exchange of information between the marine shipping and oil and gas midstream industries. The results indicated that since the COVID-19 pandemic's outbreak, the information flow patterns of the stocks in the Oil and Gas Midstream and Marine Shipping sectors had shown shifts. In a similar work, Lahmiri and Bekiros (2020) investigated the mutual information and the multiscale entropy behavior in silver markets, Gold, Gas, Brent, WTI, Bitcoin, S&P500, and VIX between August 1, 2019 and May 26, 2020. According to Rényi entropy findings, disorder and randomness are focused on events with lower probabilities. The results from mutual information showed that during the COVID-19 outbreak, the information flow network across markets had changed. Likewise, Karakaş et al. (2021) employed Shannon, Tsallis, Renyi, and approximative entropies to gauge the volatility of various world indices, including the ISE 30, FTSE 100, SP 500, NIKKEI 225, and DAX 30 before and after the COVID-19 crisis. Their results revealed that before the pandemic, the FTSE 100 had shown the highest volatility, while after the COVID-19 pandemic, the most volatile index was the ISE 30. Fernandes et al. (2022) evaluated the impact of the COVID-19 pandemic on the efficiency of the Brazilian stock market indices between August 05, 2013 and April 29, 2021. The authors found that each industrial sector was affected differently by the epidemic and that the disorder in the financial series increased during times of crisis using permutation entropy and Fisher information. Fernandes et al. (2021) used the complexity entropy plane approach to assess the impact of the new COVID-19 crisis on the Chinese sectoral indices. From their results, inefficiency has risen due to the crisis in Chinese economic sectors, although the effects varied and were not similar in all sectors.

This study contributes to the literature by studying Moroccan sectoral indices' volatility before, during, and following the severe economic and health issue caused by the novel COVID-19. Indeed, this work is the first to use the Shannon and Rényi entropies to investigate volatility in the Moroccan sectoral indices around the COVID-19 financial crisis.

Using the Shannon and Rényi entropies, this paper analyzes the impact of the COVID-19 crisis on the Moroccan sectoral indices' volatility. For this purpose, to quantify the degree of uncertainty of the Banking, Oil and Gas, Construction and Building Materials, Beverage, Food Producers and Processors, Distributors, and Mining sectors time series, the data (February 1, 2019 to May 1, 2022) were split into three equal-length periods. The first period begins on February 1, 2019, and runs until March 1, 2020. The second period runs from March 2, 2020 – the day the first COVID-19 case in Morocco was announced – through April 16,

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2021. Finally, the third period, which concludes on May 1, 2022, runs from April 17, 2021. The following hypothesis is investigated in the study:

H1: The outbreak of the COVID-19 pandemic has affected the volatility of the Moroccan sectoral indices.

2. DATA AND METHODOLOGY

This paper investigates the daily closing values of seven Moroccan sectoral indices with the highest value on the Casablanca Stock Exchange. The total period covers more than three years, from February 1, 2019 to May 1, 2022, for each Moroccan sectoral index, namely Banking, Oil and Gas, Construction and Building Materials, Beverage, Food Producers and Processors, Distributors, and Mining. After eliminating missing data, the total observation before the pandemic period is 266, during the pandemic period is 281, and after the pandemic is 260. The time series data were extracted from the Casablanca stock exchange's official website (Bourse de Casablanca, n.d.). Table 1 presents the Moroccan sectoral indices used in this investigation.

This study uses the return series in all the statistical investigations. It is calculated as the first logarithmic difference between values. The following formula was used for computation:

$$r_i(t) = \ln P_i(t) - \ln P_i(t-1), \quad (1)$$

where $P_i(t)$ is the index value of sector i ($i = 1, \ldots N$) at time t.

Table 1. Descriptions of Moroccan sectoral indices

Index code	Index label
P&G	Oil and Gas
B&MC	Construction and Building Materials
BOISS	Beverage
AGRO	Food Producers and Processors
DISTR	Distributors
BANK	Banks
MINES	Mining

Because each stock's volatility is a latent variable, it is necessary to choose a proxy. Thus, the standard deviation has been widely used to assess stock market volatility. However, this study suggests the Shannon entropy (Shannon, 1948), an advanced approach frequently used in statistical physics. The Shannon entropy H is calculated for each sectoral index as a variable with N possible states associated with a discrete random. Different estimators have been used: maximum likelihood (ML), bias-corrected maximum likelihood (MM), Jeffreys, Laplace, SG, Minimax, CS, and Shrink. It is defined as:

$$H(P) = -\sum_{i=1}^{N} p_i \log p_i, \quad (2)$$

$$\text{where} \quad \sum_{i=1}^{N} p_i = 1,$$

and $0 \log 0$ is defined as 0.

To evaluate the consistency of the results, the Rényi entropy (Rényi, 1961), a generalization of the Shannon entropy, was also computed. It has the exciting virtue of trying to evaluate the information complexity by inserting an alternative scale r ($r \geq 0$, and $r \neq 0$) to differentiate between rare and ordinary events. It is defined as:

$$H_r(P) = \frac{1}{q-1} \log\left(\sum_{i=1}^{n} P_i^r\right), \quad (3)$$

$$\text{where} \quad \sum_i P_i = 1,$$

where P is a discrete probability distribution assumed $\{P = P_1, P_2, \ldots, P_n\}$ and associated with a discrete random variable X. When $r < 1$, rare events are prioritized. On the other hand, when $r > 1$, ordinary events are favored. H_r tends to the Shannon entropy when $r \to 1$.

In practice, after dividing the log return $r_i(t)$ series of the index into N separate bins, the probabilities of each situation i were calculated and divided by the total number of values of the analyzed index. Then, the entropies were used to quantify the uncertainty for each index price series based on the number of selected bins (Please refer to Sandoval (2014) for thorough research) (Memon & Yao, 2019).

3. RESULTS AND DISCUSSION

Using the log return of the daily closing values of Moroccan sectoral indices from February 1, 2019 to May 1, 2022, this section presents the findings

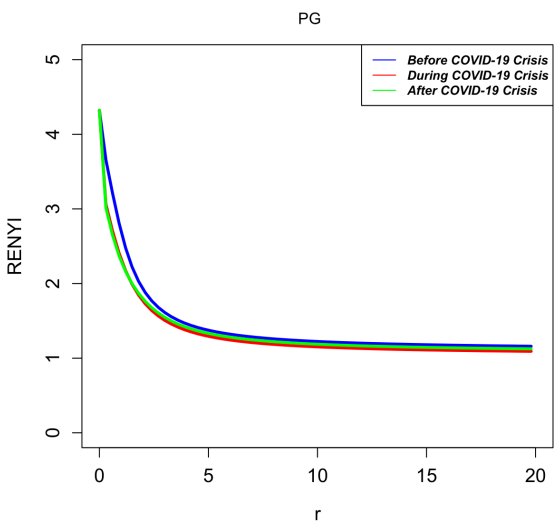

Figure 1. Rényi entropy (Hr) versus scale r for PG

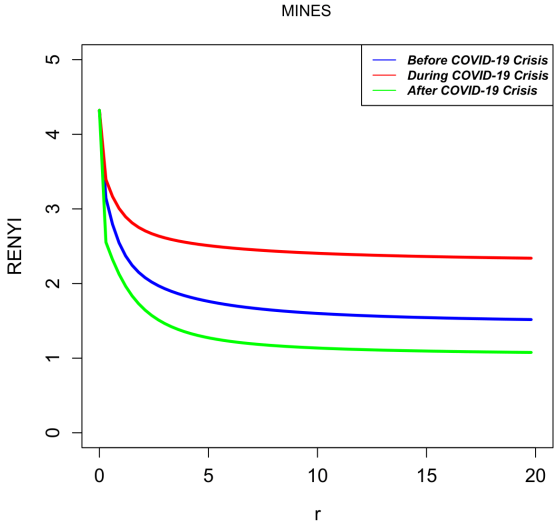

Figure 2. Rényi entropy (Hr) versus scale r for MINES

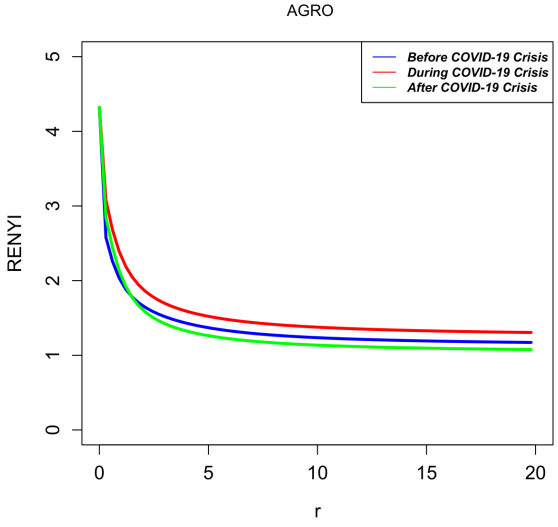

Figure 3. Rényi entropy (Hr) versus scale r for AGRO

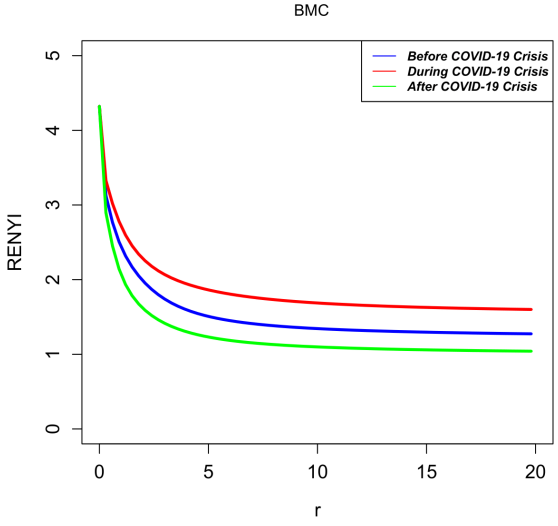

Figure 4. Rényi entropy (Hr) versus scale r for BMC

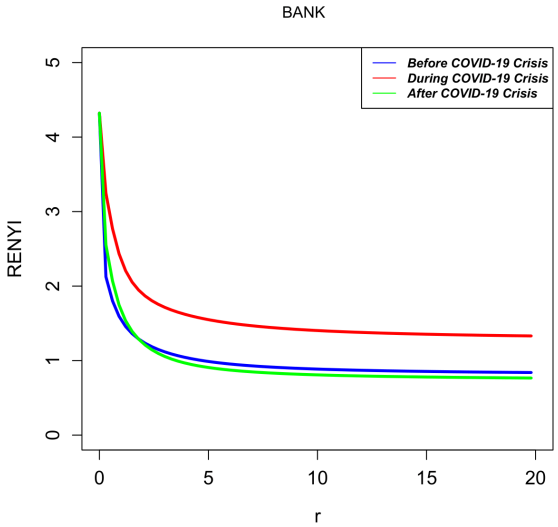

Figure 5. Rényi entropy (Hr) versus scale r for BANK

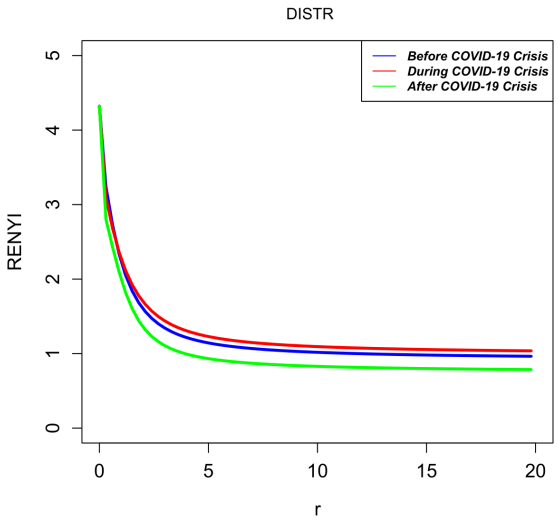

Figure 6. Rényi entropy (Hr) versus scale r for DISTR

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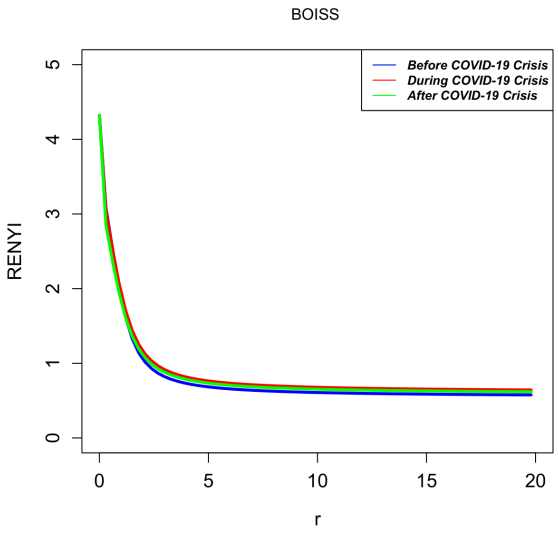

Figure 7. Rényi entropy (Hr) versus scale r for BOISS

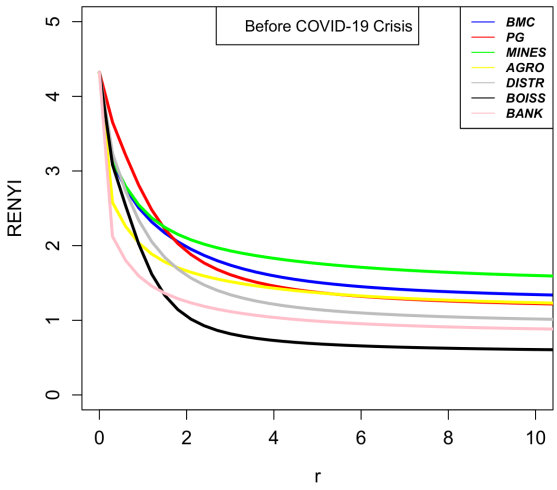

Figure 8. Rényi entropies versus scale r during the pre-crisis period for all indices

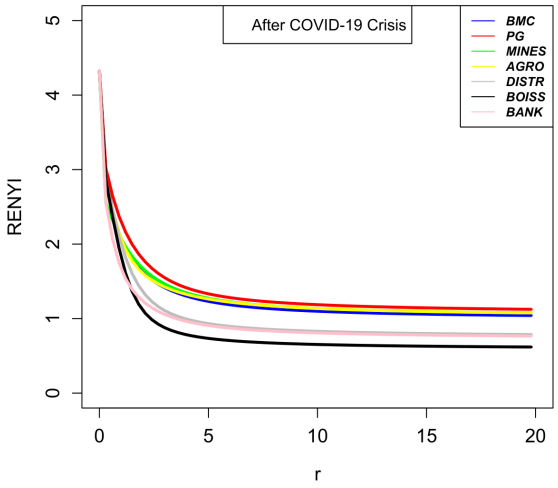

Figure 9. Rényi entropies versus scale r during the post-crisis period for all indices.

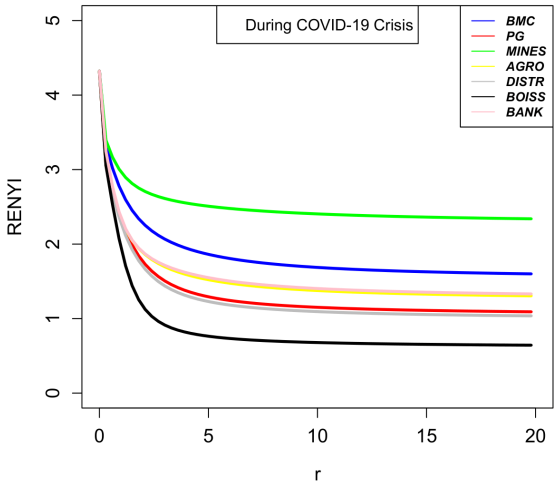

Figure 10. Rényi entropies versus scale r during the crisis period for all indices

from entropy approaches to estimate the volatility of Moroccan sectoral indices. The main subject of the analysis and discussion is the Shannon and Rényi entropies. To assess the consistency of the resulting entropy values, different estimators have been used for the Shannon entropy measure, whereas Rényi entropy has been calculated for various scales.

Tables A1 and A2 show the Rényi and Shannon entropies values for each period for the seven Moroccan sectoral indices. Based on the numerical results, the entropy values are positive; therefore, the characteristics of the data sets are nonlinear. The plot of the Rényi entropy versus scale *r* for Banking, Oil and Gas, Construction and Building Materials, Beverage, Food Producers and Processors, Distributors, and Mining sectors before, during, and after the COVID-19 crisis are presented in Figures 1-7. It is evident that during the COVID-19 pandemic, the entropy is higher than before and after the pandemic for all sectoral indices at all scales, except the Oil and Gaz (P.G.) sector. These findings suggest that the volatility corresponding to all sectors increased during the COVID-19 pandemic (Tables A1 and A2), except the one that matches the Oil and Gaz industry (Fernandes et al., 2021, 2022). This result supports the findings of Liu et al. (2020) regarding the U.S. stock market. Indeed, their

finding suggests that the pandemic had a favorable impact on crude oil and stock returns. Concerning the Beverage, Food Producers and Processors and Distributor sectors, the entropies H and H_r showed a little increase compared to other sectors (Tables A1, A2). This behavior is similar to that observed in the Turkish (Öztürk et al., 2020), Indonesian (Utomo & Hanggraeni, 2021), and Austrian stock exchanges (Alam et al., 2021), where the consumer staples sectors were the least impacted. The empirical findings also reveal that H_r increases significantly at law scales before declining at all other scales. Hence, disorder and unpredictability are more prevalent in less probability events for the studied sectors.

To compare Moroccan sectoral indices' volatility, Figures 8 to 10 show the plots of all Rényi entropies versus the scale r before, during, and after the COVID-19 crisis. According to Figure 8, during the pre-crisis period, at high scales, the highest Rényi entropy was identified in the Mining sector, followed by Construction and Building Materials, Oil and Gas, Food Producers and Processors, Distributors, Banks, and Beverage. Therefore, the Minning sector, Construction and Building Materials, Oil and Gas, and Distributors sectors showed higher volatility. In contrast, Food Producers and Processors, Banking, and Beverage sectors displayed smaller volatility. Consequently, before the COVID-19 outbreak, Food Producers and Processors, Banking, and Beverage sectors have been secure investments. During the COVID-19 crisis (Figure 10), the Minning sector kept the greatest Rényi entropy, followed by Construction and Building Materials, Banks, Food Producers and Processors, Oil and Gas, Distributors, and Beverage sectors, at all scales. Therefore, compared to Oil and Gas, Distributors, Food Producers and Processors, and Beverage sectors, Minning, Construction and Building Materials, and Banking sectors are considered the riskiest during the COVID-19 pandemic. In that period, the Banking sector showed the highest volatility drop among the seven sectors and has been identified as a critical sector in the Moroccan stock market network during and after the pandemic (Bouhlal & Brahim Sedra, 2022). In addition, unlike other sectoral indices, the entropy level corresponding to the Oil and Gas sector has declined during the pandemic. This result confirms that the pandemic has a positive influence on the Oil and Gaz sector. After the COVID-19 pandemic, Oil and Gas revealed the highest Renyi entropy at all scales, followed by Minning, Construction and Building Materials, Food Producers and Processors, Distributors, Banks, and the Beverage sectors. It is interesting to note that Minning and Construction and Building Materials sectors showed the highest volatility before and during the pandemic. This ranking could suggest that investing in a portfolio composed of Mining or Construction and Building stocks was risky due to the increased volatility before and during the epidemic. Furthermore, after the COVID-19 pandemic, a rearrangement of the entropy level corresponding to all the sectors apart from the Beverage sector kept the lowest entropy during the three periods. Therefore, this exception could indicate that the Beverage sector was a safe investment and that the COVID-19 pandemic has had little influence on the Beverage sector uncertainty.

Figure 11 shows the Shannon entropy for each period for the seven Moroccan sectoral indices. It should be noted that before the COVID-19 pandemic, Construction and Building Materials, Oil and Gas, and Mining sectors achieved the top entropy values. During the crisis, the Banking sector replaced the Oil and Gaz sectors and entered the top three with the Construction and Building Materials and Mining sectors. After the crisis, Oil and Gas replaced Mining and got the highest Shannon entropy score.

According to the Shannon and Rényi entropies, throughout the three periods, there are no sectoral indices that consistently appear in the top three. However, before and during the crisis period, Construction and Building Materials and Minning sectors kept the highest volatility, while Beverage, Food Producers and Processors, and Distributor sectors were the less volatile indices during the three periods. However, the Beverage, Food Producers and Processors, and Distributor sectors showed a weak volatility increase due to the pandemic. Indeed, the consumer staples sectors were the least impacted by the pandemic. This behavior resembles that of the Turkish (Öztürk et al., 2020), Indonesian (Utomo & Hanggraeni, 2021), and Austrian stock exchanges (Alam et al., 2021). The Banking sector showed the highest volatility drop among the seven sectors during the crisis, but after the pandemic, the entropy level returned to normal.

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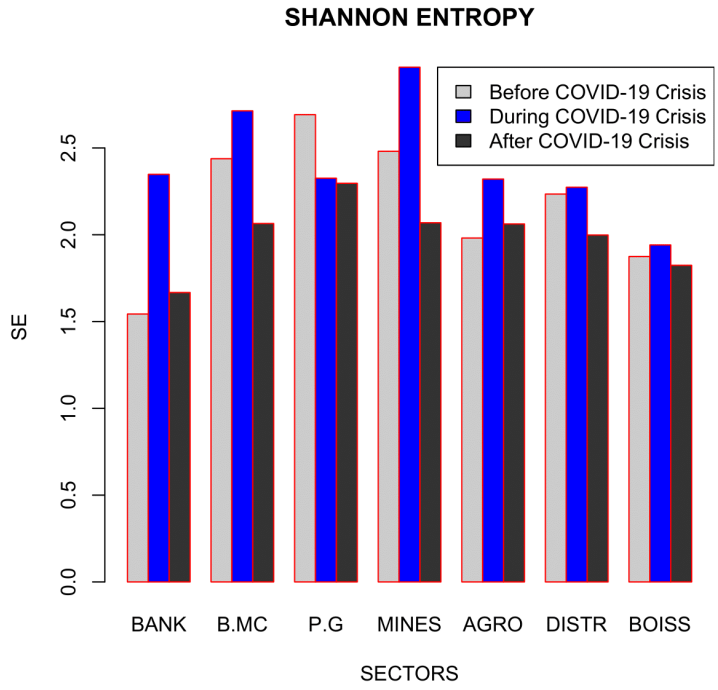

Figure 11. Shannon entropy using a maximum likelihood (ML) estimator during the three periods for all sectoral indices

CONCLUSION

Using the daily closing price of seven Moroccan sectoral indices between February 1, 2019 and May 1, 2022, this paper investigates the impact of the COVID-19 pandemic on the volatility of Moroccan sectoral indices. The data (February 1, 2019 to May 1, 2022) were split into three time periods: before (February 1, 2019 to March 1, 2020), during (March 2, 2020 to April 16, 2021), and following the COVID-19's first year in Morocco (April 17, 2021 to May 1, 2022). Shannon and Rényi entropies are used as a measure of volatility to quantify the degree of uncertainty and disorder of each sectoral index time series on the Moroccan stock market. The results reveal that the pandemic's effects are not uniform across sectors. Indeed, the economic recessions affect economic sectors differently; some sectors are more flexible and can adapt to the crisis immediately, while others are struggling.

The study's findings were consistent with the research hypothesis that the COVID-19 crisis impacted the Moroccan sectoral indices' volatility. The results from both entropies point out the same conclusion; apart from the Oil and Gas sector, the COVID-19 pandemic stimulates an increase in Moroccan sectoral indices' volatility. As a result, the pandemic positively influenced Oil and Gas sectors. On the other hand, according to the findings, the Mining and Construction and Building Materials indices represented the highest volatility before and during the pandemic, making them a risky investment. Furthermore, the Banking sector was the most impacted sector by the COVID-19 pandemic. In addition, after the COVID-19 pandemic, all sectors showed a reorganization in the entropy level, except the Beverage sector, which maintained the lowest entropy across the three periods. Thus, the Beverage sector portfolio was a safe investment during the three periods.

These insights into the volatility and disorder of particular sectoral index time series can help local and international investors in the Casablanca stock exchange manage their portfolios, and the regulatory authorities gauge the stock market's stability. In addition, a more detailed study could explore information sharing between the Moroccan stock market sectors.

AUTHOR CONTRIBUTIONS

Conceptualization: Fadwa Bouhlal.
Data curation: Fadwa Bouhlal.
Formal analysis: Fadwa Bouhlal.
Funding acquisition: Moulay Brahim Sedra.
Investigation: Fadwa Bouhlal.
Methodology: Fadwa Bouhlal.
Project administration: Moulay Brahim Sedra.
Resources: Moulay Brahim Sedra.
Software: Fadwa Bouhlal, Moulay Brahim Sedra.
Writing – original draft: Fadwa Bouhlal.
Writing – review & editing: Moulay Brahim Sedra.

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APPENDIX A

Table A1. Different Rényi entropy measures of B&MC, P&G, MINES, AGRO, DISTR, BOISS, and BANK before the COVID-19 crisis (Pre-c), during the COVID-19 crisis (C), and after the COVID-19 crisis (Post-C)

Rényi Entropy															
B&MC				P&G				MINES				AGRO			
r	Value			r	Value			r	Value			r	Value		
	Pre-C	C	Post-C		Pre-C	C	Post-C		Pre-C	C	Post-C		Pre-C	C	Post-C
0	4,322	4,322	4,322	0	4,322	4,322	4,322	0	4,322	4,322	4,322	0	4,322	4,322	4,322
0.25	3,195	3,385	2,982	0.25	3,729	3,125	3,081	0.25	3,211	3,439	2,593	0.25	2,641	3,157	2,921
0.5	2,875	3,115	2,584	0.5	3,359	2,819	2,761	0.5	2,9	3,234	2,395	0.5	2,353	2,801	2,567
1	2,438	2,714	2,065	1	2,692	2,326	2,296	1	2,481	2,965	2,069	1	1,981	2,321	2,062
2	1,983	2,279	1,615	2	1,925	1,764	1,794	2	2,1	2,72	1,67	2	1,661	1,885	1,606
4	1,596	1,943	1,301	4	1,46	1,371	1,412	4	1,83	2,55	1,346	4	1,43	1,59	1,325
8	1,382	1,732	1,13	8	1,258	1,184	1,221	8	1,642	2,434	1,168	8	1,27	1,413	1,167
16	1,29	1,621	1,055	16	1,174	1,105	1,139	16	1,537	2,357	1,091	16	1,187	1,322	1,091
32	1,249	1,569	1,021	32	1,137	1,07	1,103	32	1,487	2,311	1,055	32	1,149	1,28	1,055
64	1,229	1,544	1,005	64	1,119	1,053	1,085	64	1,463	2,285	1,039	64	1,13	1,259	1,039
Infinie	1,21	1,52	0,989	Infinie	1,101	1,036	1,068	Infinie	1,441	2,252	1,022	Infinie	1,113	1,24	1,022

DISTR				BOISS				BANK			
r	Value			r	Value			r	Value		
	Pre-C	C	Post-C		Pre-C	C	Post-C		Pre-C	C	Post-C
0	4,322	4,322	4,322	0	4,322	4,322	4,322	0	4,322	4,322	4,322
0.25	3,329	3,176	2,864	0.25	3,172	3,141	2,929	0.25	2,19	3,333	2,646
0.5	2,89	2,815	2,554	0.5	2,719	2,702	2,528	0.5	1,895	2,915	2,212
1	2,234	2,274	1,999	1	1,875	1,941	1,824	1	1,543	2,348	1,667
2	1,602	1,698	1,358	2	1,052	1,162	1,109	2	1,251	1,891	1,233
4	1,215	1,305	0,993	4	0,73	0,814	0,783	4	1,039	1,615	0,962
8	1,047	1,125	0,853	8	0,626	0,698	0,672	8	0,911	1,441	0,832
16	0,977	1,05	0,796	16	0,584	0,652	0,627	16	0,851	1,348	0,776
32	0,945	1,016	0,77	32	0,565	0,631	0,607	32	0,824	1,305	0,751
64	0,93	1	0,758	64	0,556	0,621	0,597	64	0,811	1,284	0,739
Infinie	0,916	0,985	0,746	Infinie	0,547	0,611	0,588	Infinie	0,798	1,264	0,728

Table A2. Different Shannon entropy measures of B&MC, P&G, MINES, AGRO, DISTR, BOISS, and BANK before the COVID-19 crisis (Pre-c), during the COVID-19 crisis (C), and after the COVID-19 crisis (Post-C)

Shannon Entropy															
B&MC				P&G				MINES				AGRO			
r	Value			r	Value			r	Value			r	Value		
	Pre-C	C	Post-C		Pre-C	C	Post-C		Pre-C	C	Post-C		Pre-C	C	Post-C
ML	2,438	2,714	2,065	ML	2,692	2,326	2,296	ML	2,481	2,965	2,069	ML	1,981	2,321	2,062
MM	2,468	2,745	2,092	MM	2,735	2,351	2,324	MM	2,511	2,996	2,086	MM	2	2,349	2,087
Jefferys	2,614	2,859	2,272	Jefferys	2,818	2,5	2,488	Jefferys	2,654	3,098	2,293	Jefferys	2,203	2,496	2,271
Laplace	2,748	2,97	2,429	Laplace	2,921	2,632	2,631	Laplace	2,785	3,197	2,455	Laplace	2,368	2,63	2,428
SG	2,461	2,733	2,092	SG	2,707	2,349	2,322	SG	2,504	2,983	2,1	SG	2,012	2,344	2,09
Minmax	2,701	2,936	2,372	Minmax	2,885	2,592	2,579	Minmax	2,74	3,167	2,396	Minmax	2,311	2,589	2,371
CS	2,501	2,754	2,138	CS	2,746	2,356	2,346	CS	2,535	3,004	2,071	CS	2,007	2,384	2,1
Shrink	2,514	2,797	2,126	Shrink	2,741	2,386	2,365	Shrink	2,565	3,083	2,142	Shrink	2,052	2,389	2,124

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Table A2 (cont.). Different Shannon entropy measures of B&MC, P&G, MINES, AGRO, DISTR, BOISS, and BANK before the COVID-19 crisis (Pre-c), during the COVID-19 crisis (C), and after the COVID-19 crisis (Post-C)

DISTR				BOISS				BANK			
r	Value			r	Value			r	Value		
	Pre-C	C	Post-C		Pre-C	C	Post-C		Pre-C	C	Post-C
ML	2,234	2,274	1,999	ML	1,875	1,941	1,824	ML	1,543	2,348	1.667
MM	2,27	2,302	2,021	MM	1,904	1,97	1,849	MM	1,557	2,381	1.689
Jefferys	2,41	2,448	2,211	Jefferys	2,07	2,129	2,04	Jefferys	1,801	2,512	1,907
Laplace	2,549	2,583	2,369	Laplace	2,222	2,275	2,204	Laplace	1,992	2,641	2,088
SG	2,257	2,297	2,028	SG	1,9	1,966	1,853	SG	1,579	2,369	1,699
Minmax	2,5	2,542	2,311	Minmax	2,169	2,23	2,144	Minmax	1,926	2,602	2.022
CS	2,323	2,328	2,006	CS	1,901	1,996	1,848	CS	1,565	2,428	1,728
Shrink	2,284	2,33	2,048	Shrink	1,905	1,974	1,86	Shrink	1,596	2,411	1.714