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Entropy as A Measure of Volatility : A Case Study of Special Convertible Rupee Account (SCRA) and Pakistan Stock Exchange (PSX)

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Abstract: *This study investigates the volatility of the market value of the Pakistan Stock Exchange (PSX) and the equity market value of the Special Convertible Rupee Account (SCRA). The study utilizes entropy, standard deviation, and coefficient of variation as measures of volatility to gain a comprehensive understanding of the data. The results reveal a strong correlation between SCRA and PSX during the period of analysis. Furthermore, the volatility measures indicate that SCRA exhibits higher volatility as compared to PSX. This finding contradicts what standard deviation and coefficient of variation suggest, emphasizing the importance of considering multiple volatility measures. The findings highlight the significance of SCRA as a factor influencing the market value of PSX and the need for careful consideration of volatility measures when formulating investment strategies. In conclusion, this study provides insights into the volatility comparison of SCRA and PSX..*

Key Words: Entropy, Volatility, SCRA (Special Convertible Rupee Account), PSX (Pakistan Stock Exchange

JEL Classification:

Introduction

Have you ever wondered how statisticians can make sense of the vast amount of data that exists in the world? Statistics is a science that helps us understand and describe the behavior of variables using tools such as variance, standard deviation, and Box Plot etc. However, data in natural, social, and artistic fields often exhibit randomness, uncertainty, and variation, making it difficult to assess the risk of any industry or company. Traditional measures such as standard deviation or coefficient of variation are commonly used to check uncertainty and variation in data, but they have their drawbacks, such as being affected by extreme values and ignoring nonlinear dynamics between data. In recent research, a new measure of dispersion called entropyhas been suggested, which helps to understand the true uncertainty of data and provides a more effective comparison of variation. This new technique has the potential to revolutionize the way we understand and analyze data.

Over the past few years, there has been a

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growing discussion regarding the alternative volatility measures of the stock market. According to Sonia R Bentes and Rui Menezes (2012) explores the use of Shannon entropy as a new measure of stock market volatility, propose that Shannon entropy can provide a more robust and accurate measure of volatility compared to traditional measures such as standard deviation. Muhammad Sheraz, at Al (2014) proposes the use of various entropy measures to assess market volatility in a more nuanced manner, argue that traditional measures of market volatility, such as standard deviation, fail to capture the complexity and nonlinearity of financial markets. A potential research gap that exists in the papers is the insufficient empirical testing and simulation data for the proposed measure in comparison to actual data.

This paper focuses on examining whether entropy, a concept initially introduced in physics by Clausius in the XIX century, can be a viable alternative to the standard deviation. We aim to identify the potential advantages of entropy over the standard deviation. In order investigate volatility in two financial datasets using various techniques of volatility and to Checkthe comparison of volatility of two new time series datasets more efficiently and provide better results due to their advantages. In our research, we focus on using the concept of entropy to capture nonlinear dynamics in two financial time series. While standard deviation has some limitations, we believe that entropy can provide a more comprehensive understanding of volatility. To test our hypothesis, we conduct an empirical analysis using data of total market value of Equity securities of SCRA and total market value of PSX Equity securities. Finally, we are interested in determining whether the SCRA (Securities and Commodities Regulatory Authority) is an efficient determinant of the Pakistan Stock Exchange (PSX)."

Entropy is a concept borrowed from physics that can be utilized as an alternative approach to analyze stock market volatility. It is a measure of randomness and disorder and has proven to be useful in describing financial and economic problems. The principles of informationentropy and probability theory in finance can be extended through the application of entropy.

The entropy of a communication system measures the amount of uncertainty and information interpretation quantitatively. Bonginkosi Mamba and Farai Kwenda (2020) entropy is a reliable and informative measure of volatility, especially during periods of extreme marketmovements., Li, Jinghai Li, and Bin Wang (2020) entropy can provide useful insights into market volatility. Kyohei Matsushita and Yuta Ogane (2019) Shannon entropy is a useful toolfor measuring volatility and can be applied to various financial markets. Entropy can be interpreted in various ways, with interpretations based on both thermodynamics and statistics. A higher value of entropy describes low information in a communication system. Statistical entropy, on the other hand, is interpreted differently; higher entropy data indicates a higher level of randomness. Entropy of a random variable is considered a measure of its uncertainty. Shannon's 1948 paper, "A mathematical theory of communication," provides the axiomatic basis for the original treatment of entropy, and it is formally defined as the negative expected value of the logarithm of the probability density function of the discrete random variable X.

Using Shannon's concept of entropy in communication systems provides an alternative approach to analyzing stock market volatility (2004) , For the given probability distribution of a chance variable X ,pi=p(xi=i),i=1,2 . . ., n, the Shannon entropy S is

$$(X) = -\sum_{n} p_i ln p_i \quad n$$

,

$$0 \leq p \leq 1 \quad and \quad \sum p_i = 1$$

(1)

$i=1$

$i=1$

The units of entropy are bits (When base is 2) and nats (when base is e).

The paper is structured as follows: Section 2 provides a literature review of the important aspects of usage and comparison of different volatility measures specially entropy. Section 3 present the methodology used to find the objectives of study. Section 4 presents the empirical findings obtained from the analysis, while Section 5 presents the conclusions drawn from the study.

Literature Review

Distinct approach to analyzing market volatility involves applying different concepts, which prior research has demonstrated to be advantageous in describing economic or financial issues. One such concept is entropy, which has various definitions but is frequently utilized in literature as a gauge of uncertainty, disorder, lack of information, or ignorance refer to Golan A (2002). Subsequently, Shannon (1948) offered a new perspective on this matter by illustrating that entropy is not limited to thermodynamics, but can be employed in any circumstance where probabilities are defined.

In literature, several different historical volatility measures studies have been carried out on various markets. For instance, T. Lux et al (2023) examine entropy is a useful measure of marketrisk and liquidity, and that it provides more accurate information than traditional measures such as volatility and liquidity spreads. X. Luo et al (2022) studied entropy measures provide a useful toolfor measuring stock market volatility, and can capture the dynamics of volatility better than traditional measures. X. Chen et al (2022) explores Shannon entropy is a useful tool for measuring volatility, and provides more accurate information than traditional measures. Shu-heng Chen andHsin-Yi Chi (2021) suggest that Shannon entropy provides a more robust and accurate measure of volatility in the Chinese stock market. Takuji Arai (2019) examine that Shannon entropy can providea more accurate measure of volatility than traditional measures such as standard deviation. Alexey Fomin et al (2019) indicates that Shannon entropy is a useful measure of volatility. Yongtae Kim et al (2018) suggest Shannon entropy provides a more accurate and reliable measure of volatility than the traditional measures.

Zhenyu Wu et al (2018) investigates the use of Shannon entropy as a measure of volatility in the Hong Kong stock market and compares it with traditional measures. Shannon entropy is a useful tool for risk management and provides additional insights into market behavior. Zhenyu Wu et al (2017) examines Shannon entropy can better capture the non-linear and non-normal features of the market and provide more accurate measures of volatility. Xiaoliang Wu et al (2017) investigates the volatility of the UK stock market using Shannon entropy and compares it with traditional measures. Shannon entropy is a more informative measure of volatility, especially during extreme market events.

Zhengqing Gui et al (2016) analyzes the volatility of the Chinese stock market using Shannon entropy and traditional measures. Shannon entropy can better capture the complex and non-linear behavior of the market and provide more accurate measures of volatility. YongtaeKim et al (2016) suggests Shannon entropy is a more robust measure of volatility than standard deviation and is particularly useful in capturing extreme events. Takuji Arai (2016) examines that Shannon entropy is a more accurate measure of volatility than standard deviation, particularly during market crises. Stephen V et al (2015) studied that Shannon entropy is a more sensitive and accurate measure of volatility than standard deviation. Hsiu-Lang Chen et al (2014) examines that Shannon entropy is a more accurate measure of volatility than standard deviation, particularly during market crises. Shu-heng Chen et al (2011) suggest that Shannon entropy is a more sensitive and accurate measure of volatility than standard deviation, particularly in capturing extreme events.

Methodology

In this study two variables/account are considered equity market value of SCRA, total market value of PSX, and three statistical volatility measures are used to check their variability named standard deviation, coefficient of variation, and entropy. Four decades later, standard deviation, coefficient of variation widely used in application, such as determining risk, consistency and volatility, but entropy is that it provides powerful and satisfy result.

Data Samples

The secondary data use in the present study. The data consist weekly "total market value of shares of PSX which were collected from PSX web Pakistan Stock Exchange ((https://www.psx.com.pk/), and weekly "equity security value of SCRA" which were collected from SBP web official website SBP State Bank of Pakistan (https://www.sbp.org.pk/index.html). The weekly data is obtained from PSX and SCRA for period 2011 to 2021, which yielded 724 observations.

Equity Market Value of SCRA

In 2001, the State Bank of Pakistan introduced the Special Convertible Rupee Account (SCRA) with the objective of facilitating non-residents in remitting funds without the need for approval from the State Bank of Pakistan. The SCRA facilitates trading in debt securities (PIBs and T-bills) and equity securities linked to the Pakistan Stock Exchange (PSX). Non-resident Pakistanis and foreign investors leverage the SCRA for investing in the PSX, engaging in trading activities through authorized brokers and brokerage houses. Investors closely monitor SCRA Daily Net Flows positions and regularly assess their equity holdings and market capitalization to make well-informed decisions for optimal investment in diverse securities within the Pakistan market.

Total market Capitalization of Pakistan Stock Exchange (PSX)

The Pakistan Stock Exchange (PSX) is a financial marketplace facilitating the exchange of shares among registered businesses in Pakistan. The market capitalization representing the total value of outstanding shares, providing a key metric for assessing the stock market's size and performance in Pakistan. Serves as a metric to measure both the comprehensive market scale and the significance of individual companies. Investors rely on market capitalization as a pivotal indicator to evaluate the size and performance of the stock market.

Research Design

The Shannon Entropy

The Shannon entropy [25] of a probability measure on a finite set X is given by:

$$S_n(P) = -\sum_{i=1}^{n} pi \ln pi$$

Where $\sum_{i=1}^{n} pi = 1 \geq 0$ and $0 \ln 0 = 0$.

When dealing with continuous probability distributions, a density function is evaluated at all values of the argument. Given a continuous probability distribution with a density function f(x), we can define its entropy as:

$$H = -\int_{-\infty}^{+\infty} f(x) ln f(x) dx$$

Where $-\int_{-\infty}^{+\infty} f(x)dx = 1 \ and \ f(x) \geq 0.$

Results and Discussions

The analysis consists calendar and fiscal year wise data and that data has been divided in sub- groups (year-wise). There are almost eleven years data are taking from 2011 to 2021. The analysis in first step to shows the overall and each year wise graphical presentation then descriptive analysis with mean, Standard deviation, CV, Coefficient of Correlation, Max value and minimum Value and Entropy. In second step to shows that the Normality and volatility distribution and in third step to show the overall comparison of different instrument wise for calendar yea

Graphical Presentation

Figure: 1.1

Graphical Presentation of Overall Data of PSX and SCRA for Calendar year 2011-2021.

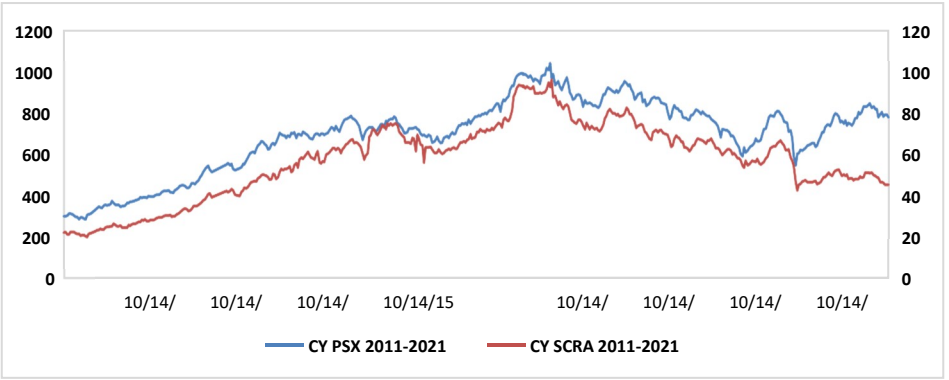

Figure: 1.1 the time series data from 2011 to 2021 shows the market capitalization of Pakistan stock exchange and the market value of equity shares held by nonresident through SCRA. The upward and downward trend is clearly visible in the figure 1.1. The trend increased from 2011 to 2014, followed by a smooth year in 2014-2015. The trend decreased from 2015 to 2016, then increased in 2016-2017 and continuously decreased from 2017 to 2020, with a smooth increase in trend from 2020 to 2021.

Descriptive Analysis

Table 1.2

Shows the Overall Descriptive Analysis of PSX and SCRA for Calendar year 2011-2021:

PSX and SCRA for Calendar Year 2011-2021		
Calendar year	PSX	SCRA
Correlation	0.94	Sig (0.00)
Mean	6,964.40	574.27
Standard deviation	1,785.21	183.63
Coefficient of variation	390.12	312.72
Shannon	8.91	6.63
Max Value	10,409.61	960.12
Min Value	2,862.75	200.44

Table No: 1.2 is indicating that the descriptive statistics of the PSX and SCRA for calendar year 2011 to 2021. There is strong perfect positive correlation between the PSX and SCRA, the

Coefficient of variation is describing that the SCRA is less volatile then PSX also SCRA has more consistent than PSX. According to the Shannon entropy results, SCRA is more consistent than PSX.

Normality and Volatility Distribution

The data were normally distributed for PSX and SCRA Calendar year, because all the probability values are greater than the specified level of significance (0.05), (see Appendix, Table No 1.3 and 1.4). By using volatility distribution for calendar year SCRA and PSX, there is extreme value presence. (see Appendix Figure No 1.1 and 1.2

Findings of Different Volatility Measures of PSX and SCRA of Calendar Year 2011- 2021

Table 1.5

The overall findings of different volatility measures of PSX and SCRA of calendar year 2011-2021

Calendar Year	Coefficient of Variation		Entropy	
	PSX	SCRA	PSX	SCRA
2011	2.69	2.84	5.81	3.24
2012	9.43	10.67	7.26	4.73
2013	10.19	11.32	7.69	5.22
2014	4.13	9.04	7.06	5.33
2015	4.00	7.07	7.10	5.28
2016	10.50	10.00	8.12	5.65
2017	6.62	9.91	7.84	5.84
2018	5.88	8.05	7.65	5.49
2019	9.32	6.91	7.93	5.16
2020	9.50	12.65	7.95	5.60
2021	2.85	4.79	6.86	4.56

From 2011 to 2021, the variability measure of CV reveals that SCRA is less volatile than PSX in only 2016 and 2019, while in the other years PSX is less volatile. This indicates that PSX is less volatile then SCRA. However, the historical trend of PSX shows/describe that 2013 and 2016 years are highly volatile than the other years. The variability measure Entropy for PSX and SCRA has found that for the period 2011 – 2021, in all years SCRA is less volatile and it is more consistent than the PSX. This indicates that SCRA is less Volatile and predictable than PSX. The entropy of SCRA describes that SCRA is less predictable for the year 2016 and 2017 as compare to the other years.

Further, Table No: 4.1 T-test has been used for comparing the average of CVs of PSX and SCRA.

The data suggests that the P-value for the calendar year's coefficient of variation exceeds the designated significance threshold and for Entropy underperform the designated level of significance. Finally, the t-test of the CVs shows that there is no significant difference between PSX and SCRA. On the other hand, entropy of PSX and SCRA has the significant difference, the test result conclude that entropy gives the better understanding of the data variability as compare to the other measures.

Table 4.1

Comparison of different measures of volatility for PSX and SCRA for calendar year 2011-2021.

Calendar year	Coefficient of Variation	Entropy
Hypothesis	CV of SCRA and PSX is same.	Entropy of SCRA and PSX is same.
T-test	-1.289	7.694
P-Value	0.167	0.000

Conclusion

In conclusion, the analysis conducted in this study reveals a strong correlation between SCRA and PSX. The smoothness observed in the time series of SCRA indicates its potential for providing improved predictability in portfolio investments. Considering SCRA as a key factor influencing the market value of PSX, understanding its behavior becomes crucial for forecasting PSX data accurately. Furthermore, the results highlight the efficacy of entropy as a superior measure for assessing variability compared to CV and standard deviation. Entropy captures the inherent unpredictability and uncertainty in the data, offering a more comprehensive understanding

of its variability. This finding emphasizes the importance of adopting entropy as a valuable tool in volatility analysis and risk assessment.

The adoption of entropy as a measure of variability provides a robust framework for evaluating and managing risk in financial markets, ultimately facilitating informed decision-making processes.

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Appendix

Normality Test

Table 1.3

Shows the One Sample

CY SCRA	P-Value	Distribution
2011	0.78	Normal
2012	0.93	Normal
2013	0.53	Normal
2014	0.68	Normal
2015	0.86	Normal
2016	0.54	Normal
2017	0.06	Normal
2018	0.27	Normal
2019	0.51	Normal
2020	0.10	Normal
2021	0.71	Normal

Table 1.4

Shows the One Sample Kolmogorov Smirnov Normality Test Kolmogorov Smirnov Normality Test on PSX of Calendar Year 2011-2021. on SCRA of Calendar Year 2011-2021

CY PSX	P-Value	Distribution
2011	0.96	Normal
2012	0.77	Normal
2013	0.32	Normal
2014	0.15	Normal
2015	0.74	Normal
2016	0.61	Normal
2017	0.21	Normal
2018	0.78	Normal
2019	0.33	Normal
2020	0.10	Normal
2021	0.70	Normal

Volatility Distribution Test

Figure 1.1

Graphical Presentation of

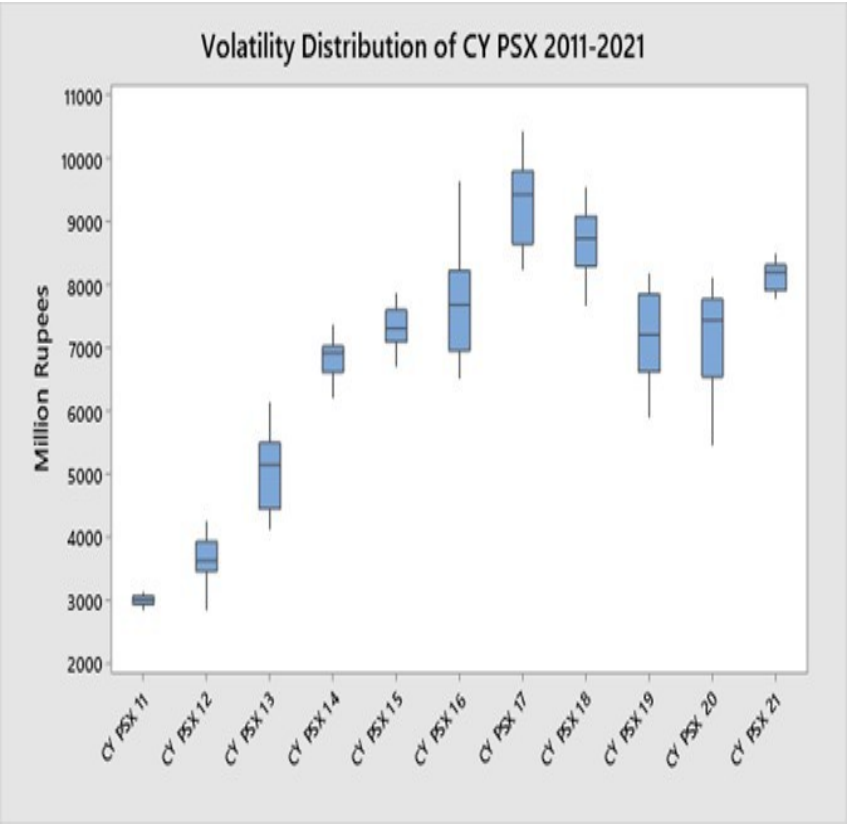

Figure 1.2

Graphical Presentation of Volatility Distribution of PSX for Volatility Distribution of SCRA for Calendar year 2011-2021. Calendar year 2011-2021.