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Original Article

Exploring Quantum Harmonic Oscillator as an Indicator to Analyse Stock Price Volatility

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Abstract *- This paper explores using the Quantum Harmonic Oscillator (QHO) indicator for predicting stock price movements in financial markets. Quantum Harmonic Oscillator is a technical analysis tool commonly used in physics that has recently gained attention in finance. By analysing the mean percentage change in price, it determines the range of energy levels that correspond to smaller price changes, suggesting stability in the price movement. The QHO indicator can help traders and investors identify potential breakouts or continuations of existing trends, leading to improved decision-making and profitability. This study presents a comprehensive analysis of the Quantum Harmonic Oscillator's performance and its potential application in financial markets.*

Keywords *- Quantum harmonic oscillator, Mean percentage change, Energy levels, Technical analysis.*

1. Introduction

The use of mathematical models and techniques in finance has grown exponentially over the past few decades, with researchers constantly seeking new and innovative methods for predicting financial markets. One such approach is the application of quantum mechanics, which has been shown to have potential in modelling financial systems. In particular, the quantum harmonic oscillator has emerged as a promising tool for predicting financial markets due to its ability to represent complex systems and its inherent mathematical elegance.

The quantum harmonic oscillator is a fundamental concept in quantum mechanics that describes the behaviour of a particle trapped in a potential well. It is a widely studied and well-understood model that can be used to describe a wide range of physical phenomena, from molecular vibrations to the behaviour of electromagnetic radiation. In recent years, researchers have applied the principles of the quantum harmonic oscillator to financial markets intending to develop novel and accurate forecasting methods.

Several studies have shown that the quantum harmonic oscillator can be used to model financial time series data, such as stock prices, with high accuracy. The quantum harmonic oscillator is a fundamental concept in quantum mechanics that describes the behaviour of particles in a harmonic potential field. In this system, the potential energy of a particle is proportional to the square of its distance from a fixed point, creating a parabolic potential well. Unlike classical harmonic oscillators, the quantum harmonic oscillator is notable for its energy spectrum, which is quantized and equally spaced. This property has important implications for the behaviour of particles in materials, as well as for various applications in physics, chemistry, and engineering. In recent years, researchers have also explored the potential of quantum harmonic oscillators for analysing and predicting financial market trends, which has led to the development of new indicators and models based on quantum principles.

The use of quantum harmonic oscillator as indicators are based on the principles of quantum mechanics, which allow for the analysis of financial data in new and innovative ways. For example, the energy spectrum of a quantum harmonic oscillator can be used to identify patterns in financial market data, such as trends and cycles, that may not be apparent using classical methods. In addition, quantum harmonic oscillator models can be used to price financial derivatives and measure financial risk, providing valuable information for investors and financial institutions.

This paper aims to use some of these approaches and their potential for improving financial forecasting and decision-making. Specifically, we will examine the use of quantum harmonic oscillator indicators and models in financial markets and explore the advantages and limitations of these approaches. We will also discuss some of the challenges and future directions for research in this area and consider the implications of quantum mechanics for financial theory and practice.

Overall, using the quantum harmonic oscillator in finance represents an exciting new field of research with great potential for further development. In this paper, we explore the application of the quantum harmonic oscillator to financial markets and present an analysis of its effectiveness in predicting stock price volatility. We also discuss the potential limitations of this approach and suggest directions for future research.

2. Literature Review

Bologna and Grigolini [2] (1990) proposed a simple approach to evaluate the propagator of the quantum harmonic oscillator. The authors used a time-slicing method to evaluate the propagator, a fundamental quantity in quantum mechanics. Their approach involved dividing the time interval into several small time slices and evaluating the propagator over each slice.

Jorgenson & Wilcoxen [5] (1990) explores the impact of environmental regulations on economic growth in the United States. While it does not directly address the use of quantum harmonic oscillator indicators in financial markets, it provides important insights into the complex relationship between economic and environmental factors.

Gao and Cheng [4] (2006) explored a quantum approach to financial risk measurement. The authors proposed a quantum method for estimating the risk associated with financial investments. They applied quantum theory to calculate the risk of a portfolio of stocks and found that their approach could provide a more accurate risk assessment than classical methods. The authors concluded that quantum mechanics may have significant applications in the field of financial risk management.

Laskar & Rebonato [6] (2009) provides an overview of the emerging field of quantum finance, which seeks to apply principles of quantum mechanics to financial modelling and analysis. The authors discuss the potential advantages of this approach and highlight some of the key challenges and limitations.

Baaquie, B. E. [1] (2013) offers a comprehensive introduction to quantum finance, including a detailed treatment of path integrals and Hamiltonians for options and interest rates. The author provides numerous examples and applications to help readers understand the concepts.

Mandelbrot [9] (2013) provides important background knowledge for understanding the complexity and self-similarity of financial market data. Moreover, he presents his theory of fractals and demonstrates how they can be used to model complex phenomena, such as turbulence, clouds, and coastlines. His work challenges traditional assumptions of smooth, linear patterns in nature and provides a new way of understanding the irregular, self-similar structures common in financial market data.

Zhang et al. [10] (2015) explored the relationship between the quantum harmonic oscillator and stock volatility. They proposed a quantum-inspired model for stock volatility based on the concept of the quantum harmonic oscillator. By comparing the model's predictions with actual stock price data, they found that their quantum-inspired model was more accurate than traditional financial models in predicting stock price volatility. This study provides evidence that quantum-inspired models may have potential applications in financial markets.

Liu & Zhou [7] (2016) explores the use of time-dependent quantum harmonic oscillators in financial analysis, focusing on the prediction of market trends and the identification of turning points. The authors provide a clear explanation of the concept and demonstrate its potential applications. The authors suggest that their approach can be extended to other types of derivatives and provide an example of pricing an exotic derivative with their model.

Chen et al. [3] (2018) propose a novel approach to financial derivative pricing using concepts from quantum mechanics. The authors apply the harmonic oscillator model and ideas from quantum field theory to develop a new pricing formula for options, which they compare to traditional pricing models. They show that their method produces more accurate pricing estimates, especially for options with complex payoffs or under extreme market conditions.

Makridakis [8] (2021) investigated using artificial intelligence and deep learning techniques for time series forecasting in the context of stock prices. The author explores the potential advantages of these approaches and provides a case study to demonstrate their effectiveness. The paper highlights the need for continued research and development in this rapidly evolving field.

3. Data Collection

This paper collects historical data from the YAHOO Finance website for various stocks: Gold Coin Health Foods Limited, Mullen Automotive Inc., EVGO Inc. and ATMOS Energy Corporation. Here these stock indices are particularly chosen through convenient sampling based on their behaviour and trend, respectively. Historical data for the same is collected in the time span of one year from 1st January 2021 to 1st January 2022.

4. Methodology

The basic concept of quantum harmonic oscillator differs from other classical models based on the ground state energy of the particle, whereas the quantum counterpart of harmonic oscillator suggests that the ground state energy of any quantum particle is nonzero and equal to the $\left(\left(\frac{1}{2}\right)\hbar\omega\right)$.

The formula for the energy of quantum particles depends on angular frequency. "Angular frequency" typically refers to the rate of change of a circular motion or oscillation derived from the formula given below:

$$\omega = \sqrt{\frac{k}{m}}$$

Where k is the spring constant which is 0.001, and m is mass based on the diffusion coefficient given by $m = \frac{\hbar^2}{2D}$

Diffusion coefficient gives the spread of the area covered by the wave, here, stock movement, so it is related to the volatility of the stock.

Therefore, the diffusion coefficient is calculated with the formula: $D = \frac{x^2}{2}$

Finally, the energy of stock will be given by: $E_n = \left(n + \frac{1}{2}\right)\hbar\omega$

Here n denotes the state of the stock, which is related to the energy of the stock. The energy of the stock is positively correlated to the volatile nature of the stock. Stock with high energy levels is highly volatile in nature, and it is also the same for stocks with low energy levels.

5. Results and Discussion

5.1. Descriptive Analysis

Table 1. Descriptive analysis

Parameters	GOLDCOINHF	Mullen	EVGO	ATMOS
Planck Constant	6.26E-34	6.26E-34	6.26E-34	6.26E-34
Mean (average return)	0.059213871	-0.08590653	-0.017794383	19.62283221
Standard Deviation	0.129067291	0.224882386	0.047622681	39.19450221
Delta T (Holding Period)	7	7	7	7
Average Square Value	8.638699409	6.244865488	6.010795716	19.62283221
Average Value	2.939166448	2.498972887	2.451692419	4.429766609
Diffusion Coefficient	4.319349704	3.122432744	3.005397858	9.811416105
mass (m)	4.54E-68	6.27517E-68	6.51954E-68	2.00E-68
Spring constant (k)	0.0001	0.0001	0.0001	0.0001
Angular frequency (w)	4.69515E+31	3.99197E+31	3.91644E+31	7.0763E+31

In this table, different parameters regarding quantum harmonic oscillators are calculated with respect to the stocks undertaken, say, GOLDCOINHF, Mullen, EVGO, and ATMOS.

5.2. Gold Coin Health Food Limited

Table 2. Gold Coin Health Food

Quantum Harmonic Oscillator					
State	0	1	2	3	4
Energy	0.014696	0.044087	0.073479	0.102871	0.132262
Mean percentage change in price	**0.196228322**				

Here mean percentage change in price for Gold Coin Health Food Limited is 0.196, which is greater than the 4th state energy level of the respective.

5.3. Mullen Automotive Inc.

Table 3. Mullen automotive Inc.

Quantum Harmonic Oscillator					
State	0	1	2	3	4
Energy	0.012495	0.037485	0.062474	0.087464	0.112454
Mean percentage change in price	**-0.094242793**				

Here mean percentage change in price for Mullen Automotive Inc is -0.094, which is in between the 3rd and 4th state energy level of the respective, while the negative sign denotes a downtrend.

5.4. EVGO Inc.

Table 4. EVGO Inc.

Quantum Harmonic Oscillator					
State	0	1	2	3	4
Energy	0.012258	0.036775	0.061292	0.085809	0.110326
Mean percentage change in price	**-0.034939459**				

For EVGO Inc., the mean percentage change in price is -0.035, which is in between the ground and 1st state energy level of the respective, while the negative sign denotes a downtrend.

5.5. ATMOS Energy Corporation

Table 5. ATMOS energy corporation

Quantum Harmonic Oscillator					
State	0	1	2	3	4
Energy	0.007240	0.021720	0.036200	0.050679	0.065159
Mean percentage change in price	**0.017969656**				

Here mean percentage change in price for ATMOS Energy Corporation is 0.018, which is in between the ground and 1st state energy level of the respective.

5.6. Graphical Representation

These below-showcased graphs interpret the same for the stocks undertaken, which gives the same result mentioned in the tables. Stock prices of EVGO and Mulan have a downtrend, whereas ATMOS and GOLDCOINHF have an uptrend, respectively.

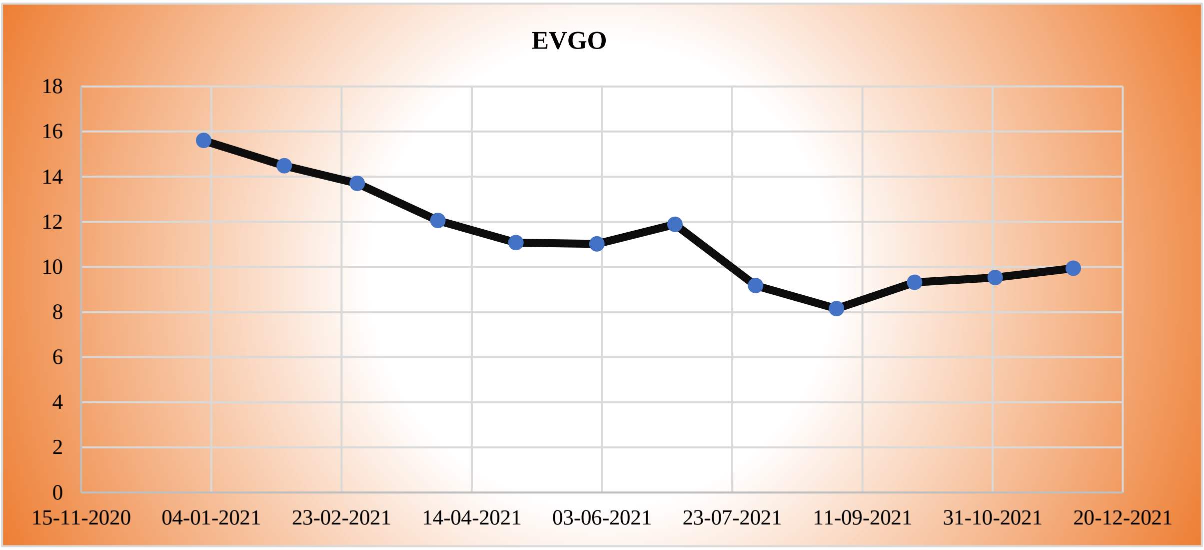

Fig. 1 EVGO

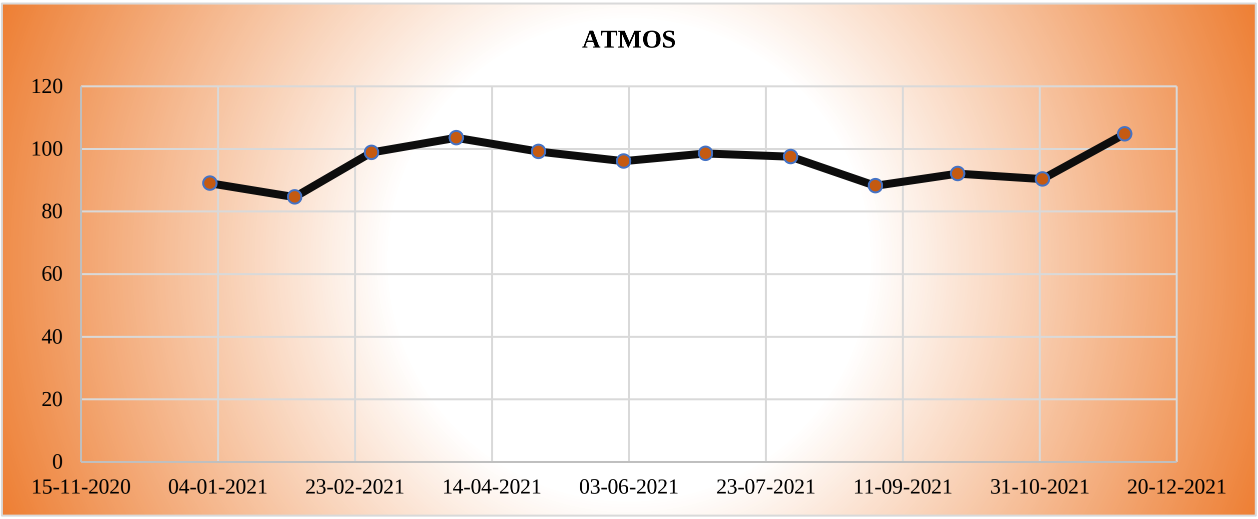

Fig. 2 ATMOS

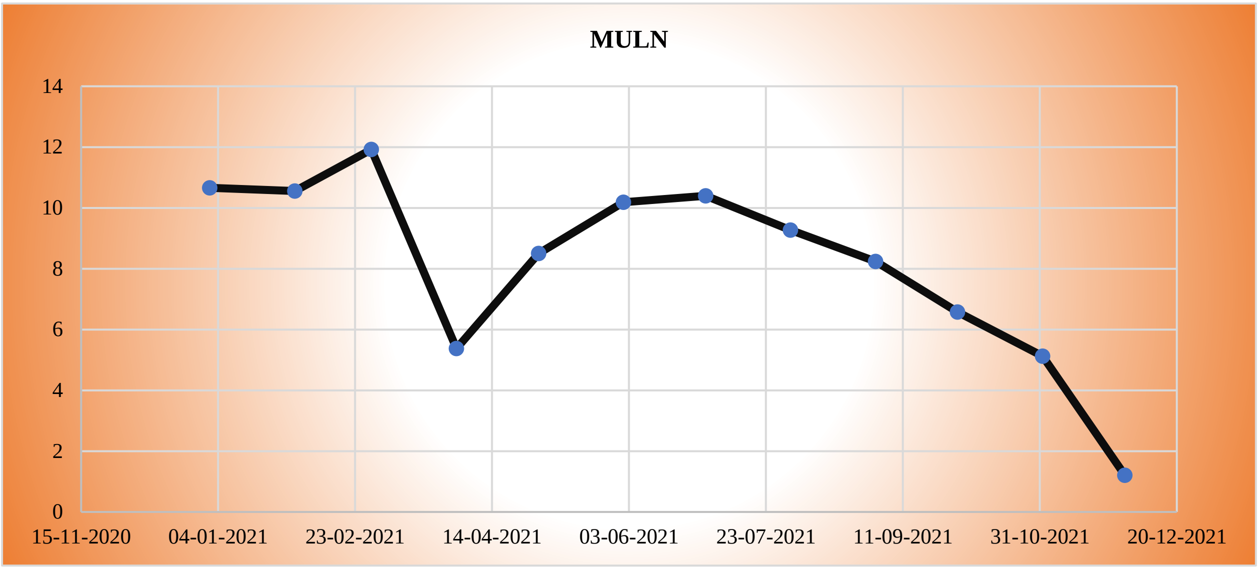

Fig. 3 MULAN

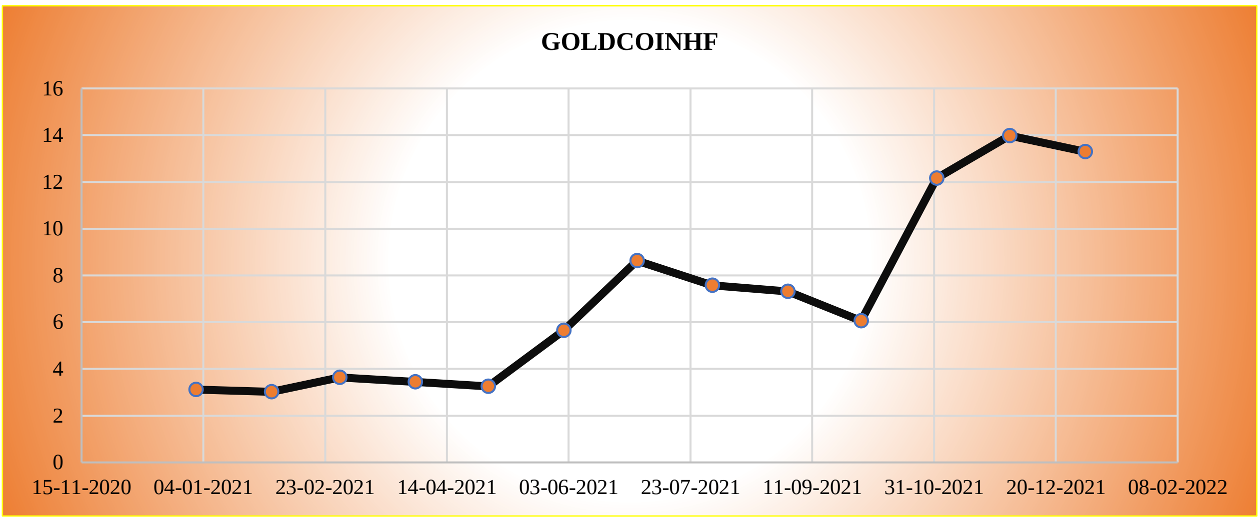

Fig. 4 GOLDCOINHF

6. Discussion

The Quantum harmonic oscillator model derives energy levels for the mentioned stocks. With the help of historical data ranging from 1st January 2021 to 1st January 2022, the mean percentage change of price can be derived. In general, the energy levels of a harmonic oscillator correspond to different states of the system; lower energy levels suggest that the stock is relatively stable and not experiencing significant price fluctuations, while higher energy levels indicate more excited or unstable states.

Predictions derived from the model can be parted into two different types:

1. If the mean percentage change in price is between 0th and 1st energy levels, the volatility of the stock is very low in nature.
2. If the mean percentage change in price is between the 3rd and 4th energy levels, the volatility of the stock is very high in nature.

Moreover, the sign of mean percentage change denotes the trend of the particular stock movement. A positive sign denotes the uptrend and vice-versa.

Now after considering the volatility and its trends, it is understood that a buy signal is generated when the percentage change in price is within the range of the first and second energy levels of the quantum harmonic oscillator (QHO) because it indicates that the stock price is experiencing a relatively small, yet significant change in price.

The first and second energy levels of the QHO are lower energy levels, which correspond to smaller changes in price. When the price change falls within this range, it suggests some stability in the price movement and that the stock may be experiencing a period of consolidation before a potential breakout or continuation of an existing trend.

Similarly, a sell signal is typically generated when the percentage change in price is within the range of the fourth and fifth energy levels of the QHO, which correspond to higher energy levels and larger changes in price. This suggests that the stock price has experienced a significant move and maybe overbought, potentially indicating a reversal or a period of consolidation before further upward momentum.

7. Conclusion

This paper applies the quantum harmonic oscillator model on four different stocks, and respective predictions are mentioned below:

1. Mean percentage change in the price of GOLDCOINHF is greater than the value of the fourth energy level of the stock, so it is highly volatile in nature and following an uptrend.
2. Mean percentage change in the price of MULN is between the third and fourth energy levels of the stock, so its volatility is comparatively high in nature and following a downtrend.
3. Mean percentage change in the price of EVGO is between zero and first energy levels of the stock, so its volatility is comparatively low in nature and following a downtrend.
4. Mean percentage change in the price of ATMOS is between zero and the first energy levels of the stock, so its volatility is comparatively low in nature and following an uptrend.

The results suggest that the quantum harmonic oscillator model indicates selling signals for GOLDCOINHF and MULN while indicating buying signals for EVGO and ATMOS.

Future Scope

Future research could focus on developing more sophisticated models that incorporate quantum principles and techniques, such as quantum machine learning and quantum computing, to improve financial forecasting and decision-making. The energy spectrum of a quantum harmonic oscillator can be used to identify patterns in financial market data, such as trends and cycles, that may not be apparent using classical methods. Future research could aim to refine and validate these indicators and explore their potential for detecting and predicting market movements. It is important to consider the practical implications and limitations of using quantum-inspired methods in financial markets, including issues such as data availability, computational resources, and regulatory frameworks.

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