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Research Paper

Investigating market efficiency of different oil markets and comparing it using Quantum harmonic oscillator

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Abstract:
The probability of determining the market in a ground state will be estimated with the help of quantum harmonic oscillator in order to evaluate market efficiency. This approach will compare the probabilities of ground state of the Mentha oil and Crude oil futures to analyse which of the following is more efficient.
Keywords: *Quantum harmonic oscillator, Market efficiency, Ground state probability, Mentha oil futures, Crude oil futures*

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I. Introduction:

Market efficiency is a term that assesses how well market prices take into account all relevant data. If the markets are efficient, then all available information has already been factored into pricing, creating opportunities for those who are buying and selling stocks for profit. The ability of the market to assimilate information, which in turn creates possibilities for buyers and sellers, is measured using a financial technique called "market efficiency." Without necessarily raising transaction costs, this procedure affects a transaction. Because of market efficiency, transaction costs should be inexpensive when compared to the anticipated returns on investment for the strategy.

Forms of Market Efficiency

Market efficiency exists in three forms. They are as explained below:

- The weak form: Weak form efficiency denotes a market where share prices fully and fairly reflect all past information. It is not possible to make abnormal gains by studying past share price movements in this type of forms.
- The semi-strong form: This type of market efficiency is predicated on the idea that equities in the market often change quickly to take in the most recent information that is made public, ensuring that investors' gains do not outweigh those of the market when they trade using that information.
- The strong form: This model of market efficiency makes the assumption that market prices take into account both public and private information. The other two versions are incorporated into this presumption (weak form and semi-strong form). Considering that stock prices take into account both private and public information, no investor will make more money than the average investor, even if they have access to insider (private) knowledge.

This research will explore weak form of market efficiency and two different oil markets of India will be going to compare for the same.

Mentha Oil

Aromatic plant known as Mentha is also known as Japanese pudina in India. Mentha oil is created by steam distilling and filtering dried Mentha arvensis leaves, and then it can be processed to create menthol and other derivatives. The food, pharmaceutical, fragrance, and flavoured industries all use Mentha oil and its derivatives extensively. Prices for Mentha oil have always been highly erratic. India has become a major export market in recent years for Mentha oil and its derivatives. Factors Influencing the Mentha Market are:

International factors

- Import demand from major importing countries.
- USD–INR rate, the commodity being export-oriented.
- Price of synthetic Mentha oil in international market.

Domestic factors

Production related

- Mentha oil price is influenced by an increase or decrease in the Mentha crop acreage which depends on the climate during sowing and the price realization in the previous season.
- Prevailing weather conditions; the incidence of cold wave and heavy rains are harmful during leaf formation.
- Quantum of arrivals during the harvest season.

Consumption related

- Domestic demand from pharmaceutical companies which usually increases in winter
- Export demand from importing countries

Crude Palm Oil

The mesocarp (reddish pulp) of the fruit of oil palms, particularly the African oil palm and to a lesser extent the American oil palm, is where palm oil is obtained. Palm oil is an edible vegetable oil. For stakeholders in crude palm oil (CPO), like importers, refiners, and merchants, risk management strategies are essential. Factors Influencing the crude palm oil Market are:

International factors

- Mainly two exporting and producing countries of Crude oil are Malaysia and Indonesia. Prices are impacted by unfavourable weather conditions for palm production. Palm prices are also impacted by significant swings in the currencies of Malaysia and Indonesia.
- Because soy oil and palm oil compete for market share in the worldwide vegetable oil industry, soy bean and other oilseed production, consumption, and ending stocks have a direct impact on prices.
- Crude oil movement has an impact on pricing as well because a major increase in energy costs increases the demand for substitute fuels like biofuel. Biofuel is also made with the help of vegetable oils.

Domestic factors

- Rupee movement
- Closing price of stocks
- Policies for import duties
- Economic well-being of final consumer
- Domestic oil production

II. Literature Review:

Ivancevic [6] (2009) proposed a bidirectional quantum associative memory structure for Black–Scholes–like option price progression. It comprised of a pair of coupled NLS equations, one controlling stochastic volatility as well as the other administering option price, both self-organizing in an adaptive ‘market heat potential' trained by continuous Hebbian learning. By using approach of lines with adaptive step-size integrator, this stiff pair of NLS equations were solved numerically. He established a quantum neural composition approach for option price modelling.

Alvarez [1] (2010) used lagged detrended fluctuation analysis (DFA) to investigate the effectiveness of crude oil markets (i.e., autocorrelations are dependent of the time scale). Results using spot price data for the years 1986 to 2009 showed significant efficiency deviations linked to lag autocorrelations, therefore implementing the random walk for crude oil prices entails significant forecasting costs.

Lean[7] (2010) explored both mean-variance (MV) and stochastic dominance (SD) techniques to analyse the market efficiency of oil spot and futures prices. They found no indication of any MV and SD correlations between oil spot and futures based on the West Texas Intermediate crude oil data for the sample period 1989–2008 indices. This implies that there is no possibility for arbitrage between these two markets, spot and futures do not dominate one another, investors have no preference between investing in spot or futures, and oil prices are unaffected by either market operate effectively and logically.

Meng et al [9] (2016) construct an econophysical structure for the stock market based on quantum mechanics' physical concepts and mathematical structures, in which we analogously map massive numbers of single stocks into a reservoir consisting of many quantumharmonic oscillators, and their stock index into a typical quantum open system—a quantum Brownian particle. In Heisenberg's uncertainty principle of quantum mechanics, the irrationality of stock transactions is quantitatively treated as the Planck constant in a similar manner. Furthermore, he uses the quantum Brownian motion model to analyse real stock data from the Shanghai Stock Exchange of China and investigate fat-tail phenomena and non-Markovian behaviours of the stock index, interpreting and studying the limitations of the classical Brownian motion model for the efficient market hypothesis from a new perspective of quantum open system dynamics.

Gao and Chen [5] (2017) offer a financially interpretable quantum model to examine the probability distributions of stock price returns. The dynamics of a quantum particle are likened to the movement of a stock market. Then, using the wave functions that evolve according to the Schrodinger equation, the probability distributions of price return can be determined. In this study, instead of using a harmonic oscillator, a quantum anharmonic oscillator is used on the stock in the liquid market. With the addition of mixed-state and multi-potential, proposed quantum model effectively recreates leptokurtic price return distributions. As a special case of the illiquid market, the trend following dominant market is examined, in which the price return follows a bimodal distribution.

Lee [8] (2020) compares the crude palm weak-form efficient market hypothesis with West Texas Intermediate crude oil market by implementing the quantum harmonic oscillator in the oil market. With this method, they may estimate one parameter—the likelihood of discovering the market in a ground state—and use it to measure market efficiency.

Ryu [10] (2021) looked at the weak-form efficient market theory because the log price series for REIT stocks for US REIT equities, contradicted the random walk theory as a model specification, the variance ratio test revealed that the general stock market and REIT markets were not efficient in the weak-form. Instead, he used the quantum harmonic oscillator to present definite evidence. The ground state solution for a random walk included in the quantum harmonic oscillator turned out to be a more effective way to test the efficient market hypothesis.

Bhatt and Gor[2] (2022) showcased an interesting structure of Risk Neutral system. They also examine single step and multistep quantum binomial option pricing model. This approach elaborates circuit proposed by A. Meyer. Bhatt and Gor[3] (2022) review applications of quantum harmonic oscillator model in financial mathematics and also discussed about different applications of quantum harmonic oscillator and its characteristics.

Data Collection:

Daily data of Mentha oil and Crude palm oil futures for fixed period of year initiated from 1st January of 2021 are collected from website namedinvesting.com.

Methodology:

Descriptive analysis of Mentha oil futures and Crude palm oil futures are calculated with the use of JAMOVI. The results of the comparison are shown below:

Table 1: *Data Exploration*

Descriptive		
	Mentha Oil Futures	**Crude Palm Oil Futures**
N	258	258
Missing	0	0
Mean	**0.0326**	**0.0914**
Std. error mean	0.161	0.229
Median	0	0.24
Mode	0	-15.6
Standard deviation	**2.59**	**3.69**
Variance	**6.71**	**13.6**
Range	25.4	25.1
Minimum	-11.1	-15.6
Maximum	14.3	9.58
Skewness	0.413	-0.88
Std. error skewness	0.151	0.151
Kurtosis	6.17	2.81
Std. error kurtosis	0.302	0.302

From the values of parameters of quantum harmonic oscillator, one can observe that crude palm oil futures market has more diffusion coefficient and lesser mass comparatively. Similarly, gamma factor is also greater for Crude palm oil market then Mentha oil futures.

Table 2: Parameter Estimation

Parameters	Mentha Oil Futures	Crude Palm Oil Futures
Planck constant	6.26E-34	
Diffusion coefficient	0.00053138	0.00417698
Mass	3.69E-64	4.69E-65
K	0.0001	0.0001
W	5.21E+29	1.46E+30
Mw	1.92E-34	6.85E-35
mean square	0.00106276	0.00835396
Gamma	1.63E-04	4.57E-04

Above mentioned results affect the quantum harmonic oscillator model for predicting probabilities and eigenvalues for the respective eigenstates. According to the probability value assigned to the ground state, the oil market is identical to other financial market in that it is relatively close to the efficient market.

Table 3: Quantum Harmonic Oscillator Model

Quantum Harmonic Oscillator					
Mentha Oil Futures					
State	0	1	2	3	4
Energy	0.000163	0.000489	0.000815	0.001141	0.001467
Hermite Polynomial	1.000000	0.036111	-1.998696	-0.216619	11.984354
Amplitude	0.558995	0.395269	0.197635	0.011646	0.001456
Eigen Function	0.558904	0.014271	-0.394947	-0.017475	0.341811
Eigen Value	0.174644	0.087294	0.021816	0.000525	0.000023
Probability	0.790232	0.197429	0.012331	0.000007	0.000000
Crude Palm Oil Futures					
State	0	1	2	3	4
Energy	0.000457	0.001371	0.002285	0.003199	0.004113
Hermite Polynomial	1.000000	0.060465	-1.996344	-0.362568	11.956141
Amplitude	0.431992	0.305465	0.152732	0.009000	0.001125
Eigen Function	0.431795	0.018461	-0.304767	-0.022597	0.263453
Eigen Value	0.080580	0.040253	0.010054	0.000242	0.000011
Probability	0.790439	0.197249	0.012306	0.000007	0.000000

Graphical Representation:

Mentha oil and crude palm oil futures' graphs are shown here. It showcases probabilities with its respective eigen values. Here differences of probabilities between two observed markets are very less so it will not give any difference while visualizing but one can observe that the Mentha oil futures have greater eigen values than the other market.

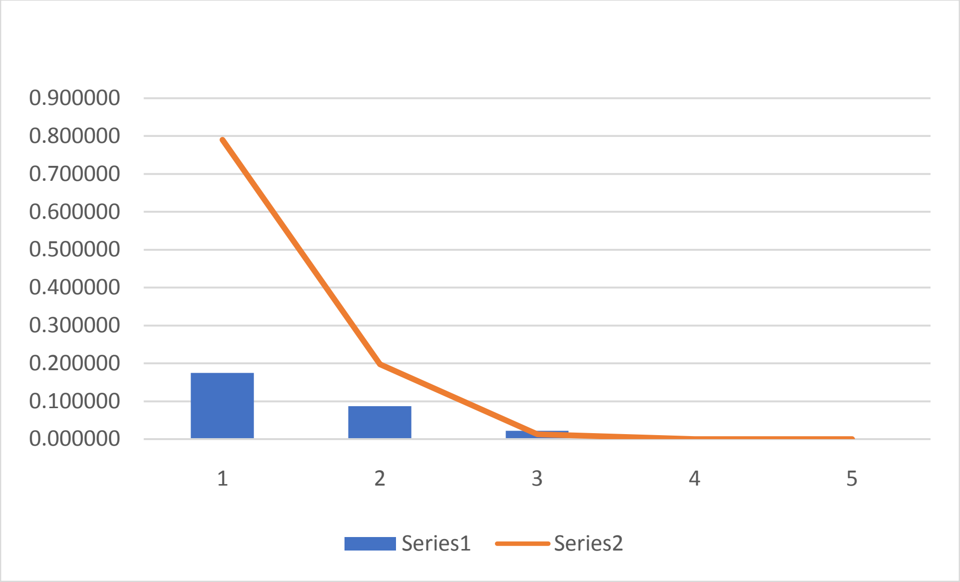

Figure 1: Mentha Oil Futures

Probability of Crude oil market is slightly greater than the probability of Mentha oil market for ground state but for all other states, the probability of Crude oil market is slightly lesser than the Mentha oil market.

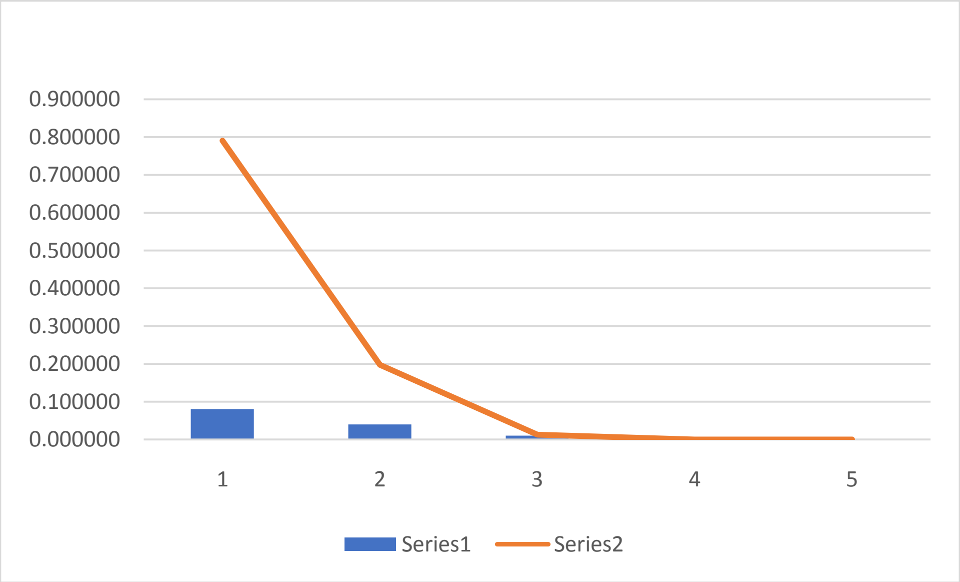

Figure 2: Crude Palm Oil Futures

III. Conclusion:

This study examines the weak-form market efficiency for the Crude palm oil and Mentha oil markets. We did not account for exogenous shocks and policy changes; rather, this study presents an overall market state in regards to market efficiency. This research draws to the conclusion that the CPO market is more efficient than the Mentha oil market because ground state probability of CPO market is 79.044% which is slightly better than the probability of Mentha oil market which is 79.023%

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