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Analysis of Financial Markets in Selected Countries: An Approach to Quantum Mechanics in Economics

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ABSTRACT

The stock market of any country plays an effective role in attracting financial resources and contributing to the development of that country. The stock market also has a significant importance in economic recession and prosperity, which are affected by national macro policies. Effective political decisions made by politicians can lead to the attraction of significantly more capital. Thus, analyzing the stock market using an accurate analytical system is essential. Following Alves et al.'s (2020) study that examined the stock market efficiency index of different countries, the present study selected and compared the stock markets in Iran, Germany, England, Brazil, Turkey, Russia, Japan, Switzerland, Saudi Arabia, South Korea, and India based on the daily data of the stock markets from 2013 to 2023. Using Schrödinger's equation and Hamilton's expansion, the present study adopted the financial quantum approach to solve the wave function and draw and compare the distribution and average rate of return diagrams. The data from the stock markets of the selected countries indicated the highest fluctuations but less efficiency in the Turkish stock market, while the lowest range of fluctuations and higher efficiency were found in the British stock market. Moreover, the British stock market has the minimum average rate of return, the minimum risk, and the maximum transparency, while the Turkish stock market has the maximum average rate of return, the highest risk, and the lowest transparency.

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1. Introduction

Financial markets play a vital role in mobilizing resources in the national economy and directing them to productive economic uses. Thus, productive investment is essential for a country's economic development. One of these markets is the stock market which holds shares of various production, service, and investment companies, provides liquidity, and reduces transaction costs. Thus, a stock market has always been a suitable place to attract stagnant financial resources while providing the capital required by companies. As a result, this market plays an essential role in times of inflation and when people have reduced purchasing power. Thus, the importance of stock markets is increasing constantly and these markets have attracted the attention of economic scholars. When a country's economy is suffering from stagflation, policymaking by statesmen and applying effective policies are of high significance. One of the factors affecting financial development is the transparency and simplicity of financial laws and regulations, which increases investment and consequently the demand for financial resources and contributes to the development of the financial sector. A financial political economy involves all macro policies adopted and put into practice by statesmen and planners. Adopting financial and monetary policies to affect the country's international relations has a significant impact on financial markets. Hence, the government plays an essential role in providing financing services, especially in developing countries. Furthermore, the government's supervisory and supportive role has always influenced the national macro-economy. Thus, the adoption of optimal policies improves efficiency in different markets, contributing to the improvement of economic development (Ashrafi et al., 2013). The analysis of financial markets using an accurate analytical system is of high significance. In 1863, Jules Regnault, a pioneer French broker's assistant, tried to develop a "random walk" model based on the assumptions of social physics to capture the market pulse. Since then, many authors have attempted to determine the exact nature of this fluctuating reality using scientific models, methods, and tools. Their research has established a connection between economics and physics. In the mid-1990s, following some essential developments in physics, a new body of knowledge emerged to examine financial prices (Jovanovic 2016). The official origin of this knowledge dates back to 1996 with the publication of an article by Stanley et al. (1996) who introduced the term *econophysics*. For over two decades, econophysics has focused on investigating stock price fluctuations using quantum physics formulas and Schrödinger's function in cases involving uncertainty and randomness, especially when investigating stock markets. Previous studies have generally adopted an econometric and financial management approach for data analysis. However, using a physical and quantum economic perspective, the present study seeks to find out if physical economics can have any new contributions to the field. To compare stock markets with different degrees of efficiency at the international level, 11 countries including Iran, Germany, England, Brazil, Turkey, Russia, Japan, Switzerland, Saudi Arabia, South Korea, and India were selected based on Alves et al.'s (2020) study that examined the stock market efficiency. The stock markets in the selected countries were then compared using their daily data from 2013 to 2023. The financial quantum approach, Schrödinger's equation, and Hamilton's expansion were used to solve the wave function and plot and compare the diagrams for the distribution and the average rate of return. This study is organized as follows: The second section describes the theoretical framework of the study. The third section introduces the research methodology. The fourth section presents the data analysis. Lastly, the fifth section presents the conclusions and new directions for future research.

2. Literature Review

2.1 Theoretical Framework of the Study

The primary economic goal of every individual and household is to maximize utility by increasing consumption. Thus, households seek to maximize the utility of consumption throughout their entire life by smoothing their consumption (Tavakolian 2011, 117). In a dynamic economy, transferring household funds to businesses and firms through financial markets leads to increased economic growth and more employment opportunities. In countries where there are no financial markets, especially advanced and active stock markets, or such markets have not yet been institutionalized and the monetary value is constantly decreasing due to inflation, people often tend to keep their assets in real (non-productive) form to avoid losses caused by inflation (Tavakolian 2011, 118). Global experience has shown a close relationship between the development of a country's capital market and its economic development (Salmani et al., 2015: 96). Moreover, providing adequate capital for economic development is one of the main concerns of countries, especially developing countries. Some countries are facing low savings and a lack of adequate capital formation. Financial markets have a significant impact on the economic development of countries with optimal supply and allocation of resources and fair distribution of wealth. Thus, some differences between developed and underdeveloped economies can be attributed to the degree to which their stock markets are efficient. The optimal performance of the stock market is one of the factors for achieving high economic growth. In addition, poorly functioning stock markets are one of the reasons many countries remain poor (Maghsoudi et al., 2021). The stock market is the economic thermometer of the country and the stock price behavior is affected by the economic and political performance. Stock returns are influenced by various factors, especially government decisions, economic policies, and information transparency to reduce the risk caused by uncertainty because otherwise, economic actors' concerns for future developments prevent them from investing, which results in continuous problems in the capital market due to lack of liquidity. Accordingly, the fluctuations of these variables over time affect investors’ economic and financial decisions and predictions (Amiri & Beiranvand, 2011: 50).

High fluctuations in financial markets cause the entry and exit of financial resources, affecting the economy and creating huge economic losses, especially in developing countries. Stock fluctuations are very essential in economic analysis. The financial-political economy is highly dependent on the mutual relationship between the government and the market, and the political economy depicts the interaction between the government and the market (Taghavi, 2000: 23). Political uncertainty or unknown policies adversely affect investors' decisions, making risk-averse economic actors leave the market and invest abroad (Dimitrios, 2000). Considering that economic actors make their decisions based on future expectations of economic policies, an effective financial political economy approach should be implemented in the capital market. Thus, it is necessary to maintain transparency and stability when enforcing economic policies to prevent the negative effects of uncertainty and lack of transparency on the capital market (Amiri & Beiranvand, 2011). The performance of the stock market has a significant macroeconomic impact. If the monetary policies influence the real part of the economy and subsequently, the prices, the monetary conditions of the economy will affect the behavior of the stock market returns. Hence, the stock market as a capital market will play an increasingly essential role in transferring monetary policy. The development of the capital market can lead to prosperity in production and contribute to economic growth through increasing productive investment opportunities, reducing transaction costs, reducing risks, equipping savings, increasing information transparency, and facilitating the flow of optimal allocation of resources (Surial, 2002).

In his published work titled "*Calculation of Chance and the Philosophy of Stock Market*", Jules Regnault presented the first known theoretical work that led to the emergence of financial economics and econophysics. Regnault used the Gaussian distribution in the central limit theorem to interpret the normal distribution trends in social phenomena. He has creatively compared stock price changes to a random walk. Based on the normal distribution of short-run estimates, there is an equal chance that the price will be lower or higher than the average value. Regnault believed that if the probability of the price being higher or lower than the average value is different, market participants can arbitrage by opting to systematically follow the highest probability (Regnault, 1863: 41). Finally, he suggested that the current stock prices demonstrate all publicly available data on which market participants make their evaluations. Hence, using the random walk model, stock market changes can be fully captured (Regnault 1863, 29-30). Research on the random walk model applied to account for stock market fluctuations began with the collaborations between Cowl (1933, 1944) and Working (1934, 1949). The failure to predict the Wall Street Crash of 1929 made them raise the possibility of the unpredictability of stock market fluctuations. To support this perspective, these researchers opposed the theories of chartism, which were very influential at that time, and claimed that they could predict stock market fluctuations based on historical stock price trends. Cowl and Working attempted to show that theories that had failed to predict the Wall Street Crash of 1929 lacked predictive power. Then, they introduced the unpredictability assumption of the stochastic nature of stock market fluctuations into financial theory to allow for the modeling of unpredictability. Such an assumption of unpredictability became the core component of the first theoretical studies on finance that matched econometrics (Juanovic & Schinkus 2017). For example, Working (1934) studied the randomness and unpredictability of prices (Working 1934, 12). He used the Gaussian distribution due to the stronger generalization of the normal frequency distribution (ibid 1934, 16). Cover (1937) and Bowley (1933) also studied stock price fluctuations at the same time. This assumption was supported as all statistical tests were designed based on the Gaussian framework. Working's method was similar to the approach employed by Slutsky (1937) in his econometric studies. Slutsky and Working believed that if price fluctuations are random, their distribution should follow the Gaussian distribution. Moreover, Cowles tested the stochastic nature of returns (price fluctuations) and hypothesized that price fluctuations are influenced by a normal distribution pattern. In addition, Cowles and Jones (1937), who sought to prove the randomness of stock price fluctuations, compared the distribution of price fluctuations with a normal distribution, as these authors believed that the normal distribution was used to describe probabilities in finance (Jovanovic & Schinkus 2017).

2.2 Empirical studies

Zhang and Huang (2010) investigated a quantum model for the stock market, and to describe the quantum characters for the stock market, they developed a price model with basic assumptions of quantum mechanics. In this study, a vector called the wave function in Hilbert space describes the state of the quantum system. Pedram (2012) studied the discrete nature of stock prices and generalized it to the uncertainty relationship by using the quantum description of the stock price and its trend and modified the Hamiltonian form to make it compatible with the discrete nature of the stock price. Cotfas (2012) examined the efficiency of a finite quantum model for stock market analysis. The equilibrium stock return was described by a finite Gaussian function and the time evolution of stock prices. A Schrödinger equation was extracted directly from numerical analysis, which ultimately aimed to propose a quantum model of the time evolution of the rate of returns. Meng et al. (2016) studied the stock market trends using the quantum Brownian motion model for the stock market. They suggested that the efficient market hypothesis (EMH) is incomplete due to irrational performance, and for this reason, they used quantum mechanics and harmonic operators, by adding Planck's constant due to the uncertainty in the stock market, to analyze the stock market data. The results indicated that stock prices are affected by and react to the information. Furthermore, the Brownian view is suitable for studying the stock market, and the correlation between the stock and the index is well shown through the non-Markovian view. Orus et al. (2019) investigated the application of quantum computing to solve financial problems and provided an overview of recent styles and potential perspectives. Behjat et al. (2019) investigated six non-homogeneous active stock companies whose value was assumed as a wave package and explained the probability of each price according to the distribution function and stated that the size of the wave function is a measurable construct that can be quantified directly from price data. Allahyari Beik et al. (2019) considered a stock market quantum model using the quantum potential to determine the price-to/earning (PE) behavior and price efficiency using the data from two industries listed on the Tehran Stock Exchange. The results indicated that quantum potential behaves like P/E and price efficiency and the fluctuations vary in the same range. Mezzetti (2020) introduced the Schrödinger equation for the Chinese stock market and found that after entering information as a variable into the distribution function of the return rate of the Chinese stock market, the average rate of return is affected and fluctuates cyclically. Chaiboonsri and Wannapan (2021) investigated the advantage of quantum mechanics to increase econometric capability, especially when predicting risk and reducing returns. They adopted the quantum wave distribution method for better risk and return analysis in the stock markets in Southeast Asian countries and analyzed the sample data using Bayesian statistics and simulations. The results indicated that quantum distributions are computationally consistent with Bayesian inferences and are even more analytically accurate. Orrell (2021) investigated the application of non-classical models for solving financial problems where the pricing is based on the quantum step model to demonstrate the investor's decision-making process and behavior. The results suggested that the quantum step model not only fully matches the classical models, but also better captures many market disturbances when considered together with the supply and demand model. Lotfi Haravi et al. (2021) investigated quantum machine learning algorithms and their applications in finance and attempted to identify the computational problems in finance where the use of quantum machine learning methods is superior to the best classical algorithms. They also analyzed the practicality of the physical realization of these algorithms in the short-run. The results suggested that as most of these algorithms require a large amount of data, performing these computations on classical computers needs substantial time and computing resources that may not be feasible in practice. Moreover, quantum computers can solve certain computational problems much faster than classical computers due to their parallel processing capabilities. Thus, the quantum speed can be increased in machine learning algorithms. Abdulahzadeh and Zare (2022) calculated money entropy in gross domestic products with an econophysic approach using the annual data from the Tehran Stock Exchange from 1991 to 2019 with a smooth transition autoregressive (STAR) model of the asymmetric behavior of monetary irregularities around a threshold limit at different capital market values. The results displayed that capital market dynamics will reduce money entropy as an indicator of resource waste and resource inaccessibility. Kuzo et al. (2022) examined the stock markets in China, Hong Kong, Germany, France, Russia, Argentina, Holland, the USA, Turkey, Italy, England, Spain, and Japan and assessed stock fluctuations using the volume of transactions. To investigate the stock index fluctuations, they used the heterogeneous economic time model to determine the critical periods and specify the fluctuations of the main stock markets in the world using quantum simulations. The results showed that stock fluctuations are high during a crisis, but less frequent under normal circumstances. The data also indicated the effect of the measured fluctuations on the indicators was different from country to country. Liu et al. (2022) proposed a method derived from element neural networks and quantum mechanics using a quantum artificial neural network to predict closing prices. To increase the network sensitivity to dynamic information, the internal self-connection signal, which is very beneficial for system modeling, was integrated into the introduced technique to adjust the learning rate of the double-chain quantum genetic algorithm. The findings indicated that the proposed model could efficiently predict the closing prices in six stock markets. The simulation data also confirmed the efficacy of the proposed algorithm. The authors provided some suggestions for financial stability in international stock markets. In their paper, Lai et al. (2022) examined effective decision-making for the composition of the low-risk stock portfolio in Singapore using quantum and trend ratios. The results indicated that the evolutionary computing system was able to make robust and sensible decisions and create an efficient portfolio with a stable upward trend in the Singapore stock market. Furthermore, Alaminos et al. (2022) compared quantum forecasting techniques and stock market crashes and developed a new stock market crash prediction model through real-time recession probabilities with the ability to accurately forecast future global stock market recession situations in a sample of 161 African, Middle Eastern, Latin American, South and East Asian, and European countries. A stock market crash prediction model was developed using three methods. The data showed that quantum Boltzmann machines had the highest accuracy using IA-generated knowledge and presented very accurate prediction outputs due to their ability to recall features and produce long-run dependencies from time series and continuous data. Challagan (2024) addressed the application of quantum technology in the stock market and stated that traders using quantum technology and a technique called telequantum can complete their buy and sell orders in the shortest possible time with proper analysis.

3. Methodology

In this study, a price model was developed following the basic rules of quantum mechanics. A vector called wave function in Hilbert space characterizes the state of the quantum system (Ye et al. 2008). The wave function square $\psi(\wp,t)$ was considered price distribution where $\wp$ denotes the price in the relevant market and t denotes time. The wave function denotes the price as follows (Schaden 2002):

$$|\psi\rangle = \sum \mid \emptyset_n\rangle\, C_n \tag{1}$$

Where $\mid \emptyset_n \rangle$ is a possible state of the financial system and C_n is equal to $\langle \emptyset_n \mid \psi \rangle$ (Piotrowski & Sladkowski 2005). Statistically, the probability density of the price in time is interpreted as follows:

$$P(t) = \int_a^b |\psi(\wp, t)|^2 dp \qquad (2)$$

In a macro system, shock is defined as the product of the mass of the particle in the first derivative of the location of the particle based on time. Accordingly, the intended financial quantum model is as follows:

$$T = m_0 \frac{d\varphi}{dt} \qquad (3)$$

Where m_0 is the "mass index" and T is the rate of "price changes". Following Heisenberg's uncertainty principle, we have:

$$\Delta\varphi \Delta T \geq \frac{\hbar}{2} \qquad (4)$$

Where Δφ is the standard deviation of the price, ΔT is the standard deviation of the price trend, and $\hbar$ is the truncated Planck's constant.

3.1 Schrödinger's equation

Following the assumptions of the wave function and operators, differential equations were used to analyze the evolution of price distributions over time. According to quantum theory, the Schrödinger equation is applied as follows:

$$\hat{H}\psi(\wp, t) = i\hbar \frac{\partial}{\partial t} \psi(\wp, t) \qquad (5)$$

Where $\hat{H}\psi(\wp, t)$ is the Hamiltonian operator and a function of price, trend, and time. By solving this equation, we can plot the price distribution curves at different times.

3.2 The stock market as an infinite potential well

Price fluctuations have been simulated as a one-dimensional infinite potential well. Using the following variable change in the coordinate system, a symmetrical potential well with width d is obtained as follows:

$$\varphi' = \varphi - \varphi_0 \tag{6}$$

$$r = \frac{\varphi'}{\varphi_0} \tag{7}$$

Where $d = r/2$. Usually, when the market is in equilibrium, the return distribution can be approximated as a Gaussian distribution (Cootne 1964). For this purpose, a cosine function can be used to estimate the wave function in the equilibrium state using the following equation (Mantegna 1995):

$$\psi_0(r) = \sqrt{\frac{2}{d}} cos(\frac{\pi r}{d}) \tag{8}$$

Where the energy eigenvalues are estimated as follows (Griffiths 1995):

$$E_0 = \frac{\hbar^2 \pi^2}{2md^2} \tag{9}$$

An ideal model was proposed to illustrate the evolution of the rate of return under information. The effect of information is assumed to be periodic in this model. In this study, a cosine function, i.e. $cos\, wt$, was used to simulate information fluctuations, where $w = 10^{-4} S^{-1}$ indicating that the information oscillates in a single cycle around four trading days. The fluctuation value, or $cos\, wt$ function varies from [-1] to [1] over time. Financial markets are like a charged particle that is circulating in an electromagnetic field, and its external field is $e\, Fr\, cos\, wt$, where e is the particle charge, which is equal to 10^{-19} and F is the magnitude of the external field. The e and w values are the same for all eleven markets and other variables have been estimated (Zhang & Huang, 2010). After obtaining the ideal Hamiltonian operator for the intended model, the Schrödinger equation was rewritten as follows (Wagner 1996):

$$i\hbar \frac{\partial}{\partial t} \psi(r,t) = \left[-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial r^2} + e\, Fr\, cos\, wt \right] \psi(r,t) \tag{10}$$

The data from solving Eq. (10) and the wave function extracted for each market were used to draw the diagrams for the return probability distribution and its mean value.

4. Estimation of the international stock market

Following Alves et al.'s (2020) study that examined the stock market efficiency index of different countries, 11 countries were selected in the present study to compare the stock markets at the international level. To this end, we used the daily data from stock markets in Iran, Germany, England, Brazil, Turkey, Russia, Japan, Switzerland, Saudi Arabia, South Korea, and India from 2013 to 2023. The index of each market in the period in question was de-trended with the Hodrick-Prescott Filter in Eviews software. Then, the mean and standard deviation for each index and the trend were calculated. Afterward, the mass index, the magnitude of the external field (information), and the width of the potential well were estimated using the relevant equations. Moreover, following Schrödinger's equation and Hamilton's expansion, the financial quantum approach was adopted to solve the wave function and draw and compare the diagrams for the distribution and average rate of return. Table 1 presents the estimated values for the mass index, the amplitude of the external field (information), and the width of the potential well (rate of return) in the studied countries:

Table 1. The values estimated for the research variables

Country	Mass Index	The amplitude of the external field (information)	The width of the potential well	Average rate of return
	m_0	F	d	
Germany	1.25×10^{-28}	10^{-18}	0.05	$\pm 5 \times 10^{-5}$
Iran	8.13×10^{-29}	10^{-18}	0.1	$\pm 8 \times 10^{-4}$
England	1.96×10^{-28}	10^{-18}	0.01	$\pm 28 \times 10^{-8}$
Brazil	6.8×10^{-29}	10^{-18}	0.07	$\pm 24 \times 10^{-5}$
Turkey	4.29×10^{-29}	10^{-18}	0.11	$\pm 24 \times 10^{-4}$

Country	**Mass Index**	**The amplitude of the external field (information)**	**The width of the potential well**	**Average rate of return**
	m_0	F	d	
Russia	8.5×10^{-27}	10^{-19}	0.03	$\pm 1 \times 10^{-4}$
Japan	2.46×10^{-28}	10^{-19}	0.05	$\pm 14 \times 10^{-4}$
Switzerland	3.86×10^{-27}	10^{-19}	0.04	$\pm 2 \times 10^{-5}$
Saudi Arabia	1.81×10^{-27}	10^{-19}	0.05	$\pm 26 \times 10^{-6}$
South Korea	3.19×10^{-28}	10^{-18}	0.03	$\pm 11 \times 10^{-6}$
India	4.08×10^{-29}	10^{-18}	0.09	$\pm 11 \times 10^{-4}$

The diagrams for the probability density and the average rate of return of the sock market index were plotted and presented separately for the stock market of each country. Figure (a) in each diagram shows the probability density of the country's stock market index and Figure (b) shows the "information" variable entered into the distribution function of the return rate and the average rate of return after entering the information as shown in the appendix.

Following the estimated data for the stock markets of the countries in question, Figure (a) shows the probability density for the stock market indices in the countries. As can be seen, the probability density curve in the center of the potential well corresponding to zero return has the highest value. However, as it moves toward the borders of the potential well, its value decreases gradually and symmetrically to zero, confirming the Gaussian distribution function. As can be seen in Figure (b), the variable "information" is entered into the distribution function of the return rate of the stock market index of the countries in question. As displayed in the figure, the average rate of return fluctuates periodically and symmetrically between certain intervals. The average rate of return in the first period is symmetric with $t=\pi/w$ due to the Hamilton bilateral symmetry (wave function in one period).

5. Conclusion and Suggestions

An analysis of the stock markets in the selected countries revealed that the distribution of the probability density curve of the return rate of the stock market index in all eleven countries follows the Gaussian distribution. After entering the information variable into the distribution function of the return rate, the average rate of return of the stock market index in the studied countries fluctuated cyclically and symmetrically with different ranges, as confirmed in previous studies (e.g., Cotfas, 2012; Mezzetti, 2020; Pedram, 2012; Zhang & Huang, 2010). A comparison of the stock markets in the selected countries indicated that the highest range of fluctuation was found in Turkey with less efficiency, while the lowest range of fluctuation was found in the British stock market with higher efficiency. Moreover, the British stock market has the lowest average rate of return, the lowest risk, and the highest transparency, while the Turkish stock market has the highest average rate of return, the highest risk, and the lowest transparency (see Alves et al., 2020). The data in this study indicated that information transparency not only reduces volatility and increases efficiency in financial markets, but also has broader social and economic effects. In particular, markets with less information transparency are more likely to create unstable economic cycles, because extreme volatility leads to impulsive investment behaviors. These behaviors usually increase systematic risk and can cause sudden capital outflows from the market. In contrast, information transparency allows investors to make more accurate analyses and rational decision-making, leading to greater stability.

From a behavioral economics perspective, reduced transparency in financial markets can lead to an increase in the “information gap” among investors. This information gap in stock markets such as Turkey, which have shown the greatest volatility, can lead to increased speculative behavior and reduced long-run investments. In contrast, greater information transparency in markets such as the UK has reduced this gap and created a better balance between short-run and long- run investments. Hence, investors in these markets analyze risk and return from a more holistic perspective and make more rational decisions. Given that, from an international perspective, the transparency of financial information directly affects the attractiveness of a market to foreign investors, and markets with higher levels of transparency and efficiency tend to act as safe havens in times of global uncertainty. Hence, these markets can attract foreign direct investments and bring greater stability to the related countries. The findings from this study also suggested that the British stock market with high transparency and lower volatility attracted more foreign investors, while the Turkish market has been more interested in short-run and speculative investors due to its high risk and lack of transparency. Moreover, the entry of foreign investors into more transparent financial markets will not only inject more financial resources but also bring more advanced technology and management knowledge into these countries. These benefits will help improve financial infrastructure, reduce transaction costs, and increase transparency at the overall market level.

The analysis of financial markets in different countries indicated that information transparency can be used as a key tool for regulating economic policies. Hence, policymakers in markets with high volatility and higher risk are recommended to focus on the promotion of digital financial infrastructure, improved supervision, and compliance with information disclosure requirements. In particular, the establishment of systems for timely disclosure of financial information and increasing public access to market data can lead to the reduction of information asymmetry and the creation of greater transparency. This goal can also be achieved by enforcing stricter rules on corporate financial disclosure, creating transparency-oriented platforms using technologies such as blockchain, and strengthening regulatory institutions to increase investor confidence. In addition, improving public financial literacy and investor awareness through education and accurate information can help investors make more rational decisions and reduce impulsive behavior. Creating digital infrastructure and strengthening international interactions in the financial sector can also increase liquidity and attract foreign investors in line with sustainable economic development goals.

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All authors contributed to drafting the manuscript.

Conflicts of interest

The authors declare no conflict of interest.

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Appendix

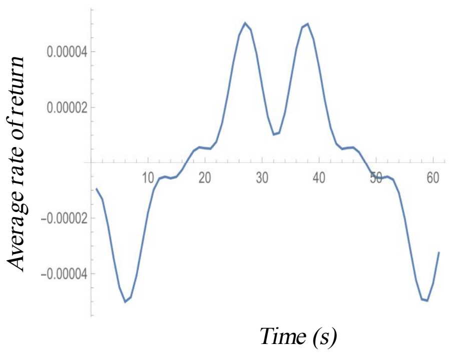
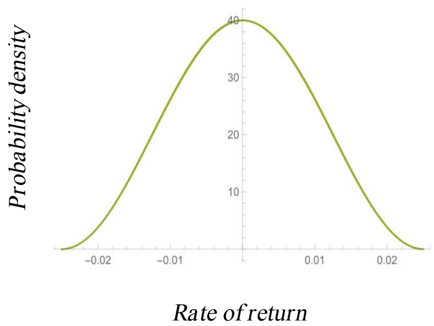
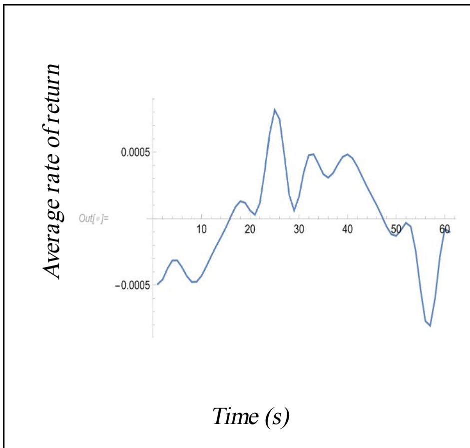
	

Fig 1 (b). The average rate of return for the German stock market index	Fig 1 (a). The probability density for the rate of return in the German stock market index

Fig 1. The estimated data for the German stock market



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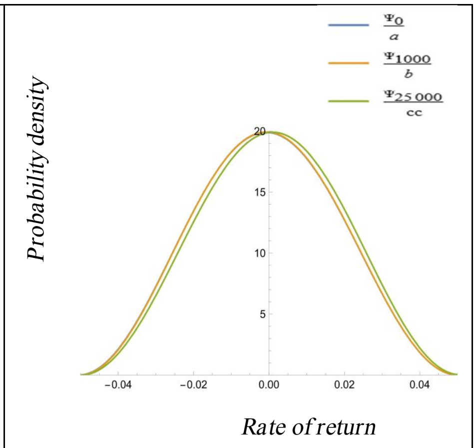

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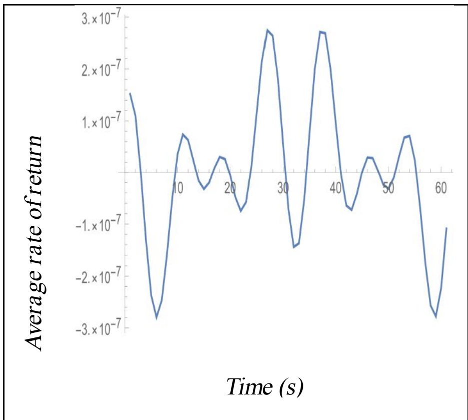
Fig 2. The estimated data for the Iranian stock market



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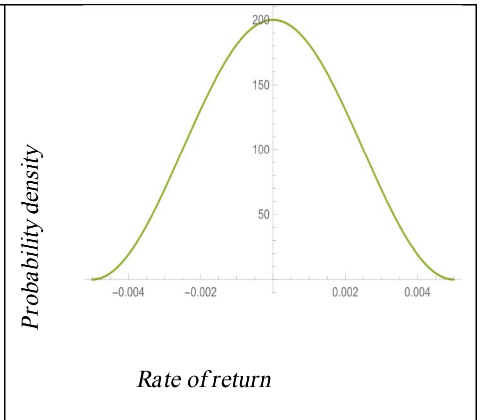

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Fig 3. The estimated data for the British stock market

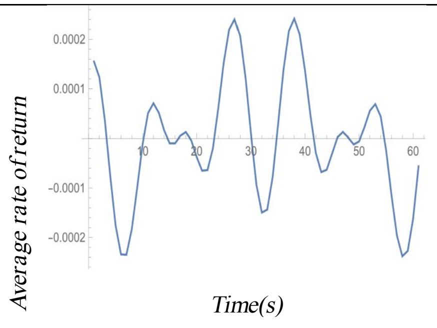
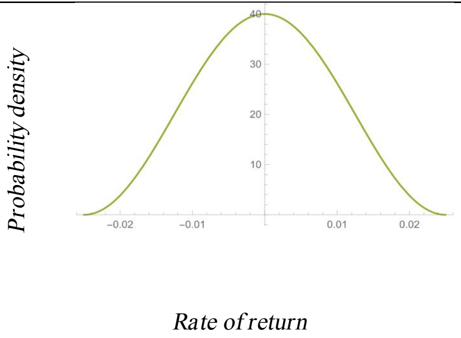
	

Fig 4 (b). The average rate of return for the Brazilian stock market index	Fig 4 (a). The probability density for the rate of return in the Brazilian stock market index

Fig 4. The estimated data for the Brazilian stock market

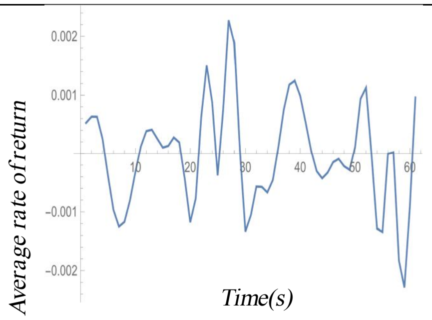
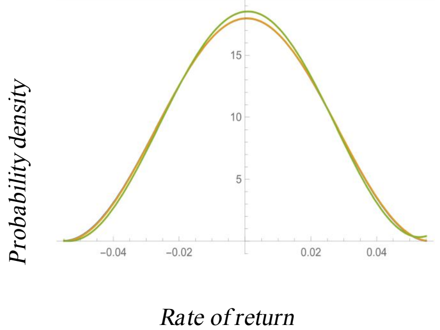
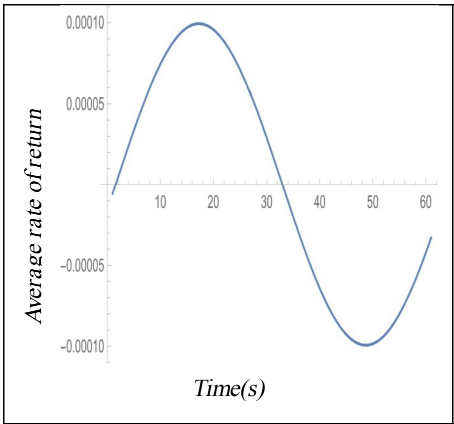
	

Fig 5 (b). The average rate of return for the Turkish stock market index	Fig 5 (a). The probability density for the rate of return in the Turkish stock market index

Fig 5. The estimated data for the Turkish stock market



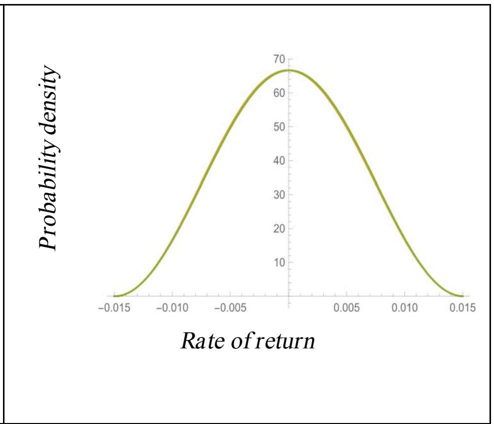


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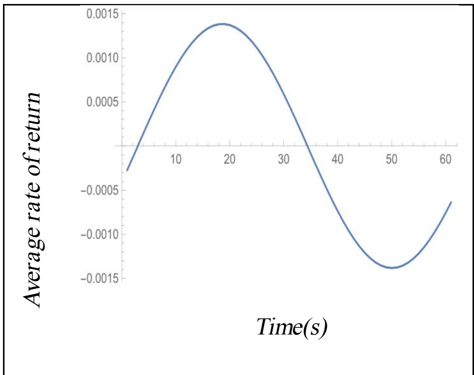
Fig 6. The estimated data for the Russian stock market



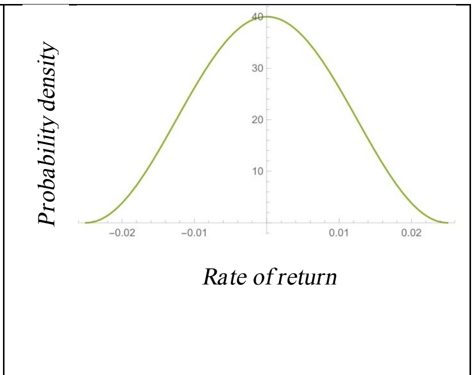
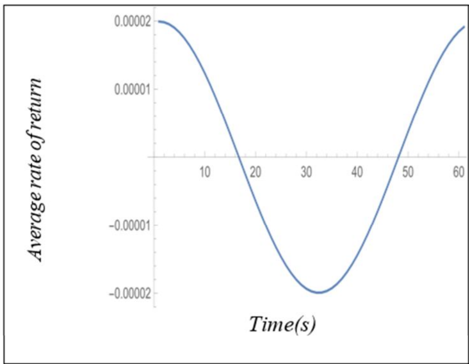


Fig 7 (b). The average rate of return for the Japanese stock market index	Fig 7 (a). The probability density for the rate of return in the Japanese stock market index

Fig 7. The estimated data for the Japanese stock market



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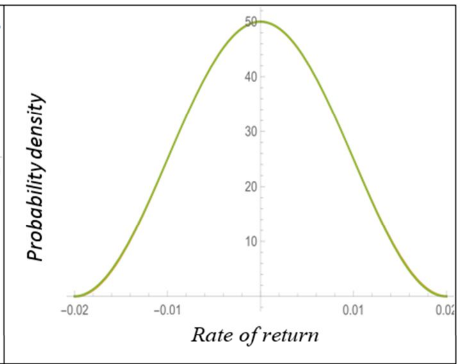

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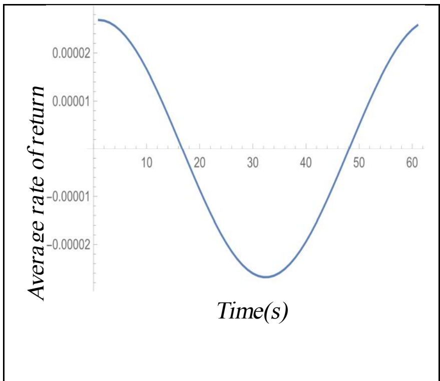
Fig 8. The estimated data for the Swiss stock market



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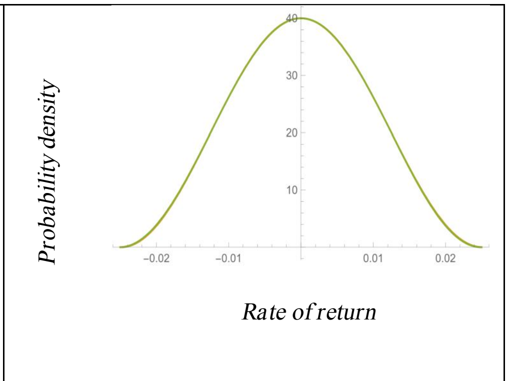

Fig 9(a). The probability density for the rate of return in the Saudi Arabian stock market index

Fig 9. The estimated data for the Saudi Arabian stock market

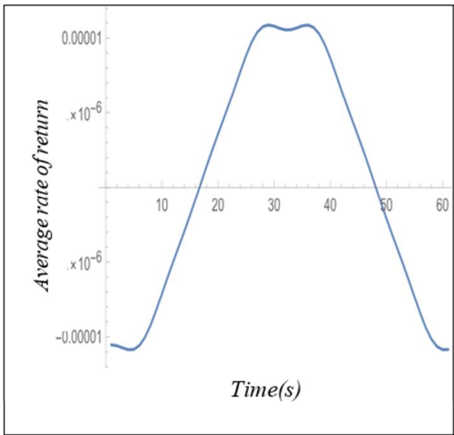	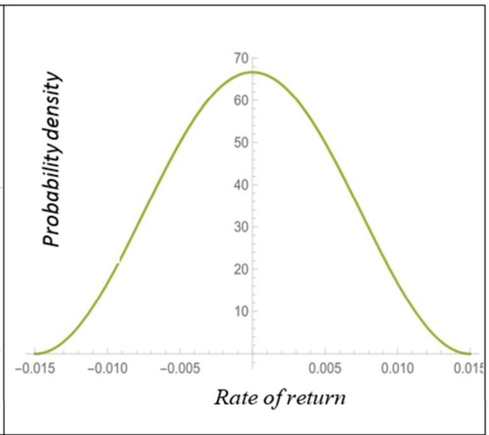
Fig 10(b). The average rate of return for the South Korean stock market index	Fig 10(a). The probability density for the rate of return in the South Korean stock market index

Fig 10. The estimated data for the South Korean stock market

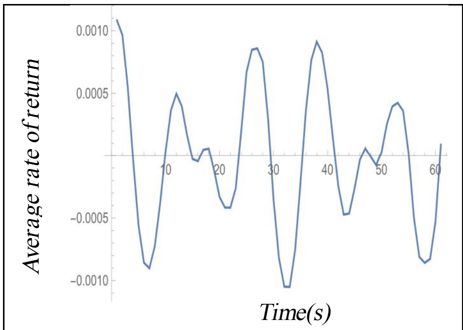	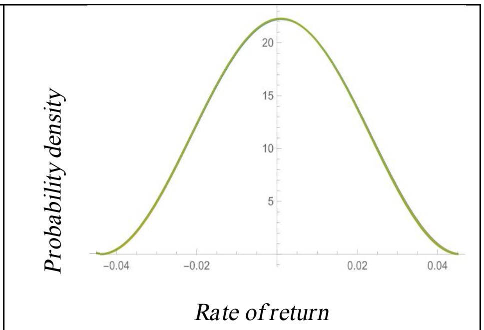
Fig 11(b). The average rate of return for the Indian stock market index	Fig 11(a). The probability density for the rate of return in the Indian stock market index

Fig 11. The estimated data for the Indian stock market