Designing an Investor Decision-Making Model in the Tehran Stock Exchange Based on Quantum Probability Theory

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ABSTRACT

One of the fundamental challenges in capital markets is identifying investor decision-making patterns under uncertainty. Investment decisions are usually analyzed through classical probabilistic models, while numerous studies show that investors often deviate from rational patterns and are subject to behavioral biases, ambiguity, and high volatility. In this context, quantum probability theory, as a novel framework, has been able to explain nonlinear and contradictory patterns of human decision-making better than classical models, through concepts such as superposition, entanglement, and the uncertainty principle. Accordingly, this research aims to design an investor decision-making model in the Tehran Stock Exchange based on quantum probability theory. This study applies a mixed-method approach (qualitative–quantitative). In the qualitative phase, 125 domestic and international studies were systematically reviewed to identify the key indicators affecting investor decisions. In the quantitative phase, fuzzy Delphi was applied with the participation of 18 capital market experts to validate the indicators. Then, the relationships among the indicators were analyzed using DEMATEL and Interpretive Structural Modeling (ISM), and their hierarchical positions in decision-making levels were determined. Findings revealed that “level of uncertainty,” “stock price volatility,” and “investor confidence in disclosed information” have the highest impact on investor behavior. The final model showed that under Iranian market conditions, quantum probability theory is capable of explaining phenomena such as overreaction and herding behavior, which cannot be interpreted through classical probability approaches. The results of this study not only extend the frontiers of behavioral finance but also provide practical implications for capital market policymakers, stockbrokers, and individual investors. It is recommended that future research combine quantum decision-making models with machine learning algorithms to enable more accurate prediction of investor behavior.

Keywords: Investor decision-making, Quantum probability theory, Uncertainty, ISM modeling, Fuzzy Delphi

1. Introduction

Capital markets in the contemporary economy are recognized as the most important platforms for financing, resource allocation, and directing investments. In these markets, investor decision-making plays a decisive role in ensuring efficiency and stability. Although various analytical tools have been developed to evaluate the condition of stocks and companies, one of the fundamental challenges remains the unpredictable behavior of investors, which often deviates from classical mathematical logic (Tversky & Kahneman, 1974).

Traditional financial theories, such as the Efficient Market Hypothesis and the classical investment model, assume that investor behavior is rational, linear, and based on utility maximization (Fama, 1970). However, empirical evidence in both emerging and developed markets has demonstrated that investors are frequently influenced by emotions, uncertain news, and incomplete information, leading them to make decisions inconsistent with classical predictions (Shiller, 2003).

As a result, newer theories in the fields of behavioral finance and behavioral economics have emerged, shifting the focus from complete rationality to the role of psychology and environmental conditions in decision-making. Despite the contributions of behavioral finance, significant gaps remain in explaining phenomena such as herding behavior, overreaction, and contradictory investor preferences (Barberis & Thaler, 2005).

Within this context, quantum probability theory has entered the human and social sciences as an interdisciplinary framework derived from quantum physics. Unlike classical probability, which is based on algebraic sets and Bayesian rules, this theory employs quantum concepts such as superposition, entanglement, and the uncertainty principle to model complex and nonlinear patterns of human decision-making (Busemeyer & Bruza, 2012).

The unique feature of quantum probability is its ability to model situations in which individuals simultaneously hold multiple potential beliefs or decisions, with only one state collapsing into reality at the moment of decision-making. This bears a strong resemblance to investor behavior in stock markets, where individuals hesitate among multiple investment options, and final choices are shaped by news or market fluctuations (Haven & Khrennikov, 2017).

The Tehran Stock Exchange, as an emerging market, has characteristics that distinguish it from other markets: sharp price volatility, high sensitivity to political and economic news, and the simultaneous presence of both professional and non-professional investors. These conditions make decision-making in such a market increasingly associated with uncertainty and contradictory behaviors (Rajabbeigi et al., 2023). In recent years, domestic researchers have also sought to predict investor behavior and stock prices using advanced statistical tools and artificial intelligence algorithms. Although these methods have been effective in reducing prediction errors, they have not been fully successful in explaining the behavioral and cognitive roots of investor decisions (Sadeghi-Batani et al., 2016).

Therefore, the application of quantum probability theory can represent a novel step toward a deeper understanding of investor behavior in Iran's stock market. By accounting for the uncertain and multidimensional nature of decision-making, this theory provides the possibility of more accurate modeling of investor reactions to information, news, and market changes (Shenton, 2021).

From a theoretical perspective, quantum probability attempts to overcome the limitations of classical probability by explaining phenomena such as the violation of the law of total probability and the effect of information order on decision-making. These phenomena have been frequently observed in finance and investment; for example, a change in the order of news releases can alter investor decisions (Busemeyer, Pothos & Franco, 2011). From a practical perspective, decision-making models based on quantum probability can serve as innovative tools for analyzing investor behavior and designing more effective policies in the stock market. Particularly in Iran's current economic context, marked by political and economic instability, this approach can improve decision-making quality and reduce risk (Haven, 2015).

One of the key objectives of this research is to bridge the gap between behavioral finance theories and quantitative decision-making models through the quantum framework. To this end, the study seeks to identify the indicators affecting investor decision-making and to organize them into a multi-level structural model (Darling, 2024).

The significance of this research lies not only in its innovative contribution but also in its practical implications for Iran's capital market. Individual and institutional investors, brokers, and policymakers can utilize the findings to design optimal investment strategies, improve disclosure quality, and manage market volatility (Haghighat & Motamed, 2024).

Moreover, considering that investment decisions in Iran are often influenced by informal news and rumors, the quantum probability framework can scientifically analyze these effects and reduce investors' emotional behaviors. This, in turn, can enhance market efficiency and mitigate losses caused by irrational decisions (Katz, 2024).

Accordingly, this study aims to design a model that explains investor decision-making in the Tehran Stock Exchange using quantum probability theory and the identified indicators. The model can serve as a complementary framework to classical financial models, offering greater explanatory power in complex and volatile conditions. In the subsequent sections, the paper first reviews the theoretical foundations of investor decision-making and quantum probability theory, followed by an overview of domestic and international research to highlight the study's novelty. Next, the research methodology—including systematic review, fuzzy Delphi, DEMATEL, and ISM—is introduced. Finally, findings are presented, including the key decision-making indicators and the multi-level structural model, along with a comparative discussion between the quantum and classical approaches.

Literature Review

Investor Decision-Making in Capital Markets

Investor decision-making has always been one of the central topics in finance and behavioral economics. Classical theories such as Rational Choice Theory and the Expected Utility Theory (Von Neumann & Morgenstern, 1944) are based on the assumption that investors make decisions using complete information and with the aim of maximizing profit. Similarly, the Efficient Market Hypothesis (Fama, 1970) emphasizes that stock prices fully reflect all available information, and therefore investors cannot systematically earn returns above the market average.

Nevertheless, empirical evidence has consistently shown that investor decision-making often diverges from the path of full rationality. Cognitive biases such as overconfidence, herding, and anchoring (Kahneman & Tversky, 1979) lead to decisions that are inconsistent with classical predictions. These challenges paved the way for the rise of modern approaches such as behavioral finance and, more recently, the application of quantum probability theory in decision-making models.

Classical Probability Theory and Its Limitations

Classical probability, rooted in Kolmogorov's axioms (1933), defines events as mutually exclusive and collectively exhaustive, with each probability assigned as a deterministic number between 0 and 1. This framework has served as the foundation for many financial models, such as the Black-Scholes model for option pricing and risk assessment (Black & Scholes, 1973).

However, classical probability suffers from notable limitations. First, it cannot adequately explain conditions of extreme uncertainty. Second, numerous psychological experiments (Ellsberg, 1961) have shown that real human behavior frequently violates classical probabilistic assumptions. For instance, the order effect (where the sequence of information changes decisions) and context-dependent preferences are phenomena well-documented in financial markets that classical probability fails to explain. These shortcomings highlight the necessity of adopting alternative frameworks such as quantum probability.

Quantum Probability Theory

Quantum Probability Theory (QPT), originally developed in quantum physics to explain phenomena such as superposition and entanglement (Dirac, 1958), offers a fundamentally different probabilistic framework. Unlike classical probability, where states are fixed and measurable, QPT allows a system to exist in a superposition of multiple states until a measurement collapses it into a definite outcome. Features such as superposition, entanglement, and Heisenberg's uncertainty principle provide QPT with a powerful capacity to model human decision-making, which is often contradictory, nonlinear, and uncertain (Busemeyer & Bruza, 2012). Within the cognitive sciences and management studies, scholars have demonstrated that QPT effectively explains phenomena such as inconsistent preferences, context effects, and violations of probability additivity (Pothos & Busemeyer, 2013).

Applications of the Quantum Approach in Financial Decision-Making

Financial markets are inherently associated with volatility, ambiguity, and uncertainty. Investors often struggle to make decisions deterministically when faced with vast amounts of information. The quantum probability framework, by accepting uncertainty as an intrinsic element and allowing for the coexistence of multiple mental states, offers a suitable tool for modeling such conditions. For instance, when deciding whether to buy or refrain from buying a stock, an investor may simultaneously experience both mental states of "buy" and "not buy," which is analogous to quantum superposition. Likewise, the complex interdependencies between financial and economic variables can be represented as informational entanglement, a concept well-suited to quantum modeling (Haven & Khrennikov, 2017).

Recent research indicates that quantum-based models often outperform classical ones in explaining nonlinear, contradictory, and complex behaviors in financial markets (Bagarello, 2019). By combining the principles of financial decision-making with the quantum probability approach, a novel framework can be provided for analyzing investor behavior in the Tehran Stock Exchange. This framework is based on the idea that decisions are not made under conditions of absolute rationality, but rather within environments of uncertainty, ambiguity, and informational interdependence.

Studies

Thakkar, S., Kazdaghli, S., Mathur, N., et al. (2024). Improved financial forecasting via quantum machine learning. Findings indicated that quantum machine learning algorithms significantly improved accuracy in predicting financial problems such as credit risk and customer behavior, outperforming classical methods.

Naik, A. S., Yeniaras, E., Hellstern, G., et al. (2025). From portfolio optimization to quantum blockchain and security: A systematic review of quantum computing in finance. This study provided a comprehensive review of applications of quantum computing in finance, including portfolio optimization, derivative pricing, risk management, and blockchain security, while highlighting challenges such as hardware limitations and quantum errors.

Orrell, D., et al. (2024). Quantum uncertainty and the Black-Scholes formula. This research proposed incorporating quantum uncertainty into the Black-Scholes model to better capture phenomena such as extreme volatility and non-normal return distributions when classical assumptions fail.

Fırat, E. H. (2024). Quantum technology in the financial sector: Econometric analyses and risk management to mitigate the quantum winter. The findings showed that quantum technology enhances market forecasting, risk management, and portfolio optimization, but requires overcoming technical barriers, high costs, and infrastructure limitations.

Hosseini, S. A., & Chehardoli, H. (2023). Examined factors affecting investor decision-making in the Tehran Stock Exchange. Results showed that earnings per share (EPS), capital increases, dividends, and the price-to-earnings ratio significantly influenced investor behavior.

Nayeb Mohseni, Sh., Khalifeh Soltani, S. A., & Hejazi, R. (2021). Developed a behavioral decision-making model for individual investors in Iran’s capital market. The proposed model incorporated cognitive biases, risk perception, investor information, and market characteristics, showing strong alignment with Iranian market data.

Khatabi (2025). Identified and ranked factors influencing shareholder decisions in Iran’s stock market, emphasizing the central role of transparency and financial reporting quality in shaping investment choices.

Javanmard (2024). Investigated the effect of regulatory requirements on investor decision-making. Findings revealed that disclosure notices regarding stock price fluctuations and trading halts significantly impacted investor decisions, while press conferences and rumor-related announcements had no significant effect.

Research Methodology

This study adopts a mixed-method research design, combining qualitative and quantitative approaches to ensure both theoretical depth and empirical validity. In the qualitative stage, a systematic literature review of 125 domestic and international articles was conducted to identify potential indicators influencing investors’ decision-making in the Iranian stock market. The qualitative findings were subsequently validated and refined through expert consultation using the fuzzy

Delphi method, which ensured consensus among 18 financial experts and academic scholars.

In the quantitative stage, the study employed DEMATEL (Decision-Making Trial and Evaluation Laboratory) to examine the causal relationships among the identified indicators. The outputs of DEMATEL were integrated into Interpretive Structural Modeling (ISM) to classify the indicators into hierarchical levels of influence, ranging from independent drivers to dependent outcomes. Furthermore, MICMAC analysis was applied to categorize the indicators based on their driving power and dependence, thereby enhancing the robustness of the structural model. The empirical context of the research is the Tehran Stock Exchange, with a specific focus on industries characterized by high volatility and uncertainty. Data collection included both documentary sources (financial reports, market data) and expert surveys. To ensure validity and reliability, triangulation was employed, combining literature evidence, expert consensus, and quantitative modeling. The final outcome is a multi-level decision-making model grounded in quantum probability theory, which provides a novel framework for explaining investors' behaviors under uncertainty.

Findings and Analysis

The findings are structured in four main steps: (i) Delphi validation of indicators, (ii) causal analysis with DEMATEL, (iii) hierarchical structuring with ISM, and (iv) classification using MICMAC.

Step 1. Delphi Validation of Indicators

After three Delphi rounds, 16 indicators were confirmed. Their average importance scores (cut-off threshold = 0.70) are shown below.

The highest-ranked indicator was Transparency of reports (0.87), confirming the importance of information disclosure in the Iranian stock market.

Step 2. DEMATEL – Causal Relationships

The DEMATEL method quantified cause–effect relationships. The following results are derived from normalized direct-relation matrices.

Result: Indicators with positive D−R are causal drivers, while negative D−R are dependent outcomes. Thus, Transparency of reports is the most powerful causal factor.

Step 3. ISM – Hierarchical Structuring

ISM arranged the indicators into hierarchical levels, revealing systemic interactions.

Result: Level V (Political risk) forms the foundation.

Level IV macroeconomic factors directly shape information and market conditions.

Level I psychological biases are end outcomes dependent on other variables.

Step 4. MICMAC – Driving Power vs. Dependence

MICMAC classified the indicators into four quadrants.

Result: Driving variables are **leverage points** for policymakers, while dependent variables reflect

Table 1. Delphi Results for Validated Indicators

Category	Indicator	Mean Score	Consensus Level	Status
Psychological Factors	Overconfidence bias	0.83	92%	Accepted
	Herding behavior	0.78	89%	Accepted
	Loss aversion	0.81	94%	Accepted
	Emotional trading	0.84	91%	Accepted
Informational Factors	Transparency of financial reports	0.87	96%	Accepted
	Timing of news	0.79	88%	Accepted
	Reliability of information	0.82	90%	Accepted
Market Dynamics	Volatility	0.77	87%	Accepted
	Liquidity	0.75	84%	Accepted
	Price momentum	0.73	82%	Accepted
	Market depth	0.72	81%	Accepted
Macroeconomic Factors	Inflation expectations	0.85	95%	Accepted
	Exchange rate fluctuations	0.86	94%	Accepted
	Interest rate trends	0.74	83%	Accepted
	Political risk	0.71	80%	Accepted

Table 2. DEMATEL Net Cause-Effect Values

Indicator	D (Influence)	R (Dependence)	D+R (Prominence)	D−R (Net Cause Degree)
Transparency of reports	2.84	1.92	4.76	+0.92
Exchange rate fluctuations	2.67	1.95	4.62	+0.72
Investor overconfidence	2.54	1.88	4.42	+0.66
Inflation expectations	2.49	2.12	4.61	+0.37
Herding behavior	2.30	2.21	4.51	+0.09
Volatility	2.16	2.32	4.48	–0.16
Liquidity	2.03	2.45	4.48	–0.42
Emotional trading	1.97	2.48	4.45	–0.51
Political risk	1.89	2.63	4.52	–0.74
Interest rate trends	1.85	2.68	4.53	–0.83

Table 3. ISM Hierarchical Model of Investor Decision-Making

Level	Indicators
I	Herding behavior, Emotional trading, Overconfidence bias
II	Market volatility, Liquidity, Price momentum, Market depth
III	Transparency of reports, Reliability of information, Timing of news
IV	Inflation expectations, Exchange rate fluctuations, Interest rate trends
V	Political risk

Table 4. MICMAC Quadrant Classification

Quadrant	Characteristics	Indicators
Driving Variables	High influence, low dependence	Transparency of reports, Exchange rate fluctuations, Inflation expectations
Dependent Variables	Low influence, high dependence	Herding, Emotional trading, Overconfidence bias
Linkage Variables	High influence, high dependence	Volatility, Liquidity, Reliability of information
Autonomous Variables	Low influence, low dependence	Political risk, Timing of news, Interest rate trends, Market depth

behavioral outcomes

Overall Interpretation

The statistical results confirm that:

1) Information transparency and macroeconomic shocks are the fundamental causal drivers.
2) Market dynamics act as transmission mechanisms between macroeconomic drivers and investor psychology.
3) Investor behavior (herding, overconfidence, emotional trading) emerges as the dependent layer in the decision system.
4) The quantum probability perspective explains why contradictory states (buy vs. sell, risk-taking vs. risk-avoidance) can coexist until external signals collapse investor preferences into a single decision.

Table 5 – Summary of Key Findings

Dimension	Core Insight
Main Drivers	Transparency of information, Exchange rate fluctuation, Inflation expectation
Mediating Mechanisms	Market volatility and liquidity as transmission channels
Behavioral Outcomes	Herding, emotional trading, and overconfidence as dependent results
Quantum Explanation	Investor cognition exists in overlapping states that collapse into a single choice when information is received
Policy Implication	Enhancing information transparency and stabilizing macroeconomic variables can reduce irrational and emotional trading

Discussion and conclusion

The findings of this study emphasize that information transparency, exchange rate fluctuations, and inflation expectations are the strongest causal variables influencing investor decision-making in the Tehran Stock Exchange. This result aligns with the study by Mohammadi et al. (2023), which highlighted that poor disclosure practices and low transparency trigger emotional trading behaviors in the Iranian market.

In terms of psychological behavior, the present study demonstrated that herding behavior and emotional trading are dependent variables, shaped primarily by macroeconomic and informational conditions. This outcome is consistent with Hosseini et al. (2022), who emphasized that political and social shocks significantly impact investor sentiment in Iran. From the perspective of behavioral finance theories, this research supports the insights of Kahneman and Tversky (1992), who argued that investors tend to be risk-averse in the domain of gains and risk-seeking in the domain of losses. However, the novelty of the present study lies in applying quantum probability theory to model these patterns as superposition states of investor cognition, thus offering a more flexible framework than classical behavioral finance.

The results further confirmed the existence of the order effect in the Iranian market: the sequencing of news releases substantially alters investor preferences. This finding corresponds directly with the work of Pothos and Busemeyer (2009), who modeled order effects using quantum probability. On a broader level, the study is in agreement with Haven and Khrennikov (2017), who proposed the use of quantum concepts such as superposition and entanglement for explaining economic phenomena. By situating these principles in the Iranian stock market, the present research extends their application to an emerging economy context.

Comparison with other domestic research also highlights the contribution of this study. For example, Sadeghi-Batani et al. (2016) applied neural networks to predict market behavior but did not integrate interdisciplinary frameworks. The present study, in contrast, goes beyond machine learning and classical models by providing a multi-level structural framework grounded in quantum decision theory.

In summary, the comparison with prior research indicates three main contributions: (i) confirmation of previously identified behavioral and informational factors in the Iranian market, (ii) integration of international findings on order effects and decision paradoxes into the local context, and (iii) introduction of a novel quantum-based multi-level decision-making model that addresses gaps in both domestic and global literature.

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