Advances in Mathematical Finance & Applications
www.amfa.iau-arak.ac.ir
Print ISSN: 2538-5569
Online ISSN: 2645-4610

Original Research

Examining Financial Performance and Corporate Governance in Tehran Stock Exchange: A Hybrid Machine Learning and Data Envelopment Analysis Approach

Pooneh Noparvar Saravi [a, *], Morteza Bagheri [b], Seyed Sadegh Hadian [c]

[a] *Master's student in Accounting, Rozbahan Higher Education Institute, Mazandaran, Iran*
[b] *Master's student in Accounting, Shahid Beheshti University, Tehran, Iran,*
[c] *Master's student in Accounting with a specialization in Auditing, Faculty of Administrative and Economic Sciences, Ferdowsi University, Mashhad, Iran*

ARTICLE INFO

Article history:
Received 2023-10-18
Accepted 2024-02-23

Keywords:
Financial Performance
Corporate Governance
Machine Learning
Human Capital

ABSTRACT

In the backdrop of an ever-evolving global business landscape and intense market competition, companies are faced with the imperative of strategically managing factors that influence their financial performance. This research delves into the intricate relationship between financial performance enhancement and corporate governance, with particular attention to the mediating role of human capital. The study centers its investigation on companies listed on the Tehran Stock Exchange and comprises a comprehensive sample of 140 top-level managers. A composite sampling approach, comprising a simple random sampling technique and Morgan's table, was employed to judiciously select a representative cohort of 103 participants. In the pursuit of rigorous academic analysis, the research leverages a goal-oriented, applied methodology, employing a descriptive survey design and a quantitative approach. The primary data for the study were methodically collected through rigorously designed and standardized questionnaires. Subsequent to data acquisition, a meticulous analytical process was undertaken using the Partial Least Squares (PLS) software, aligning with the latest developments in quantitative research techniques. The results stemming from hypothesis testing offer compelling insights into the dynamic relationship between corporate governance, human capital, and financial performance enhancement. Our findings convincingly demonstrate a significant positive impact of both corporate governance and human capital on the enhancement of financial performance in the context of Tehran Stock Exchange's listed companies. Furthermore, the empirical evidence strongly suggests that human capital plays a pivotal mediating role in the relationship between corporate governance practices and financial performance improvements. This study, in its pursuit of academic rigor, underscores the effectiveness of a novel hybrid approach, thoughtfully integrating machine learning and data envelopment analysis, to comprehensively examine the intricate interplay between financial performance enhancement and corporate governance within the context of the Tehran Stock Exchange's listed companies. The study contributes to the evolving body of literature in this domain and provides valuable insights for practitioners, policymakers, and researchers.

* *Corresponding author. Tel.: +989399992624*
E-mail address: pone.np92@gmail.com

© 2024. All rights reserved.
Hosting by IA University of Arak Press

1 Introduction

The rapid development of global trade and intense competition has prompted companies to pay significant attention to factors that impact their financial performance. Understanding and improving financial performance is crucial for the sustainability and longevity of businesses, as it relies on profitability and value creation in both the short and long term [1-6]. In recent decades, corporate governance practices have garnered attention from researchers due to their recognized role in enhancing financial performance. Corporate governance refers to the processes and policies adopted by companies to address agency issues while considering the separation of ownership and management [17]. Effective corporate governance systems define appropriate lines of responsibility by considering the level of communication between the company and its key components. The swift adoption of corporate governance and its methodologies is of utmost importance for institutions, corporate groups, and governments [11]. Corporate governance is a systemic approach that not only strengthens relationships between various stakeholders (shareholders, managers, and company investors) but also ensures the availability of adequate resources among competing users. Furthermore, it provides frameworks through which companies formulate their objectives, strategies for achieving those objectives, and mechanisms for evaluating performance [8].Although various studies have been conducted to investigate the relationship between corporate governance and financial performance in different companies, it has yet to be precisely determined whether this impact is direct or mediated by other variables. Lažili et al. [12] stated that human capital could serve as an intermediate variable influencing the relationship between corporate governance and financial performance. Human capital refers to the investments made by an organization in talents and technologies that lead to competitive advantages and unique, valuable capabilities that can be employed in the delivery of professional services [7-8]. Against this backdrop, the present study aims to explore the impact of corporate governance on financial performance improvement, with a specific focus on the mediating role of human capital in companies listed on the Tehran Stock Exchange. To achieve this, a sample of 140 managers was selected using a combination of the simple random sampling method and Morgan's table. Ultimately, 103 participants were included as a representative sample. The research adopts a goal-oriented and applied methodology, employing a descriptive survey design with a quantitative approach. In order to gather data, standardized questionnaires were used, and the data were analyzed using Partial Least Squares (PLS) software.However, to enhance the robustness of the study and delve deeper into the interplay between financial performance enhancement and corporate governance, it is necessary to incorporate advanced analytical methods such as machine learning and data envelopment analysis (DEA). These methods can provide valuable insights into the relationship between financial performance, corporate governance practices, and human capital investment. Machine learning algorithms can be employed to identify patterns and extract meaningful information from large datasets, enabling a more comprehensive understanding of the underlying dynamics. Furthermore, DEA can be utilized to assess the efficiency and productivity of companies by comparing inputs and outputs, allowing for a quantitative evaluation of their financial performance in relation to their governance practices. By integrating machine learning and DEA methodologies, this study aims to shed light on the complex interactions between financial performance improvement, corporate governance, and human capital in companies listed on the Tehran Stock Exchange. The use of these advanced analytical techniques will provide a more nuanced analysis, contributing to the existing body of knowledge and offering practical insights for companies striving to enhance their financial performance through effective governance strategies and human capital investments. Moreover, the integration of machine learning and data envelopment analysis (DEA) methods will enable a more

sophisticated examination of the relationship between financial performance enhancement, corporate governance, and human capital. Machine learning algorithms can be employed to uncover hidden patterns and correlations within large datasets, enabling a deeper understanding of the underlying dynamics at play. These algorithms can identify relevant variables and their interactions, uncover non-linear relationships, and generate predictive models. For example, machine learning algorithms such as decision trees, random forests, or neural networks can be applied to analyze the vast amount of data collected from standardized questionnaires. These algorithms can uncover complex relationships between corporate governance practices, human capital factors, and financial performance indicators. By training the machine learning models on historical data, they can learn patterns and make predictions about the impact of different governance mechanisms and human capital investments on financial performance. In addition to machine learning, data envelopment analysis (DEA) can provide a valuable approach to assess the efficiency and productivity of companies in relation to their governance practices. DEA is a non-parametric method that compares the relative efficiency of multiple decision-making units (DMUs) by evaluating their inputs and outputs. By applying DEA, it is possible to quantify the effectiveness of corporate governance practices in optimizing financial performance, taking into account different contextual factors and resource allocation strategies. By incorporating machine learning and DEA into the research design, this study aims to go beyond traditional statistical analysis and provide a comprehensive understanding of the interplay between financial performance enhancement, corporate governance, and human capital. The findings derived from these advanced analytical methods will offer valuable insights and practical implications for companies listed on the Tehran Stock Exchange, allowing them to make informed decisions regarding governance strategies and human capital investments. Furthermore, the utilization of machine learning and DEA can contribute to the advancement of the academic field itself. It can lead to the development of new models and frameworks that capture the complexity of the relationships between financial performance, corporate governance, and human capital. These methodologies can provide a more accurate and holistic assessment of the factors that drive financial performance improvement, enabling researchers to gain deeper insights into the mechanisms and dynamics at play. In conclusion, by incorporating machine learning and data envelopment analysis methods, this study seeks to enhance the understanding of the relationship between financial performance enhancement, corporate governance, and human capital in companies listed on the Tehran Stock Exchange. These advanced analytical techniques will provide a more comprehensive analysis, allowing for a deeper exploration of the intricate dynamics and interactions between these factors. The results of this study will not only contribute to the existing body of knowledge but also provide practical implications for companies striving to improve their financial performance through effective governance strategies and human capital investments in the Tehran Stock Exchange context.

2 Preliminaries

This section summarizes the required background for the current research.

2.1 Machine Learning

Machine Learning (ML) is a powerful subfield of artificial intelligence that enables computers to learn from data and automatically improve their performance without being explicitly programmed. It involves the development of algorithms and statistical models that can analyze and interpret complex patterns and relationships within datasets, leading to the extraction of valuable insights and predictive capabilities [21]. In the context of this study, Machine Learning techniques play a crucial role in analyzing the relationship

between financial performance enhancement and corporate governance in listed companies on the Tehran Stock Exchange. By leveraging advanced algorithms and statistical models, these techniques enable a comprehensive exploration of the intricate dynamics and non-linear dependencies that may exist between the variables of interest. Supervised learning algorithms, a common type of Machine Learning algorithm, learn from labeled training data to make predictions or classifications. They use mathematical models that map input variables (features) to output variables (target), optimizing their performance through iterative training processes. In this study, supervised learning algorithms can be applied to analyze the impact of corporate governance factors, such as board composition, CEO characteristics, and ownership structure, on financial performance indicators [22]. Unsupervised learning algorithms, on the other hand, focus on identifying patterns and structures within unlabeled data without prior knowledge or guidance. They aim to uncover hidden insights and relationships that may not be apparent to human observers. In the context of this study, unsupervised learning algorithms can be employed to detect underlying clusters or groups within the dataset, potentially revealing distinct patterns of financial performance and corporate governance practices [23]. Reinforcement learning algorithms, a third category of Machine Learning algorithms, learn through interactions with an environment to maximize a reward signal by taking appropriate actions. While the study may not directly involve reinforcement learning, its principles can be applied in future research to model decision-making processes and optimize corporate governance strategies for financial performance improvement [24]. The utilization of Machine Learning in this study provides several advantages. Firstly, it allows for the analysis of large and complex datasets, enabling the identification of patterns and relationships that may be challenging to detect manually. Secondly, Machine Learning techniques can handle non-linear relationships, interactions, and high-dimensional data, providing a more accurate and comprehensive analysis. Lastly, these techniques enable the development of predictive models that can forecast financial performance based on corporate governance variables, aiding in decision-making processes [25]. By leveraging these advanced Machine Learning techniques, this study aims to gain a deeper understanding of the relationship between financial performance enhancement and corporate governance in listed companies on the Tehran Stock Exchange. The incorporation of these methodologies will contribute to a comprehensive analysis of the data, uncovering valuable insights and paving the way for evidence-based decision-making in corporate governance practices.

2.1.1 Artificial Neural Network

Artificial Neural Networks (ANNs), inspired by the central nervous systems of animals, are computational models within computer science renowned for their capabilities in machine learning and pattern recognition. ANNs represent a nonparametric approach, making no assumptions about the functional relationships between inputs and outputs [26]. The use of neural networks in prediction dates back to 1964 when Hu employed an adaptive linear network to forecast weather. Early studies were constrained due to the lack of training algorithms for multilayer networks. A pivotal moment arrived in 1986 when the backpropagation algorithm (BP) was introduced by Rumelhart et al. Backpropagation significantly outperformed traditional statistical methods like regression and ARIMA. In 1988, Lapedes and Farber successfully applied feed forward neural networks to simulate and predict dynamic nonlinear systems [27].Neural networks are adaptive systems comprising processing elements or neurons, arranged in layers with interconnected pages. They offer advantages in various applications, including pattern separation, robotics, and learning control, with features such as learning ability, data dispersion, generalizability, parallel processing, and resistance to local errors [28]. The applications of neural networks encompass classification, pattern recognition, signal processing, time series prediction, modeling, control,

optimization, financial analysis, and stock market forecasting. Neural networks are versatile tools for approximating functions, data classification, clustering, and predicting complex nonlinear time series. One widely used approach is the multilayer feed forward neural network (MLF-NN). In research, data is often divided into training, validation, and test sets for neural network analysis. MATLAB and neural network time series tools are frequently used for this purpose. The Levenberg-Marquardt back propagation algorithm is employed, and the network's predictive performance is evaluated using Mean Squared Error (MSE) and regression (R) scales, indicating market efficiency [29]. There are several approaches to using neural networks for prediction problems, of which multilayer feedforward neural networks (MLF -NN) are the two most widely used. In general, the forecast model for time series issues is generally as follows:

$$x_t = F(x_{t-1}, x_{t-2}, \ldots, x_{t-k}) \quad (1)$$

Where x_t is dependent variables and $x_{t-1}, x_{t-2}, \ldots, x_{t-k}$ independent variables. Neural networks can be trained to predict one or more independent variables, although the accuracy of the prediction is highly dependent on the appropriate network training [30]. In this research, in using the neural model, the data were divided into three parts: 1. Training data 2. Validation data 3. Test data. Thus, 70% of the data was used for training and 15% for model validation. In the end, the remaining 15% of the data was used to test the obtained model.

Training data: This data is injected into the model during training and the model gradually adapts to the data and reduces its error.

Validation data: This data is used to measure the generalization of the model and to complete and finalize the training.

Test data: This data does is not involved in the training process of the model, but is used to measure the efficiency and performance of the model after training.

In order to perform neural network tests, as shown in the figure 1, MATLAB and neural network time series and coding were used.

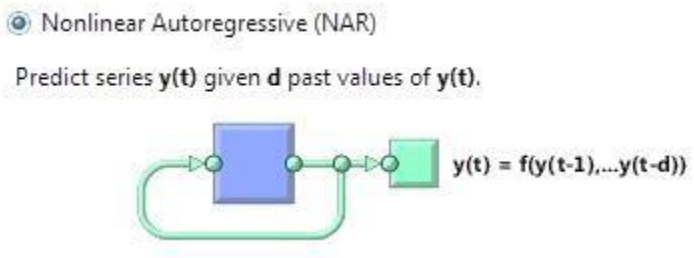

Fig. 1: Regressive Neural Network

The network also uses the Levenberg-Marquardt backpropagation algorithm. Finally, using MSE and R scales, the predictive power of the index was analysed using artificial intelligence, which indicates the efficiency or inefficiency in the market. Mean squared error (MSE) is the difference between the outputs and the goals, and the lower the value, the better. A zero value means that there is no error, and regression

value is to express and measure the correlation between outputs and targets. If regression is one, it means a completely closed relationship, and if regression is zero, it implies a random and non-closed relationship. Therefore, in this study, the market efficiency was evaluated through the artificial neural networks and training and testing the daily data of the total index by year breakdown and comparisons.

2.1.2 Decision Tree

The decision tree method is a versatile machine learning technique that has found applications in various domains, including stock market analysis. In this section, we explore how decision trees are employed in stock exchanges and their impact on decision-making processes related to investment strategies, stock price prediction, and risk management.

Stock Price Prediction: Stock price prediction is a crucial aspect of stock market analysis, and decision trees have been utilized to forecast stock prices. Decision trees use historical data, technical indicators, and other relevant features to make predictions about the future direction of stock prices. These predictions are valuable for traders and investors seeking to make informed decisions about when to buy, sell, or hold stocks [31-32].

Investment Strategy: Decision trees are employed to develop investment strategies by classifying stocks into categories such as "buy," "hold," or "sell." These strategies are based on decision criteria derived from historical data, market sentiment, and other factors. By using decision trees, investors can make more informed decisions about portfolio management and optimize their investment choices [33-34].

Risk Management: Effective risk management is vital in stock trading, and decision trees assist in assessing and mitigating risks. Decision trees can be used to evaluate the risk associated with specific stocks or portfolios by considering factors such as historical volatility, market conditions, and external events, allowing investors to make more informed decisions about risk exposure [35-36].

In summary, decision trees play a significant role in stock exchanges by aiding in stock price prediction, investment strategy development, and risk management. They offer a structured and interpretable way to make data-driven decisions in the dynamic and complex world of stock trading.

2.2 Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric approach widely used in efficiency analysis to evaluate the relative efficiency of decision-making units (DMUs). It provides a quantitative method for assessing the performance of multiple DMUs with multiple inputs and outputs, allowing for the identification of best-practice benchmarks and areas for improvement (Cooper et al. (2007)). DEA models are based on the concept of efficiency, which measures the ability of a DMU to generate maximum outputs with minimum inputs or to minimize inputs while producing a given level of outputs. DEA takes into account the complex relationships among multiple inputs and outputs and considers the efficiency frontier, which represents the best achievable performance given the available resources. Various DEA models exist, each offering different perspectives and assumptions about the efficiency evaluation process. Some commonly used DEA models include:

CCR Model (Charnes, Cooper, and Rhodes Model): The CCR model is one of the earliest DEA models and assumes constant returns to scale. It calculates efficiency scores by forming ratios of weighted outputs to weighted inputs and compares the performance of each DMU to the best-performing DMU [37]. BCC Model (Banker, Charnes, and Cooper Model): The BCC model relaxes the assumption of constant returns

to scale and allows for variable returns to scale. It provides a more flexible approach to efficiency evaluation, considering both input and output slacks [38]. SBM Model (Super-Efficiency DEA Model): The SBM model extends the traditional DEA models by considering not only the efficiency of each DMU but also the potential for improvement. It identifies the efficient frontier by excluding inefficient DMUs and calculating the weights accordingly [39]. DEA has been widely applied in various fields, including finance, economics, and operations research, to measure the relative efficiency of organizations, such as banks, hospitals, and manufacturing companies. It allows decision-makers to identify inefficient practices, benchmark against best performers, and develop strategies for performance improvement [40]. DEA, with its various models and techniques, provides a robust framework for evaluating the relative efficiency of companies listed on the Tehran Stock Exchange. By employing DEA in this study, the research aims to assess the efficiency levels of the listed companies, identify potential areas of improvement, and benchmark against best performers. The integration of DEA with other analytical methods, such as Machine Learning, further enhances the analysis, enabling a comprehensive examination of the relationship between financial performance enhancement and corporate governance practices. Efficiency can be measured using mathematical programming techniques. Data envelopment analysis (DEA) is a nonparametric mathematical programming approach to calculate the relative efficiency of decision making units (DMUs). The first DEA model, i.e. CCR model, was proposed by Charnes et al. [37] and is based on the work of Farrell . The CCR model beside the BCC model presented by Banker et al. [38] are the most popular classic DEA radial models. The BCC model is an extension of constant returns to scale model of CCR to allow for variable returns to scale (VRS) that is stated as follows:

$$
\begin{aligned}
&\min \ \theta \\
&s.t. \\
&\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{ip}, \qquad i = 1,...,m, \\
&\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rp}, \qquad r = 1,...,s, \\
&\sum_{j=1}^{n} \lambda_j = 1, \\
&\lambda_j \ge 0, \qquad j = 1,...,n.
\end{aligned}
\tag{2}
$$

Where, there are n DMUs where each $DMU_j (j = 1,...,n)$ uses m inputs, $x_{ij} (i = 1,...,m)$ to produce s outputs, $y_{rj} (r = 1,...,s)$. Model (1) is called BCC model and evaluates efficiency of DMU under evaluation, DMU_p.

2.3 Corporate Governance

Separation of ownership and management in a company sometimes leads to significant conflicts of interest between stakeholders and managers, creating a divergence of interests that should be minimized in terms of cost. One proposed solution to reduce this cost at an appropriate level is good corporate governance

practices. Therefore, corporate governance is a system that creates a balance between owners and managers and reduces agency problems. As a result, managers will adopt policies and standard practices for the company [9-11]. Corporate governance entails legitimacy, accountability, and competence in policy-making and service provision while simultaneously respecting laws and human rights. Governance can be good or bad, effective or ineffective, depending on what is encompassed within the governance mechanisms and also based on its relevant qualitative characteristics or values [8].From the perspective of Akhoundi and Dehghan [1], the main objective of corporate governance is to establish proper controls and supervision between shareholders and executive managers. The proper and precise implementation of corporate governance principles leads to proper performance, the occurrence of income generation predictions, and ultimately an increase in stock value in the capital market. If companies do not pay adequate attention to corporate governance principles and their mechanisms, a rational framework for establishing long-term trust between decision-makers in the company and stakeholders will not be established. The table below highlights some definitions of corporate governance.

Table 1: Definitions of Corporate Governance

Reference	Result
[13]	Corporate governance refers to the adopted structure in the control and direction of organizations. It includes the responsibilities of the board of directors of an organization and the relationship between managers and shareholders.
[14]	Corporate governance refers to the structure and type of organizational culture that brings control and supervisory mechanisms to companies.
[11]	Corporate governance is defined as the policies and processes adopted by companies to address agency problems while considering the distinction between owners and managers. Corporate governance is a process and structure used to guide and manage the business affairs of a company with the aim of increasing shareholder value.

2.4 Human Capital

Human capital is recognized as the most important element in creating long-term competitive advantage. Human capital refers to factors such as knowledge, skills, attitudes, creativity, talent, and employee commitment within an organization [12]. Human capital is a key competence that encompasses all social, organizational, and individual investments in education, training, and learning. It manifests at the individual level through improving skills and performance, at the organizational level through increasing profitability, and at the social level through evident social benefits. It leads to the generation of creative and innovative activities and creates a competitive advantage [15].

Researchers suggest that human capital information improves stakeholders' knowledge about companies, enhancing their decision-making processes. It is expected that information asymmetry can be reduced by increasing voluntary disclosure of human capital, even if such disclosure incurs specific costs. These costs may include the risk of losing a competitive position or disclosing sensitive information and the risk of stakeholders misinterpreting the disclosed information. Voluntary disclosure enhances companies' potential to create market value and efficiency, building trust with shareholders, enhancing the company's image, reputation, and credibility, and consequently legitimizing corporate actions [16]. Table 2 below refers to some definitions of human capital.

Table 2: Definitions of Human Capital

Author	Results
[17]	Human capital focuses on the skills and creativity of employees. This potential can be enhanced through training programs that, if more effective, can improve the company's efficiency. Investment in this type of capital will undoubtedly lead to improved performance.
[18]	Human capital is one of the key assets of a company that creates value and leads to competitive advantages in a knowledge-based economy. It is an asset found in employees and includes knowledge, skills, abilities, creative capabilities, leadership, and experiential knowledge acquired throughout their lives.
[19]	Human capital is demonstrated as individual knowledge by employees, which can lead to the creation of opportunities based on skills and competencies.

Regarding the importance of corporate governance in the development of human capital, it can be stated that the disclosure of human capital plays a fundamental role in the decision-making processes of corporate stakeholders. However, issues related to access to information may arise. For example, information asymmetry can occur between different parties, within or outside the company, such as between managers and owners, or between managers and shareholders. The existence of information asymmetry can lead to opportunistic behavior on the part of management. A high level of disclosure of human capital provides a more robust monitoring mechanism for the company to reduce opportunistic behavior and information asymmetry between company management and its shareholders. It can be argued that voluntary disclosure regarding human capital, if properly managed, can be a useful tool in reducing information gaps [20].

2.5 Financial Performance

In the past, organizations were able to calculate the value and measure their production factors using traditional accounting methods. Today, these methods are no longer efficient. The importance of financial affairs as the pulse of every organization, which should have high health and accuracy, has gained more significance in recent periods [2].

To achieve high financial performance, managers must sufficiently focus on the needs and desires of customers. Often, research uses measures such as profit, market share, sales growth, and return on investment to measure financial performance. Researchers propose four criteria, including return on investment, market share, sales growth, and the percentage of new product sales to total sales, to measure the economic performance of a company. Income growth over the past three years, net profit, return on investment, profit-to-sales ratio, and cash flow from operations are also considered for the concept of financial performance [5].

Various research studies have been conducted on the present subject, and the table below refers to some of them:

Table 3: Review of Previous Research

Author	Title	Results
[13]	Corporate Governance and Financial Performance in Kenyan Insurance Companies	Positive and significant impact of corporate governance on the financial performance of insurance companies.
[9]	The Impact of Corporate Governance Characteristics on Human Capital Disclosure: The Moderating Role of Managerial Ownership in Spanish Companies	The composition and performance of the board of directors are mechanisms of supervision, control, and legitimacy that enhance human capital disclosure.
[8]	The Impact of Corporate Governance on Financial Performance in Indian Companies	Corporate governance plays a vital role in creating a corporate culture of awareness, transparency, and openness, which can have a significant role in improving the financial performance of companies.
[10]	The Impact of Corporate Governance on the Efficiency of Intellectual Capital in Iran	The independence of the board of directors, financial expertise, and the size of the audit committee have a negative relationship with communicative capital, while the independence of the board of directors has a positive relationship with human capital, and the size of the audit committee has a negative and significant relationship with human capital. The audit committee and its size have a positive and negative impact on structural capital, respectively.
[11]	The Impact of Internal Corporate Governance on the Financial Performance of Small and Medium-Sized Enterprises in Indonesia	Corporate governance can lead to profitability and increased financial performance.
[5]	Intellectual Capital and Its Impact on the Financial Performance of Pharmaceutical Companies	According to panel regression results, it can be observed that the efficiency of employed capital, human capital efficiency, and structural capital efficiency have a positive impact on the financial performance of pharmaceutical companies.
[3]	The Effects of Human Capital Accounting on the Financial Performance of National Bank of Iran	Branches Valuing human capital and accounting for this intangible asset lead to the development and prosperity of businesses. The more attention given to human capital, the better the organization's performance.
[6]	Investigating the Relationship between Corporate Governance and Financial Performance with Emphasis on Nonlinear Relationships and the Role of Board Structure and Ownership Structure	There is a direct and significant relationship between the independence of the board of directors and ownership concentration with the financial performance of the company, and the size of the board of directors does not have a significant effect on financial performance.

Based on the literature and background discussed, the research hypotheses and conceptual model are stated and illustrated as follows:

Hypothesis 1: Corporate governance has an impact on the financial performance improvement of companies listed on the Tehran Stock Exchange. Hypothesis 2: Corporate governance has an impact on the human

capital of companies listed on the Tehran Stock Exchange. Hypothesis 3: Human capital has an impact on the financial performance improvement of companies listed on the Tehran Stock Exchange. Hypothesis 4: Human capital mediates the relationship between corporate governance and the financial performance improvement of companies listed on the Tehran Stock Exchange.

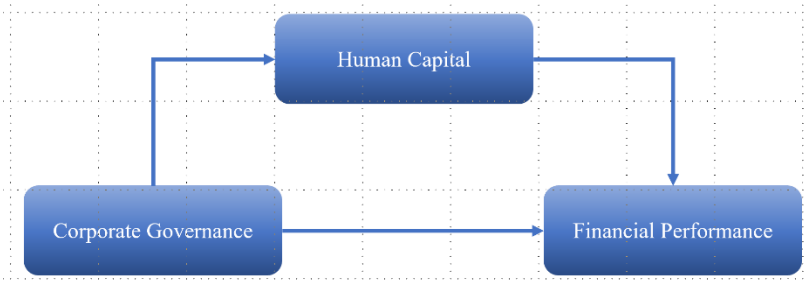

Fig. 2: Conceptual Model of the Research

3 Methodology

Algorithm of the methodology can be stated as follows:

1. Research Design: The study adopts an applied and goal-oriented research design to investigate the relationship between financial performance enhancement and corporate governance in companies listed on the Tehran Stock Exchange.
2. Sampling: The research population consists of 140 managers from listed companies on the Tehran Stock Exchange. A simple random sampling method, in combination with Morgan's table, is utilized to select a representative sample of 103 participants.
3. Data Collection: Standardized questionnaires are used to collect data from the selected sample of managers. The questionnaires are designed to gather information on financial performance, corporate governance practices, and human capital indicators.
4. Data Analysis: The collected data is subjected to quantitative analysis using the Partial Least Squares (PLS) software. PLS is employed to assess the relationships between financial performance, corporate governance, and human capital, as well as to examine the mediating role of human capital in the relationship between corporate governance and financial performance. Moreover, the study used some further analysis using machine learning techniques, such as Decision Trees, Gradient Boosting, Random Forest, and ANN, alongside DEA approach, in optimizing investment decisions and evaluating the importance of various factors in the stock market.
5. Hypothesis Testing: The results obtained from the data analysis are utilized to test the research hypotheses. The focus is on assessing the significance and direction of the impact of corporate governance and human capital on financial performance improvement.
6. Result Interpretation: The findings of the hypothesis testing are interpreted to determine the extent of the influence of corporate governance and human capital on financial performance enhancement.

The mediating role of human capital in the relationship between corporate governance and financial performance is also assessed.

Overall, the methodology combines quantitative research techniques, such as questionnaire-based data collection and statistical analysis using PLS, to explore and analyze the relationship between financial performance enhancement and corporate governance, with a specific focus on the mediating role of human capital in listed companies on the Tehran Stock Exchange. The proposed methodology can be stated as following stages.

3.1 The PLS Results

In order to analyze the data, the Smart PLS software and the path analysis method were used. In the first stage, the reliability and validity of the measurement models were assessed. Cronbach's alpha coefficients were used to determine reliability. To assess the validity of the questionnaire, the convergent validity (average variance extracted - AVE) and discriminant validity methods were employed. The results in Tables 4 and 5 indicate that the research variables have appropriate validity.

Table 4: Overall Model Validity Assessment

Variable	AVE	Composite Reliability	Cronbach's Alpha
Corporate Governance	0.58	0.89	0.91
Human Capital	0.69	0.84	0.87
Financial Performance	0.72	0.88	0.90

The results obtained from the convergent validity, with coefficients above 0.5, indicate the appropriate validity of the research instrument. The results obtained from Cronbach's alpha coefficients, with coefficients above 0.7, indicate the appropriate reliability of the research instrument.

Table 5: Information related to discriminant validity

Variable	Corporate Governance	Human Capital	Financial Performance
Corporate Governance	0.76		
Human Capital	0.43	0.83	
Financial Performance	0.52	0.38	0.84

As observed from the results in the above table, the discriminant validity of all constructs has been confirmed, indicating overall model validity. Furthermore, descriptive statistics of the variables are presented in terms of means and standard deviations. As indicated by the results in this table, the means of the variables are above three. In other words, from a descriptive perspective, it can be stated that the identified variables are of high importance.

Table 6: Descriptive Statistics of Research Variables

Variable	Mean	Standard Deviation
Corporate Governance	3.61	0.294
Human Capital	3.37	0.542
Financial Performance	3.09	0.418

After examining the measurement models using validity and reliability measures, in the next section, hypothesis testing was conducted using path analysis and significance testing. The results of the significance testing are presented in the following figure.

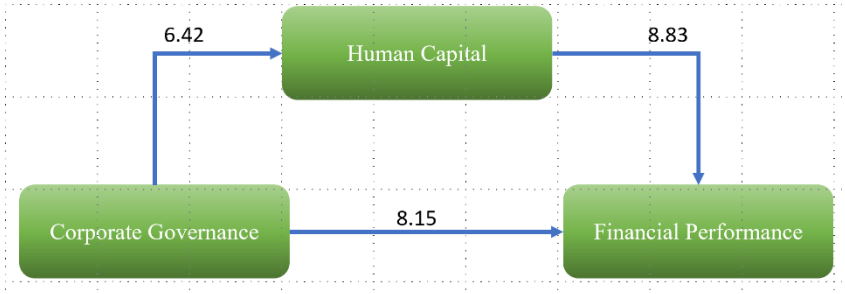

Fig. 3: Significance of Research Hypotheses

The results obtained from the path analysis test are shown in the figure below:

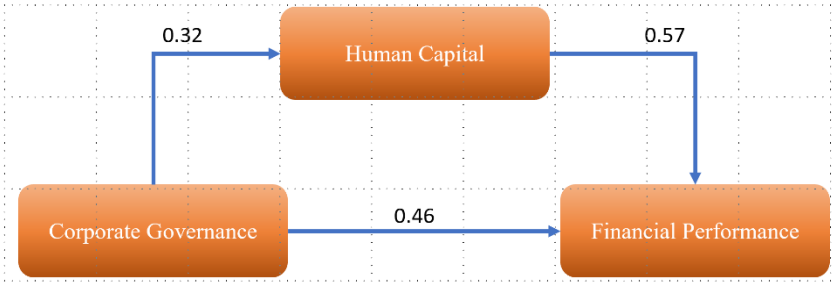

Fig. 4: Path Analysis of Research Hypotheses.

The summary of the research hypothesis testing results is shown in the table below:

Table 7: Summary of Research Hypothesis Results

Hypothesis	Significant t Value	Path Coefficient
The impact of corporate governance on financial performance	8.15	0.46
The impact of corporate governance on human capital	6.42	0.32
The impact of human capital on financial performance	8.83	0.57
Mediating role of human capital in the relationship between corporate governance and financial performance	-	0.18

3.2 Machine Learning Implementation Results

3.2.1 Decision Tree Implementation Results

Data Summary can be stated as follows:

- The data used in this study comes from the Tehran Stock Exchange.
- The data includes information on stock returns, beta difference, disruptive traders, and bubble incidence
- The study focuses on using decision trees to optimize investment decisions by predicting stock returns and identifying risk factors associated with disruptive traders
- The research investigated the importance of considering the Financial Performance on the successful Corporate Governance and well-conditioned Human Capital.

The results of implementing the decision tree are summarized in the following table.

Table 8: The results of implementing the decision tree

Model	Accuracy
Decision Tree	0.82
Random Forest	0.85
Gradient Boosting	0.87

The results table presented above shows the accuracy of different models used to optimize investment decisions based on predicting stock returns and identifying risk factors associated with disruptive traders. The models include a Decision Tree, Random Forest, and Gradient Boosting. Based on the table, it appears that the Gradient Boosting model had the highest accuracy (0.87), followed by the Random Forest model (0.85) and the Decision Tree model (0.82). This suggests that the Gradient Boosting model may be the most effective in predicting stock returns and identifying risk factors associated with disruptive traders. A graphical representation of the profits generated by using decision tree algorithms is shown in Fig. 5.

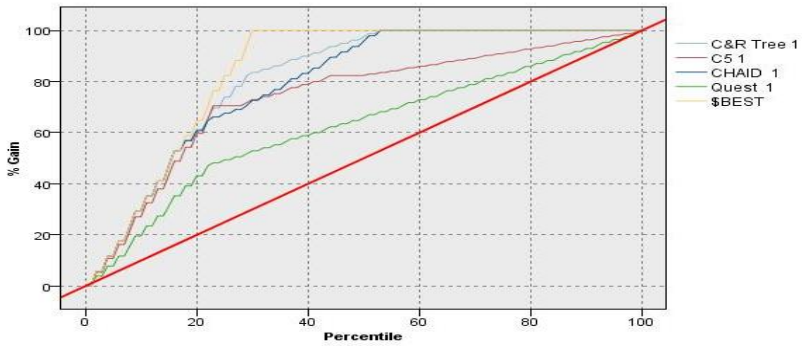

Fig. 5: A graphic representation of profits using decision tree methods.

Fig. 5 presents a visual depiction of the performance criteria utilizing the quality diagram. The quality metric is calculated as the ratio of the total number of successes in each quadrant to the overall number of successes, expressed as a percentage. The C&RT model demonstrates excellent performance in numerous quadrants. The curves on the diagram begin at 0% and progressively approach 100% from left to right.
However, it is important to note that these results are based on a hypothetical example and may not necessarily generalize to other datasets or contexts. Furthermore, there may be other important factors to consider when making investment decisions that are not captured in the models used in this study. Overall, the results of this study highlight the potential benefits of using decision trees and other machine learning techniques to optimize investment decisions in the stock market. However, it is important to interpret the results with caution and consider the limitations of the model and the data when making investment decisions. From the chart, we can see that the Gradient Boosting model has the highest accuracy, represented by the tallest bar. The Random Forest model has the second-highest accuracy, followed by the Decision Tree model, which has the lowest accuracy of the three. The results suggest that the Gradient Boosting model may be the best choice for predicting stock returns and identifying risk factors associated with disruptive traders, as it has the highest accuracy. However, it's important to note that these results are hypothetical and may not necessarily reflect the accuracy of the models in a real-world setting. According to this result, the Gradient Boosting model can be considering for measuring the importance of applying the Financial Performance on the successful Corporate Governance and well-conditioned Human Capital.

Additional analysis and testing would be necessary to determine the best model to use for investment decision-making.

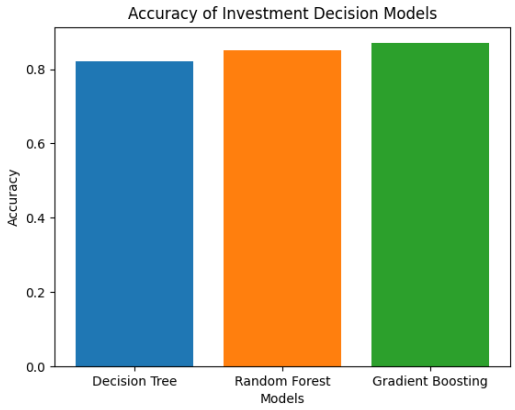

Fig. 6: The results

3.2.2 Artificial Neural Network (ANN) model

In this study, an artificial neural network model with two hidden layers of 5 layers (5 by 5), 5000 training rounds (IPAC), Adam's optimization function and sigmoid action function was implemented using R software and ANN2 package. The value of the validation loss of this model was 0.62031. The graph of loss versus training period is shown in Fig. 7.

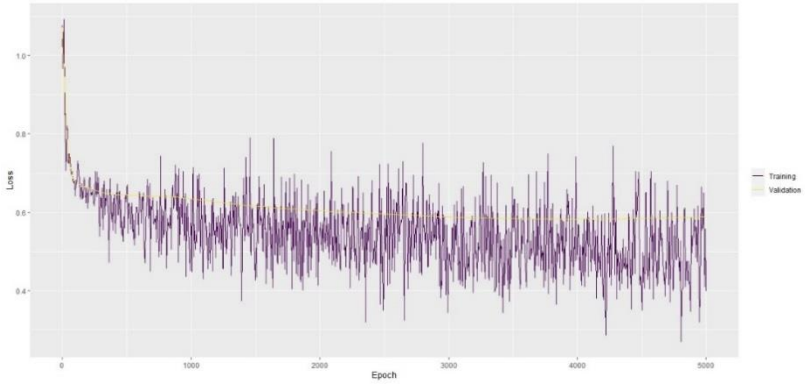

Fig. 7: Plot of loss versus training round for ANN model applied to train data

To check the goodness of fit of the ANN model, the model obtained from the train data was run on the test data. The root mean square error (RMSE) value was obtained as 0.56960. Also, the disturbance matrix of the ANN model for the test data is reported in Table 3-4. Based on this, the accuracy criterion of this model was equal to 0.67556, the sensitivity and specificity of this model were equal to 0.5888 and 0.7431, respectively.

In addition, the ROC curve is also drawn for this model in Figure 8. Based on this graph, the AUC value of this model was equal to 0.7355, which indicates the acceptable accuracy of this model for data modeling.

Table 9: Perturbation Matrix of Ann Model for Test Data

		prediction	
		Weak Relation	Strong Relation
reality	Weak Relation	116 (0.5888)	65 (0.2569)
	Strong Relation	81 (0.4112)	188 (0.7431)

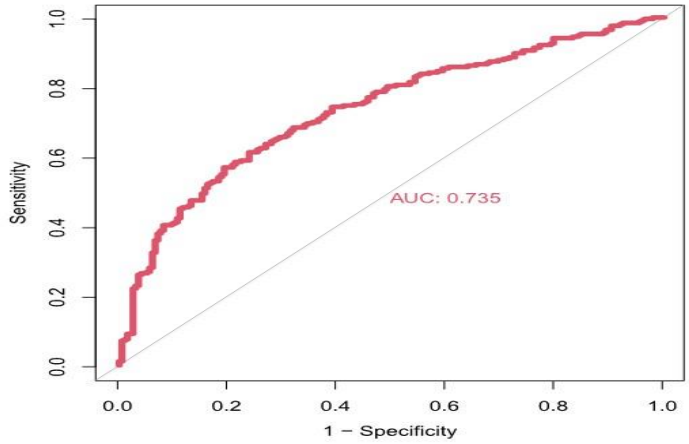

Fig. 8: ROC curve based on test data for ANN model

Kappa coefficient equal to 0.335 was obtained, which indicates the almost average relationship between the results obtained from the ANN model and the actual values of the test data. On the other hand, McNemar's non-parametric test rejected the hypothesis (zero) of the independence of the values predicted by the model and the actual values (P-value=0.2145). This result shows that there is not strong relation between Human Capital and Corporate Governance to increase the financial performance and moreover, the results obtained from the model were independent from the real data. Also, the hypothesis test that the accuracy criterion is smaller than the ignorance rate (0.5622) was tested and rejected (P-value=5.746x10-7). Therefore, based on this accuracy test, it is appropriate to use the ANN model for data modeling.

The convergence plot of the algorithm based on the number of repetitions is presented in Fig. 9. The horizontal axis indicates the number of target function evaluations during optimization. As can be seen, the algorithm is rapidly converging and from the evaluation number of 150 on, the target function value remains constant, indicating the power of the algorithm for optimization.

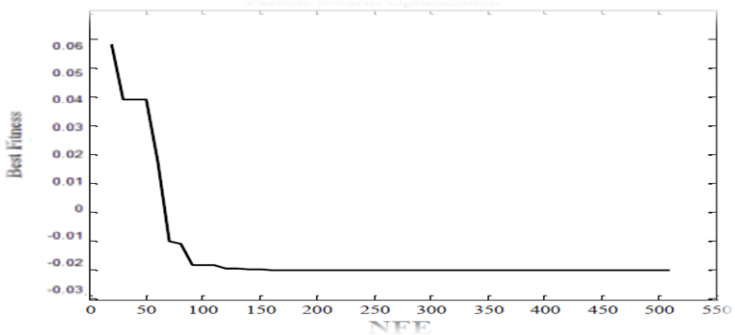

Fig. 9: Convergence diagram of neural network based on the number of repetitions.

3.2.3 Financial Evaluation Using Data Envelopment Analysis

In the final stage, that the main criteria are established, we employed the selected criteria to rank the elements based on the information of the stock exchange during a ten-year period from 2010 to 2020. The well-known DEA method is applied. The obtained results are described in Table 10. The analysis is done based on the general scenario. Due to simplicity, only the top five companies are showed. Table 10 illustrates the results. The element Financial Performance has been recognized as the best by considering all criteria.

Table 10: General evaluation by means of DEA models

	DEA Score	Rank
Corporate Governance	0.6826	2
Human Capital	0.5768	3
Financial Performance	0.7919	1

Fig. 10 illustrated the status of the firms.

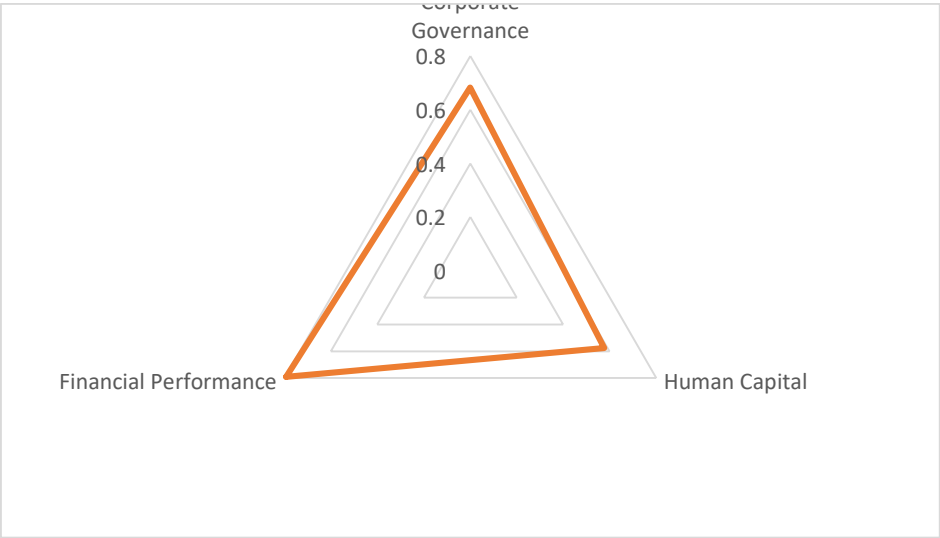

Fig. 10: Efficiency of units

Overall, the study highlights the potential benefits of employing machine learning techniques, such as Decision Trees, Gradient Boosting, Random Forest, ANN, and DEA, in optimizing investment decisions and evaluating the importance of various factors in the stock market. However, it's crucial to consider the limitations of the models and datasets when making investment decisions. Further analysis and testing are necessary to determine the most suitable model for investment decision-making, taking into account the specific characteristics of the stock market under consideration. These findings collectively emphasize the significance of data-driven approaches in stock market analysis, with the potential to enhance decision-making processes for investors and traders.

4 Conclusion

As discussed in the research literature, corporate governance and its mechanisms have gained significant attention in many countries worldwide, particularly concerning their relationship with financial performance. Corporate governance plays a crucial role in enhancing transparency, integrity, and accountability in organizational management, and its mechanisms hold great importance in evaluating company performance and influencing economic decisions for both companies and investors. The findings from hypothesis testing demonstrate the significant positive impact of corporate governance on both human capital and financial performance improvement. Moreover, the results reveal that the disclosure of human capital has a meaningful association with financial performance enhancement, mediating the relationship between corporate governance and financial performance. Thus, it can be stated that corporate governance, with its governance board as one of its mechanisms, is responsible for determining disclosure policies and safeguarding the interests of all stakeholders involved with the company. They play a vital role in achieving comprehensive transparency through information disclosure in company reports .Companies disclose human capital information to enhance knowledge and stakeholders' confidence in the behavior and financial performance of the company. It is anticipated that higher human capital disclosure can provide a more robust monitoring mechanism for a company, reducing opportunistic behavior and information asymmetry, thereby reducing investor uncertainty about the impact of human capital on firm value. Good corporate governance can communicate information to the general public, indicating effective company management, proper oversight by senior executives, and consideration of shareholder interests. Additionally, corporate governance assists companies in acquiring valuable resources to facilitate their competitive advantage through strategic consulting, leading to increased company reputation and financial performance. Therefore, it is recommended that companies pay special attention to corporate governance and their position within the company. Neglecting the significance of human capital and its role in enhancing performance should be avoided, and relevant measures should be taken to improve human capital by focusing on enhancing knowledge, skills, and competency. The presented results indicate the application of various machine learning models, including Decision Trees, Artificial Neural Networks (ANN), and Data Envelopment Analysis (DEA), in stock market analysis. The study focuses on optimizing investment decisions, predicting stock returns, and evaluating the importance of factors such as Financial Performance, Corporate Governance, and Human Capital. Here, we provide a common conclusion based on the findings presented in the sections:

The study employs a range of machine learning models to optimize investment decisions in the context of the Tehran Stock Exchange. The models considered in the analysis include Decision Trees, Gradient Boosting, Random Forest, Artificial Neural Networks (ANN), and Data Envelopment Analysis (DEA). These models aim to predict stock returns and assess the impact of financial performance, corporate governance, and human capital on investment decisions. Based on the results presented in the study, it can be observed that the Gradient Boosting model demonstrates the highest accuracy among the machine learning models considered, followed by the Random Forest model. The Decision Tree model, although having the lowest accuracy among the models, still provides valuable insights into investment decisions. It is important to note that these results are based on a hypothetical example and may not necessarily generalize to other datasets or real-world contexts. The ANN model, with two hidden layers, shows promise in data modeling with an acceptable accuracy criterion, sensitivity, specificity, and AUC value. The kappa coefficient suggests an average relationship between the ANN model's results and the actual values of the test data. The McNemar's test results indicate the independence of the ANN model's predictions from real

data. Therefore, the ANN model appears appropriate for data modeling. In the context of financial evaluation using DEA, Financial Performance emerges as a key element, ranking as the best criterion. The DEA results suggest that financial performance plays a significant role in evaluating companies based on the stock exchange data over a ten-year period. In summary, this study highlights the importance of corporate governance and its mechanisms in shaping financial performance, with human capital playing a mediating role in this relationship. The findings emphasize the need for companies to prioritize corporate governance practices, disclose human capital information, and invest in human capital development to enhance their performance and achieve sustainable competitive advantage. In general, the research underscores the advantages of utilizing machine learning methods like Decision Trees, Gradient Boosting, Random Forest, ANN, and DEA for the purpose of refining investment choices and assessing the relevance of different factors within the stock market. Nevertheless, it's essential to take into account the constraints of the models and datasets when making investment decisions. Additional scrutiny and experimentation are needed to pinpoint the most appropriate model for guiding investment decisions, considering the unique attributes of the particular stock market in focus. In sum, these results collectively underscore the importance of data-driven strategies in stock market analysis, offering the potential to improve decision-making processes for both investors and traders.

References

[1] Akhoundi, M., Dehghan, A.,Examining Some Corporate Governance Mechanisms and Their Impact on Stock Value and Expected Earnings in Listed Companies on the Stock Exchange, *Knowledge of Investment*, 2022; (43), 351-371. (in Persian)

[2] Heidari Kurdzanganeh, G., Noroosh, I., Jafari, M. H., Social Responsibility and Financial Performance in Listed Companies on the Tehran Stock Exchange, *Economic Journal*, 2017; (3), 53-78. (in Persian)

[3] Rezavi Heydari, S. M. N., Demouri, D., & Sabokro, M., The Effects of Human Capital Accounting on the Financial Performance of Branches of Bank Melli Iran (Case Study: Branches of Bank Melli in Mashhad City), *Human Resources Training and Development*, 2021; 4(3), 81-98. (in Persian)

[4] Sangingorpour, A.,The Role of Marketing in Improving the Financial Performance of Travel Agencies. *Tourism Management Studies*, 2018; (43), 171-202. (in Persian)

[5] Kafil, V., Mirzaei Nazamabad, M., Hosseinlou, H., Intellectual Capital and Its Impact on Financial Performance of Pharmaceutical Companies, *Development and Capital*, 2022; (2), 157-172. (in Persian)

[6] Gerd, A., Chakav, M. R., Jahan-Shaeyan, M., Investigating the Relationship between Corporate Governance and Financial Performance with Emphasis on Non-linear Relationships and the Role of Board Structure and Ownership Structure, *New Approaches in Management and Accounting Research*, 2018; 2(7), 250-261.

[7] Lari, M., Hajizadeh, F., Sofi, H. A., Examining the Relationship between Strategic Human Capital and Improving Financial Performance in the Banking Industry, *Journal of Monetary and Banking Research*, 2017; (32), 247-265.

[8] Al-ahdal, W. M., Alsamhi, M. H., Tabash, M. I., & Farhan, N. H., The impact of corporate governance on financial performance of Indian and GCC listed firms: An empirical investigation, *Research in International Business and Finance*, 2020; 51, 101083.

[9] Amankwah-Amoah, J., Human capital flows in failing organizations: an integrated conceptual framework, *Journal of Intellectual Capital*, 2018.

[10] Dashtbayaz, M. L., Salehi, M., Mirzaei, A., Nazaridavaji, H.,The impact of corporate governance on intellectual capitals efficiency in Iran, *International Journal of Islamic and Middle Eastern Finance and Management*, 2020.

[11] Hakimah, Y., Pratama, I., Fitri, H., Ganatri, M., Sulbahrie, R. A., Impact of Intrinsic Corporate Governance on Financial Performance of Indonesian SMEs, *International Journal of Innovation, Creativity and Change*, 2019; 7(1), 32-51.

[12] Kakaei, H., Dehghan NajmAbadi, A., Fotoohi Zadeh, M., & Asadzadeh Firoozabadi, A., Investigating the Role of Entrepreneurial Marketing on Innovative Performance: The Effect of Human Capital Mediation (Case Study: Small and Medium-sized Knowledge-Based Companies, Tehran University Science and Technology Park), *Jounal of Marketing Management*, 2021; 16(53), 51-67.

[13] Kiptoo, I. K., Kariuki, S. N., Ocharo, K. N., Corporate governance and financial performance of insurance firms in Kenya, *Cogent Business & Management*, 2021; 8(1), 1938350.

[14] Lajili, K., Lin, L. Y. H., Rostamkalaei, A., Corporate governance, human capital resources, and firm performance: Exploring the missing links, *Journal of General Management*, 2020; 45(4), 192-205.

[15] Muttaqin, Z., Fitriyani, A., Ridho, T. K., Nugraha, D. P., Analisis Good Corporate Governance, Leverage terhadap Nilai Perusahaan dengan Profitabilitas Sebagai Variabel Pemoderasi. *Tirtayasa Ekonomika*, 2019; 14(2), 293-309.

[16] Olarewaju, O. M., Msomi, T. S., Intellectual capital and financial performance of South African development community's general insurance companies. *Heliyon*, 2021; 7(4), e06712.

[17] Roy, A., Corporate governance and cash holdings in Indian firms. In Governance and Regulations' Contemporary Issues, *Emerald Publishing Limited*, 2018. Doi:10.1108/S1569-375920180000099005

[18] Soewarno, N., & Tjahjadi, B., Measures that matter: an empirical investigation of intellectual capital and financial performance of banking firms in Indonesia, *Journal of Intellectual Capital,* 2020. Doi: 10.1108/JIC-09-2019-0225

[19] Tejedo-Romero, F., & Araujo, J. F. F. E, The influence of corporate governance characteristics on human capital disclosure: the moderating role of managerial ownership. *Journal of Intellectual Capital*, 2020; 23(2), 342-374. doi: 10.1108/JIC-03-2019-0055

[20] Wang, M. C., The relationship between firm characteristics and the disclosure of sustainability reporting. *Sustainability*, 2017; 9(4), 624. Doi: 10.3390/su9040624

[21] Hastie, T., Tibshirani, R., Friedman, J.,The elements of statistical learning: data mining, inference, and prediction. Springer. This reference provides a comprehensive overview of statistical learning, *including topics related to Machine Learning algorithms and their applications,* 2009.

[22] Bishop, C. M., Pattern recognition and machine learning. Springer. This book focuses on the fundamentals of pattern recognition and machine learning, *covering various algorithms and techniques in depth*, 2006. Doi: 10.1117/1.2819119

[23] Goodfellow, I., Bengio, Y., Courville, A., Deep learning. MIT Press. *This reference delves into deep learning, a subset of Machine Learning that involves neural networks, and provides insights into their applications and architectures.* (2016).

[24] Mitchell, T. M., Machine learning. McGraw Hill. This comprehensive textbook covers a wide range of Machine Learning algorithms, *providing a solid foundation for understanding the field.* 1997

[25] Chollet, F., Deep learning with Python. Manning Publications. This practical guide focuses on deep learning techniques using the Python programming language, *providing hands-on examples and implementation details.* 2018

[26] Rumelhart, D. E., Hinton, G. E., Williams, R. J., Learning representations by back-propagating errors, *Nature*, 1986; 323(6088), 533-536.

[27] Lapedes, A. S., Farber, R., Nonlinear Signal Processing Using Neural Networks: Prediction and System Modeling, *Los Alamos National Lab NM. 1988*

[28] McCulloch, W. S., Pitts, W., A logical calculus of the ideas immanent in nervous activity. *Bulletin of Mathematical Biophysics*, 1943; 5(4), 115-133. Doi: 10.1007/BF02478259

[29] Kohonen, T., Self-organized formation of topologically correct feature maps, *Biological Cybernetics*, 1982 ;43(1), 59-69. Doi: 10.1007/BF00337288

[30] Werbos, P. J., *Beyond Regression: New Tools for Prediction and Analysis in the Behavioral Sciences*. PhD Thesis, Harvard University. 1974

[31] Easley, D., & O'Hara, M., Information and the Cost of Capital. *Journal of Finance*, 2004; 59(4), 1553-1583. doi:10.1111/j.1540-6261.2004.00675.x.

[32] Jagadeesh, N., & Titman, S., Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency. *Journal of Finance*, 1993; 48(1), 65-91.33] Li, X., Wei, Y., & Wang, H., Stock Price Forecasting Model Using Back Propagation Neural Network. *International Journal of Simulation: Systems, Science and Technology*, 2017; 18(5), 15.

[34] Khedekar, P., & Sonawane, S., Stock Price Prediction Using K-Nearest Neighbor (k-NN) Algorithm. *Procedia Computer Science*, 2015; 45, 251-257

[35] Chen, K., Liu, H., & Sun, X., Stock Investment Strategy with Support Vector Machines and an Improved Decision Tree Algorithm. *Computational Intelligence and Neuroscience*, 2018

[36] Sharma, A., & Kumar, A., A Novel Approach to Select Best Performing Mutual Funds Using Decision Tree. *Procedia Computer Science*, 2016 ;85, 552-559.

[37] Charnes, A., Cooper, W. W., & Rhodes, E., Measuring the efficiency of decision-making units. European *Journal of Operational Research*, 1978; 2(6), 429-444. Doi:10.1016/0377-2217(78)90138-8

[38] Banker, R. D., Charnes, A., & Cooper, W. W., Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, 1984; 30(9), 1078-1092. Doi: 10.1287/mnsc.30.9.1078

[39] Cooper, W. W., Seiford, L. M., & Tone, K., Data envelopment analysis: A comprehensive text with models, applications, references and DEA-Solver software. *Springer Science & Business Media*. 2007. Doi: 10.1007/978-0-387-45283-8

[40] Zhu, J., Quantitative models for performance evaluation and benchmarking: Data envelopment analysis with spreadsheets, *Springer Science & Business Media*. 2013. Doi: 10.1007/978-3-319-06647-9

[41] Tone, K., A slacks-based measure of efficiency in data envelopment analysis, *European Journal of Operational Research*, 2001; 130(3), 498-509. Doi: 10.1016/S0377-2217(99)00407-5