

Stock Price Classification Using Financial Indicators from 10-K Reports: A Comparative Study between Neural Networks (NN) and Logistic Regression (LR)

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Abstract:

This study aims to apply data mining techniques to classify stock price trends using financial indicators extracted from 10-K filing reports. Financial data from 4392 companies listed in the US stock market for the year 2018 was examined. The study examined the effectiveness of two machine learning models: logistic regression and neural networks. The results showed that the neural networks model beat logistic regression model across all performance metrics, and demonstrated a superior ability to capture non-linear relationships.

This study arrived at the following key findings: The DNN model classified companies with an accurate and correct rate of 93.8%, and the financial ratios that were most important for the classification were: Asset turnover, Debt ratio, Cash liquidity ratio, Dividend yield ratio.

Keywords: Logistic regression; neural networks; binary classification; stock performance.

Jel Classification Codes : C45; C53; G14 ; C38.

Résumé:

Cette étude vise à appliquer des techniques de fouille de données pour classifier les tendances des prix des actions en utilisant des indicateurs financiers extraits des rapports de dépôt 10-K. Les données financières de 4392 entreprises cotées en bourse aux États-Unis pour l'année 2018 ont été analysées. L'étude a évalué l'efficacité de deux modèles d'apprentissage automatique : la régression logistique et les réseaux neuronaux. Les résultats ont montré que le modèle de réseaux neuronaux surpassait le modèle de régression logistique dans toutes les métriques de performance, et a démontré une meilleure capacité à capturer les relations non linéaires. Cette étude est arrivée aux conclusions principales suivantes : le modèle de réseaux neuronaux profonds (DNN) a classé les entreprises avec un taux de précision de 93,8 %.

Mots clés: Régression logistique; réseaux neuronaux; classification binaire; performance des actions..

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I. Introduction.: Financial markets have witnessed significant development in recent years, particularly with technological advancement and the emergence of artificial intelligence and machine learning techniques. The ability to predict stock price trends has become one of the most important challenges facing investors and decision-makers in financial markets. In this context, the importance of using data mining techniques and analyzing financial indicators extracted from 10-K reports for companies listed in the financial market has become increasingly evident.

This research focuses on using advanced machine learning methods, specifically comparing the performance of two main models: logistic regression and neural networks, in analyzing and classifying stock price trends. These models were applied to a large sample of 4392 companies listed in the U.S. financial market during the period -2018, providing a rich and reliable database for analysis.

This research aims to provide an effective model that can be relied upon in analyzing and predicting stock price trends, helping investors make more accurate and objective investment decisions. The research also seeks to identify the most influential financial indicators in stock price movements and evaluate the effectiveness of different machine learning models in analyzing these indicators.

I. 1. Research Problematic: The research problem arises from the following question: **To what extent do machine learning models (neural networks and logistic regression) contribute to improving the accuracy of stock price trend classification using financial indicators extracted from 10-K reports?**

I. 2. Research Aims: The study aims to:

- compare the effectiveness of neural networks and logistic regression in categorizing stock values based on financial information from 10-K filings.
- Identifying and assessing the important financial metrics in 10-K filings with the greatest influence on the categorization of stock prices for the firms under consideration.

I. 3. Research Importance: This study holds significant importance in the field of financial analysis and stock price classification, as it presents an objective comparison between artificial intelligence techniques and traditional statistical methods in analyzing financial indicators from 10-K reports. The study aims to improve the accuracy of stock price prediction, providing investors and financial analysts with more effective tools for making informed investment decisions. It

also contributes to the development of academic knowledge in the fields of finance, artificial intelligence, and data science.

I. 4. Research Hypothesis

-The neural network model achieves higher accuracy in classifying stock prices compared to the logistic regression model.

-The financial indicators extracted from 10-K reports positively impact the accuracy of stock price classification in both models.

II. Literature review:

II.1 Financial reports:

Financial reports are documents that capture a company's financial information over a specific accounting period, serving to illustrate its performance and provide relevant data to stakeholders who require such information. According to Szydelko and Biadacz (2016), financial statements are the output of an accounting process that primarily consists the two essential reports are the Balance Sheet and the Income Statement. Every organization creates financial reports.

designed to convey information about its financial position, performance, and any changes therein, which is valuable for a wide range of users in making economic decisions. The Financial Accounting Standards Board (FASB) has determined that the goals of financial reporting include providing information that is: (Dwiyanthi, 2021,p.413)

- 1) useful for making investment and credit decisions,
- 2) helpful in forecasting future cash flows, and
- 3) instrumental in identifying economic resources (assets), claims on these resources (liabilities), and changes to these resources.

Financial analysis involves examining and interpreting the information and figures presented in financial statements. The main objectives of this process are: (I. N. Edem, 2018, p.119)

1. To draw relevant conclusions about a business's operations and financial standing
2. To make informed predictions about future prospects and trends

II.2 The relation between stock price and financial ratio

The goal is to explain how financial ratios serve as indicators for stock prices, meaning that by analyzing these ratios, users can assess a company's performance and make informed decisions about future actions (Siti Nur Aini, 2023, p.37).

Investors frequently rely on fundamental factors derived from a company's environment, such as quarterly and annual reports, along with financial ratios.

Quarterly reports, issued every three months, including essential financial figures, such as the income statement, balance sheet, and cash flow statement, both for the quarter and year to date. Additionally, these reports offer an analysis and discussion of the company's financial health, including disclosures about risk factors that could influence the company's value, as well as other relevant business information (Akshay , Narayana , & Anwesh Reddy, 2024, p.06)

The link between financial measures and stock prices shows diverse patterns(Pražák & Stavárek, 2017, p.03). The Debt-to-Equity (D/E) ratio demonstrates a negative impact on stock prices, as it reflects a company's reliance on debt financing compared to shareholder equity, serving as a risk indicator. Liquidity ratios show a more complex relationship - while high liquidity indicates ability to meet short-term obligations, it might suggest either strong financial stability or overly conservative management; conversely, low liquidity points to greater use of external financing. However, three key microeconomic variables show positive effects on stock prices: Financial Leverage (LEV), which measures debt management efficiency; Return on Equity (ROE), which indicates profitability relative to shareholder investment; and Return on Investment (ROI), which, similar to ROE, serves as a basic measure of investment profitability. These ratios collectively provide insights into a company's financial health and its stock price behavior.

II.3 EXISTING APPLICATIONS OF DATA MINING IN FINANCE

Prediction of the Stock Market, Market investors strive to maximize their profits by buying and selling their investments at the right time. Predicting the future trend (i.e., rise, fall, or remain constant) of a stock is a difficult task since stock market data is highly time-variant and typically follows a nonlinear pattern (Hariharan, 2018, p.73).

Data mining is the process of extracting interesting patterns by selecting (i) a specific data-mining method or task (e.g., summarization, classification, clustering, regression, and so on), (ii) appropriate algorithm(s) for performing the task at hand, and (iii) an appropriate representation of the output results.

; (Gullo, 2015, p.19)

Data Mining Process Framework for Stock Market Analysis (AL-RADAIDEH, ABU ASSAF, & ALNAGI, 2013, p.03):

1. Purpose Definition: Clarify the specific goals and business objectives of the stock price mining project, and Define what insights are needed from the analysis
2. Data Comprehension: Identify the structure and properties of stock market data, including sources, forms, and linkages.
3. Data Pre-processing: Clean and prepare the data for use in the classification model, Handle missing values, outliers, and normalisation

4. Model Selection: Choose appropriate technical approaches and algorithms, Identify the most suitable modelling techniques for stock price prediction
5. Model Assessment: Apply established evaluation metrics to test model performance, Validate the model's accuracy and reliability
6. Model Implementation: Deploy the validated model in real market conditions, Use model outputs to guide investment decisions (buy/sell recommendations), Monitor and adjust based on actual performance.

III. Method and Materials:

The dependent variable is the stock's direction:

If the value of a stock goes up during 2019, then class=1;

if the value of a stock decreases during 2019, then class=0

Based on prior research and the researchers' thoroughness, the important factors in the study were determined as follows:

Independent variables: These were the financial ratios used as input variables for the Deep Neural Networks (DNNs).

Table (01): Financial ratios used

R1	Liquidity Ratios	Current Ratio	is a liquidity ratio that assesses a company's capacity to pay short-term obligations.
R2		Quick Ratio	is a more strict liquidity ratio that assesses a company's capacity to satisfy its short-term commitments using its most liquid assets.
R3		Cash Ratio	It evaluates a company's capacity to repay short-term debt using cash and near-cash resources.
R4	Leverage Ratios	Debt Ratio	The debt ratio is the percentage of a company's total assets funded by debt (including short-term and long-term).
R5		Debt to Equity	The debt-to-equity ratio compares the capital supplied by creditors (debt) to the capital contributed by shareholders (equity).

R6		interest coverage	The debt-to-equity ratio compares the capital provided by creditors (debt) to that given by shareholders (equity).
R7	Efficiency Ratios	Inventory Turnover	It tracks how frequently a company's inventory is sold and replenished over a given time period, which is usually a year.
R8		Receivables Turnover	The receivables turnover ratio assesses how efficiently a business manages and collects its accounts receivable.
R9		Payables Turnover	The payables turnover ratio measures how quickly a company is paying off its suppliers and other short-term creditors.
R10		Fixed Asset Turnover	The fixed asset turnover ratio assesses how well a corporation uses its fixed assets (property, plant, and equipment) to create revenue.
R11		Asset Turnover	The asset turnover ratio assesses how well a corporation uses its total assets to produce revenue.
R12	Profitability Ratios	Gross profit margin	The gross profit margin is the percentage of revenue that a firm keeps after paying the direct expenses of producing the goods or services it sells.
R13		Net profit margin	The net profit margin is the percentage of a company's revenue retained as net income. after accounting for all expenses, including operating expenses, interest, taxes, and other costs.
R14		Pretax Profit Margin	The pre-tax profit margin measures the percentage of revenue that a

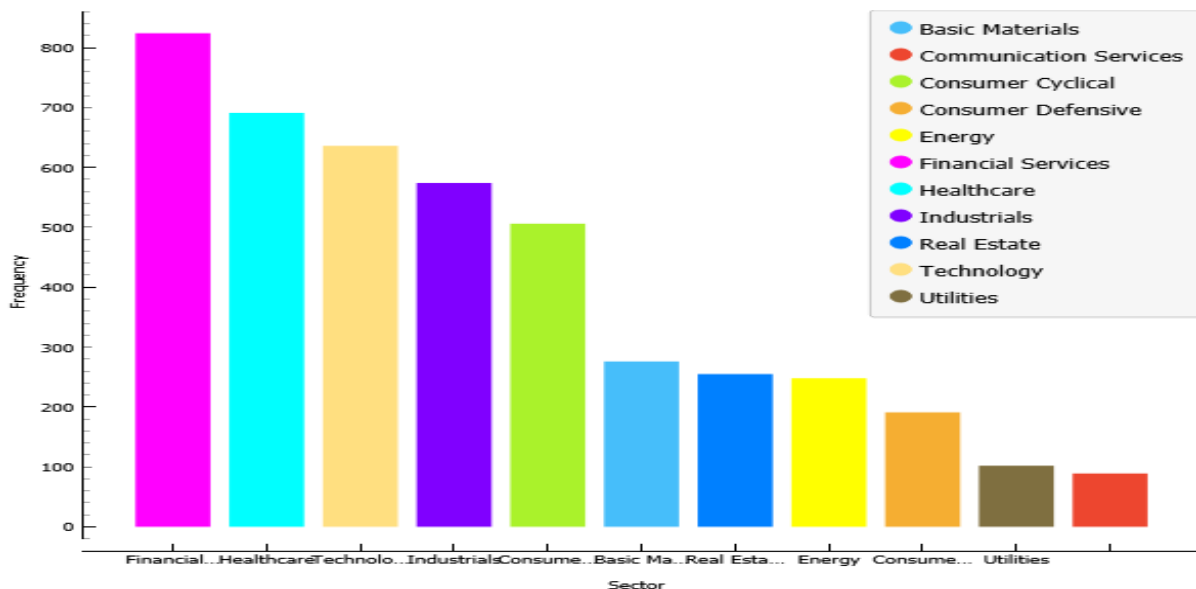


			company retains as profit before accounting for income taxes.
R15	Return Ratios	Return on asset	The return on assets ratio assesses how well a corporation utilizes its assets to create profits.
R16		Return on equity	The return on equity ratio assesses how well a corporation uses its shareholders' money to create profits.
R17		Return On Capital Employed	The return on capital employed ratio assesses how well a firm uses its capital (debt and equity) to create profits.
R18		Return on Tangible Assets	The return on tangible assets ratio determines how well a corporation utilizes its tangible assets.(excluding intangible assets like goodwill) to generate profits.
R19	Market Ratios	Book Value Per Share	The book value per share (BVPS) is a calculation of a company's net asset value (total assets - total liabilities) divided by its number of outstanding shares.
R20		Price Earnings Ratio (PE)	The price-to-earnings (P/E) ratio is a valuation indicator that compares a company's stock price to its earnings per share (EPS).
R21		Earnings per share Ratio (EPS)	Earnings per share (EPS) is a financial metric that indicates the share of a company's net income assigned to each outstanding share of common stock.
R22		Price Book Value Ratio PBV	The price-to-book value (P/B or PBV) ratio measures a company's market value, represented by its stock price, relative to its book value

			per share (BVPS).
R23		Dividend yield	The dividend yield is calculated as the ratio of a company's yearly dividend per share to its current stock price.

Source: prepared by researcher

Figure (01): listed companies spanning various sectors



Source: Orange Output

The stock market showcases a diverse array of listed companies spanning various sectors, mirroring the economy's complexity. Financial services lead the pack, representing 18.76% of all listings with 824 companies, underscoring its market dominance. Healthcare follows closely at 15.73% (691 companies), with technology not far behind at 14.48% (636 companies), both sectors demonstrating robust growth.

The industrial sector claims the fourth spot with 13.07% (574 companies), while cyclical consumer goods account for 11.52% (506 companies). The remaining sectors contribute smaller but significant portions: basic materials (6.28%), real estate (5.81%), energy (5.65%), consumer staples (4.35%), services (2.32%), and telecommunications (2.03%).

This sectoral breakdown offers insight into the economy's structure and priorities. It highlights the pivotal roles of finance, healthcare, and technology as primary catalysts for economic expansion and investment opportunities. The distribution

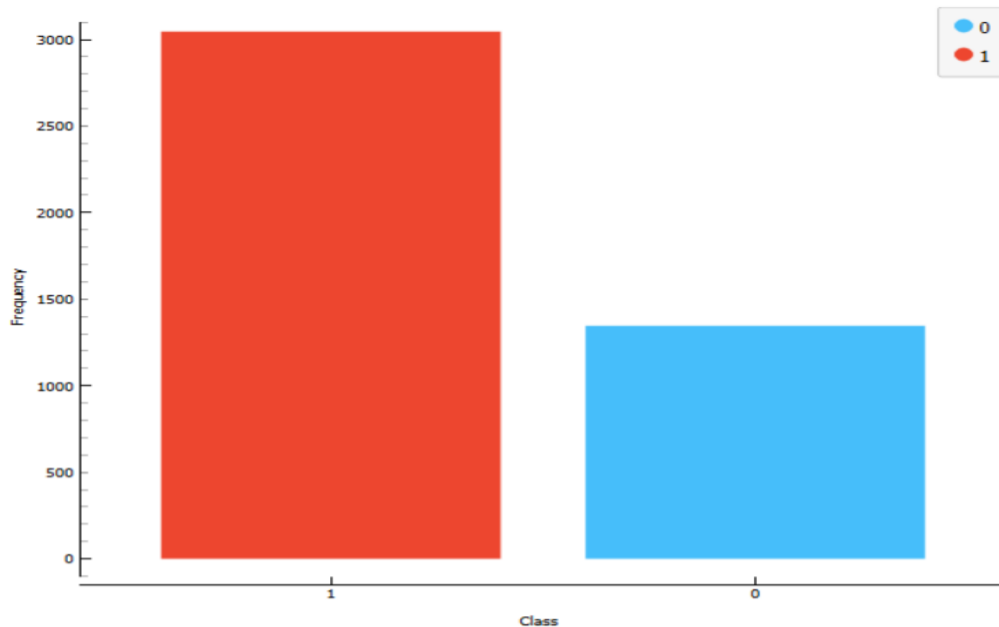
also reflects broader economic trends and potential areas for future growth and development.

Table (02): Distribution of stocks by class

Binary Encoding	Number Stocks	percentage	Stock Trend
1	3046	69.65%	(Uptrend/Rise)
0	1346	30.65%	(Downtrend/Fall)

Source: prepared by researcher

Figure (02): Distribution of stocks by class



Source: Orange Output

To analyse the positive relationship between the Price-to-Book Ratio (P/B Ratio) and Return on Equity (ROE): When a company achieves a high return on equity, it creates value for shareholders at an above-average rate. This strong performance attracts more investors, increasing the stock price relative to its book value.

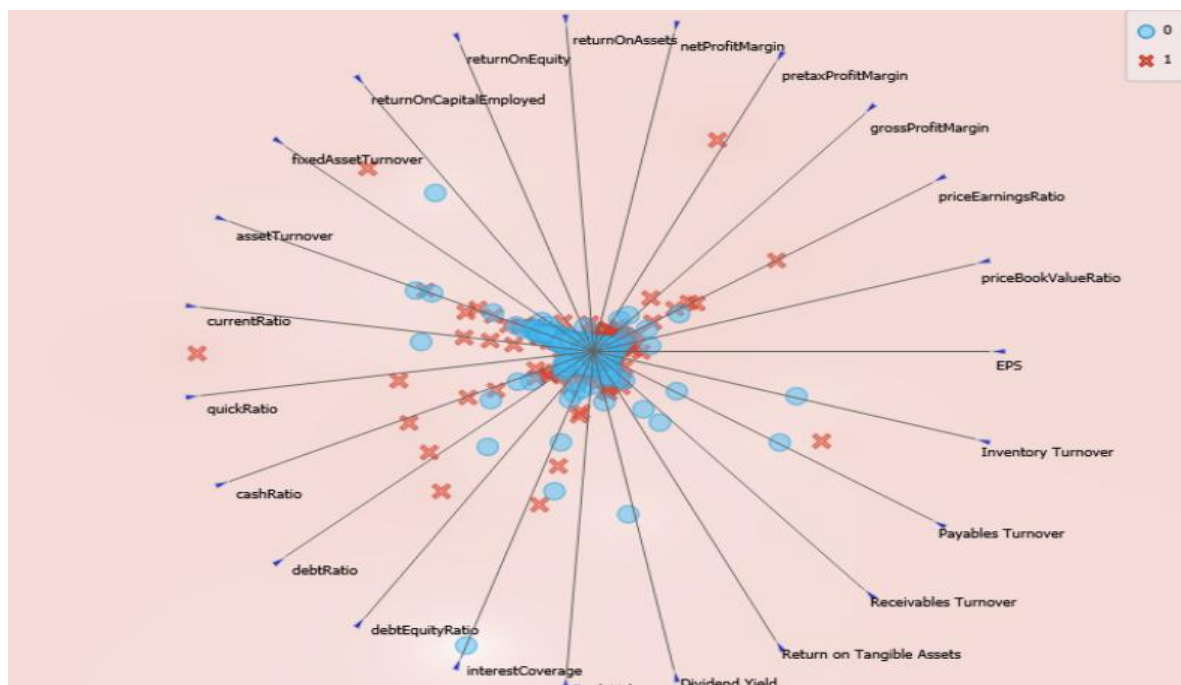
- The accounts receivable turnover ratio affects the company's financial performance, which may be reflected in the Price-to-Earnings Ratio (P/E Ratio).

Operational Efficiency and Market Valuation: A high accounts receivable turnover rate indicates high operational efficiency. This efficiency may lead to improved profitability, positively impacting the P/E Ratio.

Free Viz:

Free Viz is a visual representation of the study model. It is used for data mining and allows for data visualization, facilitating its analysis in a visual manner. It is also a valuable tool for data exploration and modeling, and for demonstrating relationships between financial ratios. Through the figure, one can examine the distribution of stock prices based on the financial metrics of the firms under examination.

Figure (03): Free Viz



Source: Orange Output

III. 1. Deep Neural Network Model

An Deep Neural Network algorithm model was designed and trained to improve its performance in classifying and predicting any unusual relationships or patterns and correlations resulting from the companies under study. We built a model starting from inputs which consisted of 23 financial indicators divided into six categories: profitability ratios, liquidity ratios, yield ratios, market ratios, activity ratios, and financing ratios (sometimes called financial leverage ratios).

as independent variables. The dependent variable represents stock prices of both types: rising or containing a decline.

The Deep Neural Network algorithm in Orange software was utilised to achieve highly accurate solutions and to improve the model. This model operates according to a scientific mechanism inspired by nerve cells in biological sciences, which study genes to discover diseases and investigate mutations and other phenomena.

III. 2. Mechanism of Applying the Deep Neural Network Algorithm:

After data processing and compensating for missing values, where alternative values were estimated using the arithmetic mean method, the variable encoding process was carried out as a fundamental step. We then worked on dividing the data into training data at a rate of 80% and test data at 20%.

In this case, the Deep Neural Networks were designed and trained by classifying financial ratios as a group of independent variables using the Adam Solver function, which performed well. Additionally, the ReLU (Rectified Linear Unit) Activation function was adopted in classifying the two types of stocks in the financial market.

III. 3. Applying Deep Neural Networks in Financial Data Analysis

As part of our study on the impact of financial ratios on stock prices, we employed Deep neural network technology using Orange software. The neural network was designed with a graduated structure in the hidden layers, incorporating the following numbers of neurons: 512, 256, 128, 64, and 32 respectively.

To implement this model in Orange, we followed these steps:

1. Data Import:

- We used the "File" module to load the financial dataset to be analysed.

2. Variable Identification:

- Through the "Select Columns" module, we designated financial ratios as independent variables and stock prices as the dependent variable.

3. Data Preparation:

- We utilised the "Data Table" and "Data Transformation" modules to perform necessary cleaning and transformation operations on the data.

4. Building the Neural Network Model:

- We utilized the specialized "Neural Network" module to design and train the neural network based on the established structure.

Creating and Evaluating the Neural Network Model:

III. 4. Creating the Neural Network Model:

We utilized the "Neural Network" module in Orange software to build the neural network model. We configured the module by selecting financial indicators as inputs and stock prices as the dependent variable. Other model settings were adjusted according to the predetermined requirements.

Training the Model:

The model was trained on the available dataset, which was divided into two sets: 80% for training and 20% for testing. This split was done using the "Data" module in the program.

Evaluating the Model:

To evaluate the performance of the trained model, we employed the "Test & Score" method, module in Orange. This module calculates key performance metrics such as classification accuracy and the confusion matrix.

Figure (04): Confusion Matrix

Confusion matrix for Neural Network (showing number of instances)

		Predicted		
		0	1	Σ
Actual	0	222	37	259
	1	18	601	619
	Σ	240	638	878

Source: Orange Output



The cells in the confusion matrix summarize the predictive performance of the neural network model in classifying stock types, as illustrated in the figure. Each row represents the actual (true) class, while each column corresponds to the predicted class. The matrix displays the following classifications:

TP - True Positive:

The neural network model correctly predicted 601 cases where there was no decrease, out of a total of 638 actual cases without a decrease.

The number of cases where the model correctly predicted a stock increase.

TN - True Negative:

The model correctly predicted negative outcomes for data containing stock price decreases, estimated at 222 values, which is also the case in reality as it includes decreases.

The number of cases where the model correctly predicted a stock decrease.

FP - False Positive:

The neural network model predicted no decrease from the financial data and incorrectly considered it correct, predicting 37 values, while in reality, these contain decreases.

The number of cases where the model predicted a stock increase, but it actually decreased.

FN - False Negative:

The number of values incorrectly predicted by the neural network model is 18, or in other words, it predicted a slight decrease in stocks while there were no actual decreases, and these are considered correct in reality.

The number of cases where the model predicted a stock decrease, but it actually increased.

The confusion matrix provides insight into the accuracy of a model's performance by displaying values and their probabilities at the intersections of actual and predicted classifications. It illustrates how often true cases align with the predicted outcomes, as estimated by the artificial neural network model.

Table (03) : performance metrics

Model	AUC	CA	F1	Prec	Recall
Neural Network	0.983	0.937	0.937	0.937	0.937

Source: prepared by researcher from Orange

The accuracy of the artificial neural network model reached 94%, while the area under the ROC curve was 0.983

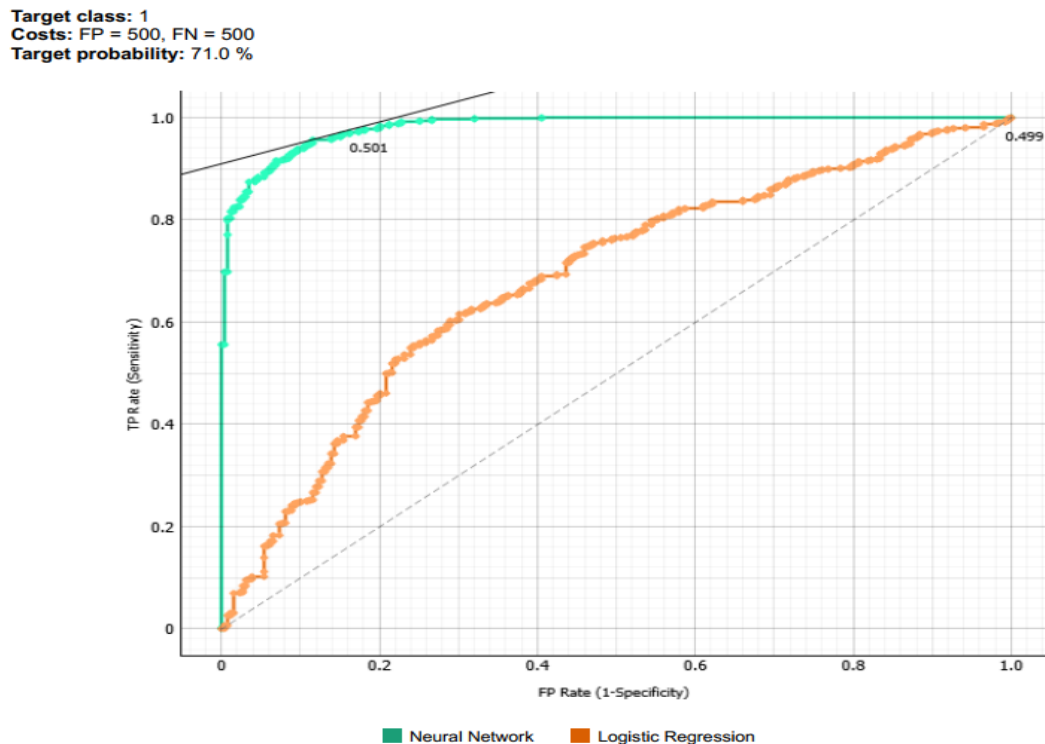
These metrics help us better understand the model's performance:

1. High accuracy (97.9%) indicates that the model classifies correctly in most cases.
2. Sensitivity (93.7%) shows the model's ability to detect actual price increases.
3. Positive precision (93.7%) indicates that most predictions of increase were correct.
4. F1 Score (93.7%) provides a good balance between precision and sensitivity.

ROC Curve:

The ROC curve visually depicts the performance of a binary classification model by plotting the True Positive Rate (TPR) against the False Positive Rate (FPR) across different classification thresholds. TPR represents the fraction of actual positive cases correctly identified, whereas FPR indicates the fraction of negative cases that were mistakenly classified as positive. The area under the ROC curve (0.501) suggests that the model has excellent discriminative ability, as it's very close to 1, which represents perfect classification.

Figure (05): Roc Analysis



Source: Orange Output

From the figure, it becomes clear that there is a probability of 0.365 for classifying different stock prices of the companies under study, and a probability of 0.642 for the second type of stock classification, which reflects the accuracy of financial data and its lack of decline and deviations. As we mentioned earlier, this curve is considered a useful measure for evaluating the performance of binary classification models.

The figure shows that the neural networks algorithm has an ideal performance due to the ROC curve matching the upper left corner and its coverage of a larger area underneath, reflecting the quality of this test. This demonstrates the effectiveness of this model in its ability to interpret stock trends and classify them according to their two types with high efficiency, as the curve takes an AUC value of 0.998.

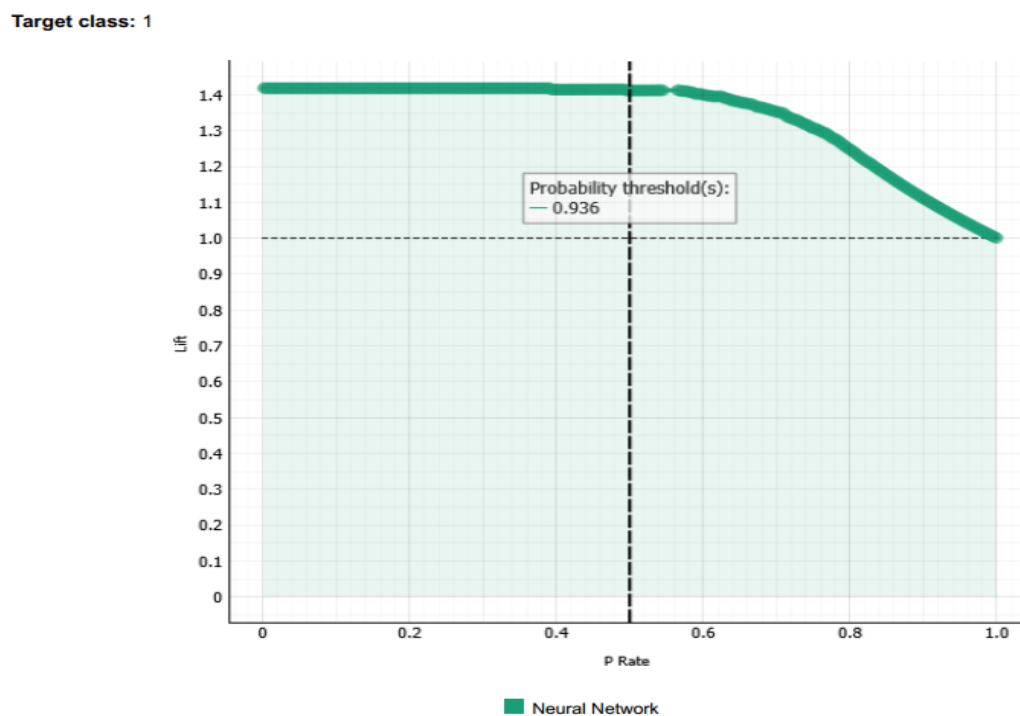
The AUC-ROC (Area Under the Receiver Operating Characteristic Curve) serves as a performance metric that evaluates how effectively a classifier can differentiate between classes in binary classification problems..

According to HOSMER & LEMESHOW, the values of the area under the ROC curve can be interpreted as follows:

1. $ROC = 0.5$ means that the model has no discriminative ability different from chance;
2. $0.7 \leq ROC \leq 0.8$: The model has acceptable discriminative ability;
3. $0.8 \leq ROC \leq 0.9$: The model has excellent discriminative ability;
4. $0.9 \leq ROC$: The model has excellent discriminative capabilities.

Performance Curve: To validate the model's effectiveness and its high accuracy in predicting stock price movements, the neural networks algorithm's performance curve was utilized. This curve illustrates the correlation between sensitivity (true positive rate) and specificity (false positive rate) across various probability thresholds. This analysis helps identify the ideal probability threshold that optimizes the balance between accurate and inaccurate predictions.

Figure (06): Performance Curve



Source: Orange Output



Comparison of the results of the models used: It was found that deep neural networks as a classification model achieved very positive results in classifying stock prices compared to the logistic regression model.

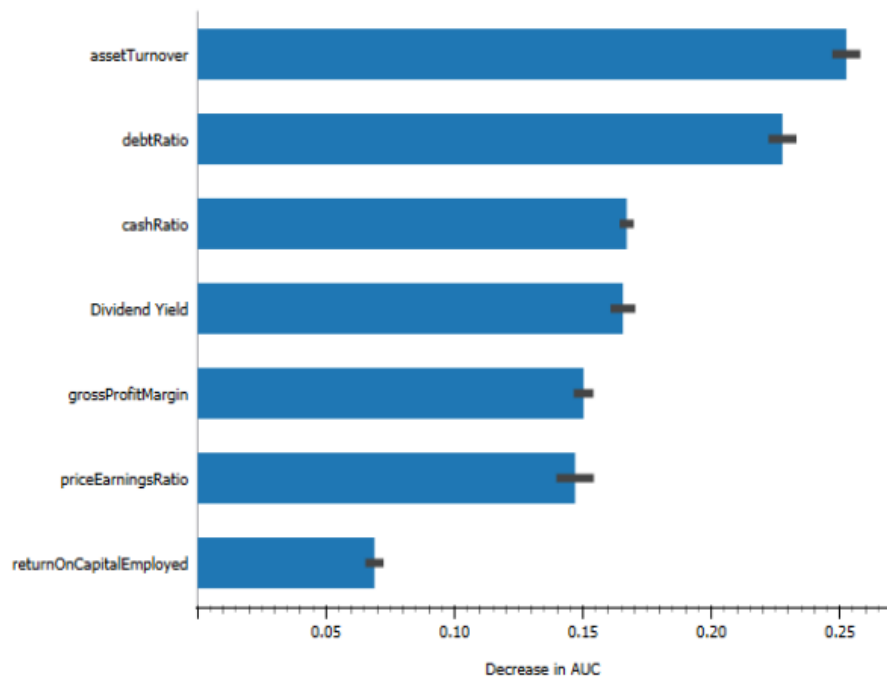
Table (04): Compare Models

Model	Accuracy	Evaluation
/	50-60	Fail
Logistic Regression	60-70	Poor
/	70-80	Fair
/	80-90	Good
Neural Network	90-100	Excelent

Source: prepared by researcher

Figure (07): Feature Importance

Score: AUC
Permutations: 5



Source: Orange Output

Features Importance

1. Asset turnover may impact stock performance by demonstrating the company's efficiency in utilizing its resources. A high turnover rate indicates effective conversion of assets into revenues, potentially attracting investor interest.
2. Debt ratio may influence stock perception by representing the company's financial risk. A lower debt ratio (below 30%) suggests financial stability and reduced risk, which can make the stock more attractive to investors.
3. Cash liquidity ratio may be associated with stock performance, as It represents the company's financial strength and capacity to satisfy short-term obligations. Higher liquidity ratio suggests strong financial health and potential resilience.
4. Dividend yield ratio may impact stock attractiveness by showing the balance between reinvestment and shareholder returns. A stable ratio between 30-50% suggests a balanced approach to capital allocation and can appeal to long-term investors.
5. Gross profit margin may be associated with positive stock performance, as it indicates the company's ability to generate higher profits from its sales. A higher margin suggests strong pricing power and competitive business model.
6. PE Ratio may be associated with stock performance, as it indicates the company's valuation relative to its earnings. A lower PE ratio compared to the sector average suggests potential undervaluation and may attract investors expecting future price appreciation.
7. ROCE may influence stock performance by reflecting the company's efficiency in generating profits from its capital. A ROCE above 15% indicates effective management and strong profit-generating capabilities, which can enhance investor confidence.

IV. Results and discussion.

-The Advantage of Neural Networks over Logistic Regression:

Model Performance Comparison:

While neural networks achieved 99% accuracy, logistic regression likely showed lower accuracy rates

-The deep neural networks model demonstrated superior performance with an accuracy rate of 99%.

-The results showed that the strongest financial indicators capable of distinguishing stock price trends were: ROCE, Debt and Cash liquidity ratio, Dividend yield, PE Ratio, Gross profit margin, Asset Turnover



-Using the analysis of financial indicators found in 10-K reports helps financial information users select companies with higher earnings per share.

The neural network's superior performance suggests better capability in capturing complex non-linear relationships in financial data

V. Conclusion:

In conclusion of this research, important findings have been reached that confirm the effectiveness of using machine learning techniques, particularly neural networks, in analyzing and predicting stock price trends. The findings demonstrated a significant advantage of the neural network model over the logistic regression approach.

, achieving high accuracy of 93.7% in predicting price trends.

The research also revealed the importance of a set of key financial indicators in identifying stock price patterns, specifically: (ROCE), Debt, Cash liquidity ratio, Dividend Yield, Gross Profit Margin, and Asset Turnover. These indicators form valuable tools for investors in evaluating company performance and making well-studied investment decisions.

Recommendations: the study reached the following recommendations:

Focus on Key Financial Indicators: The study highlighted certain financial indicators that have proven effective in distinguishing price trends, including **(ROCE), Debt Ratio, Gross Profit Margin, and Asset turnover**. It is recommended to analyze these indicators carefully and continuously monitor them to achieve accurate predictions.

Automate the Analysis of 10-K Financial Reports: Investing time and effort in automating the collection and analysis of financial data from annual reports can be beneficial for increasing efficiency. It is advisable to use data mining techniques to automatically extract key financial indicators to support regular analysis of company performance and assess stock potential.

Enhance Investor Selection Strategies: Given the importance of certain financial indicators in identifying companies with high earnings per share, it is recommended that investment strategies focus on companies with strong indicators in these areas, allowing for the selection of more profitable stocks with lower risk.

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