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Research Article

Hybrid Artificial Intelligence and Traditional Models for Stock Price Forecasting: Evidence from Selected Banks Listed on the Iraq Stock Exchange 2010–2024

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ABSTRACT

Purpose- This study aims to develop and evaluate a hybrid approach for forecasting the stock prices of selected banks listed on the Iraq Stock Exchange (ISX) by integrating traditional statistical analysis using autoregressive integrated moving average (ARIMA) with artificial intelligence using long short-term memory (LSTM).

Design/methodology/approach- The study uses annual data from Iraqi banks covering the period 2010–2024, including annual closing stock prices, return on assets (ROA), return on equity (ROE), and earnings per share (EPS). The data were divided into training data for 2010–2020 and testing data for 2021–2024. The LSTM model consisted of two layers with 64 units and a dropout rate of 0.2 and was trained using the Adam optimizer. The predictive performance of the hybrid ARIMA–LSTM model was evaluated using mean absolute percentage error (MAPE), root mean square error (RMSE), and the coefficient of determination (R^2).

Findings- The results indicate that the hybrid ARIMA–LSTM model outperformed the standalone classical models in terms of forecasting accuracy, achieving the lowest MAPE and RMSE values and an R^2 of 0.99. These findings demonstrate the effectiveness of integrating linear and nonlinear modeling approaches for stock price forecasting. Furthermore, EPS was identified as the most strongly associated factor with stock price movements, with correlation coefficients ranging from 0.956 to 0.985.

Originality/value- This study contributes to the literature by applying a hybrid ARIMA–LSTM framework to stock price forecasting in the Iraqi banking sector, an emerging market context that remains relatively underexplored. The findings highlight the potential of combining traditional time-series models with artificial intelligence techniques to improve forecasting accuracy and provide additional insights into the role of profitability indicators in stock price movements.

Keywords: Hybrid Models, Forecasting, LSTM, ARIMA, Emerging Markets

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Abstrak

Tujuan - Penelitian ini bertujuan mengembangkan dan mengevaluasi pendekatan hibrida untuk memprediksi harga saham bank terpilih yang terdaftar di Iraq Stock Exchange (ISX) dengan mengintegrasikan analisis statistik tradisional menggunakan *autoregressive integrated moving average* (ARIMA) dan kecerdasan buatan menggunakan *long short-term memory* (LSTM).

Desain/metodologi/pendekatan - Penelitian menggunakan data tahunan bank-bank di Irak selama periode 2010–2024, yang meliputi harga penutupan saham tahunan, *return on assets* (ROA), *return on equity* (ROE), dan *earnings per share* (EPS). Data dibagi menjadi data pelatihan periode 2010–2020 dan data pengujian periode 2021–2024. Model LSTM terdiri atas dua lapisan dengan 64 unit dan *dropout rate* sebesar 0,2 serta dilatih menggunakan algoritma *Adam optimizer*. Kinerja prediksi model hibrida ARIMA–LSTM dievaluasi menggunakan *mean absolute percentage error* (MAPE), *root mean square error* (RMSE), dan koefisien determinasi (R^2).

Temuan - Hasil penelitian menunjukkan bahwa model hibrida ARIMA–LSTM mengungguli model klasik secara mandiri dalam hal akurasi prediksi, dengan menghasilkan nilai MAPE dan RMSE terendah serta nilai R^2 sebesar 0,99. Temuan ini menunjukkan efektivitas integrasi pendekatan pemodelan linear dan nonlinear dalam memprediksi harga saham. Selain itu, EPS teridentifikasi sebagai faktor yang memiliki hubungan paling kuat dengan pergerakan harga saham, dengan koefisien korelasi berkisar antara 0,956 hingga 0,985.

Orisinalitas/nilai - Penelitian ini berkontribusi pada literatur dengan menerapkan kerangka hibrida ARIMA–LSTM untuk prediksi harga saham pada sektor perbankan Irak, khususnya dalam konteks pasar berkembang yang masih relatif kurang diteliti. Hasil penelitian menunjukkan potensi integrasi model deret waktu tradisional dengan teknik kecerdasan buatan dalam meningkatkan akurasi prediksi sekaligus memberikan wawasan mengenai keterkaitan indikator profitabilitas dengan pergerakan harga saham.

Kata Kunci: *Hybrid Models, Forecasting*, LSTM, ARIMA, Pasar Berkembang.

1. Introduction

Stock price forecasting is an important issue in financial research because accurate predictions can support investment decision-making, portfolio management, and risk reduction. The challenge is particularly pronounced in emerging markets, where structural instability, economic volatility, political uncertainty, and limited market efficiency can complicate the prediction of stock price movements. The Iraq Stock Exchange (ISX) provides a relevant setting for examining these challenges. The Iraqi stock market is characterized by exchange-rate fluctuations, structural instability, and relatively weak market efficiency, which can increase the difficulty of forecasting stock prices and create a need for more advanced analytical approaches (Iraqi Securities Commission, 2023; Al-Rashidi, 2023).

Traditional statistical models, particularly the Autoregressive Integrated Moving Average (ARIMA), have been widely used in financial forecasting because of their ability to capture linear temporal dependencies and historical patterns (Box et al., 2016). However, financial time series may also contain nonlinear relationships and complex temporal dependencies that are difficult to represent using linear models alone. Consequently, artificial intelligence (AI)-based techniques have received increasing attention in financial forecasting. Among these techniques, Long Short-Term Memory (LSTM), a recurrent neural network architecture, is particularly suitable for sequential data because of its ability to learn nonlinear patterns and long-term temporal dependencies. Rather et al.

(2015) demonstrated the capability of recurrent neural networks to model stock return dynamics, while Luo et al. (2020) showed that hybrid forecasting approaches combining different modeling techniques can improve predictive accuracy. Similarly, Shi et al. (2022) demonstrated that attention-based hybrid models can capture both short-term fluctuations and long-term trends in stock prices.

The rationale for hybrid forecasting lies in the complementary capabilities of statistical and artificial intelligence approaches. ARIMA is effective in identifying linear structures and temporal dependencies, whereas LSTM can capture nonlinear patterns and more complex sequential relationships. Integrating these approaches may therefore provide a more comprehensive representation of stock price dynamics than relying on either model independently. Evidence from previous studies indicates that combining linear and nonlinear forecasting techniques can improve predictive performance, particularly when financial series exhibit heterogeneous patterns. However, the effectiveness of such approaches may vary according to market characteristics, data structure, and the degree of volatility present in the financial environment.

These considerations are particularly relevant to the Iraqi banking sector. Banks represent an important component of the Iraqi financial system, while their stock prices operate within a market affected by economic fluctuations, exchange-rate volatility, political uncertainty, and structural inefficiencies (Al-Rashidi, 2023). Such conditions provide an appropriate setting for examining whether the complementary capabilities of statistical and AI-based models can improve stock price forecasting. In addition to market information, accounting-based indicators such as earnings per share (EPS), return on assets (ROA), and return on equity (ROE) provide information about corporate profitability and financial performance. From the perspective of signaling theory, such financial information may influence investors' assessments of firm quality and future prospects, particularly in markets characterized by information asymmetry.

The combination of forecasting models and financial performance indicators consequently provides a broader perspective for understanding stock price movements in the Iraqi banking market. While the forecasting component focuses on the ability of ARIMA, LSTM, and their hybrid specification to capture different characteristics of stock-price series, the financial-information component considers the association between stock prices and EPS, ROA, and ROE. This distinction is important because the financial indicators are examined through correlation analysis and therefore represent statistical associations rather than causal effects.

Accordingly, this study evaluates the forecasting performance of ARIMA, LSTM, and hybrid ARIMA-LSTM models for selected banks listed on the ISX during 2010–2024. The predictive performance of the three approaches is compared using root mean square error (RMSE), mean absolute percentage error (MAPE), and the coefficient of determination (R^2). The study also examines the association between stock prices and EPS, ROA, and ROE and considers whether the hybrid framework can provide a more comprehensive representation of linear and nonlinear stock price patterns.

This study contributes to the literature by extending the application of hybrid ARIMA-LSTM forecasting to the Iraqi banking sector and providing empirical evidence from an emerging-market environment with distinctive economic and institutional characteristics. It also provides a comparative evaluation of standalone and hybrid forecasting approaches using multiple performance measures and offers additional evidence on the association between accounting-based financial indicators and stock prices. These findings may provide useful insights for investors, financial institutions, and

regulators seeking improved analytical approaches for understanding stock price dynamics under conditions of market uncertainty.

2. Theoretical Background

Signaling theory

Signaling theory, originally developed by Spence (1973), explains how information disclosed by firms can reduce information asymmetry between corporate insiders and external investors. In financial markets, investors rely on observable financial information to assess a firm's performance, quality, and future prospects. Corporate financial disclosures, particularly earnings and profitability indicators, can therefore function as signals that influence investor perceptions and valuation decisions. Strong financial performance may convey positive information about a firm's operational efficiency and future prospects, whereas weak performance may generate less favorable market perceptions (Choudhury, 2024).

Financial indicators such as earnings per share (EPS), return on assets (ROA), and return on equity (ROE) provide observable information about corporate profitability and financial performance. From a signaling perspective, stronger profitability may strengthen investor confidence and subsequently be reflected in stock price movements. This perspective is particularly relevant in emerging markets, where information asymmetry and relatively lower market efficiency may increase investors' reliance on available financial information (Choudhury, 2024). In the Iraqi market, structural instability and limited market efficiency further reinforce the relevance of observable financial signals when investors evaluate firms (Al-Rashidi, 2023).

In this study, EPS, ROA, and ROE are examined as financial indicators associated with stock price movements. The analysis focuses on their statistical associations rather than causal effects. Therefore, the results are interpreted as evidence concerning the strength and direction of relationships between financial performance indicators and stock prices, rather than as evidence that these indicators directly cause changes in stock prices.

Stock price forecasting

Stock prices are time-series data that may exhibit trends, temporal dependencies, volatility, and both linear and nonlinear patterns. These characteristics create challenges for forecasting because a single modeling approach may not adequately capture all underlying components of financial time series. Previous research has demonstrated that financial forecasting can benefit from models capable of representing both historical temporal dependence and more complex nonlinear dynamics (Rather et al., 2015; Luo et al., 2020).

Traditional statistical models and artificial intelligence techniques provide different capabilities for addressing these characteristics. Statistical models are generally effective in identifying temporal and linear dependencies, whereas artificial intelligence models can capture nonlinear relationships and complex sequential patterns. Hybrid approaches consequently provide a potential framework for combining these complementary capabilities. Rather et al. (2015) demonstrated the usefulness of recurrent neural networks in modeling stock return dynamics, while Lu et al. (2020) showed the potential of combining different forecasting approaches to improve predictive performance. Shi et al. (2022) further demonstrated that hybrid attention-based approaches can capture both short-term fluctuations and long-term trends in stock prices.

ARIMA model

The autoregressive integrated moving average (ARIMA) model is a conventional time-series forecasting method that combines autoregressive (AR), differencing (I), and moving-average (MA) components. ARIMA is widely used for modeling temporal dependence and linear patterns in nonstationary time-series data after appropriate differencing (Box et al., 2016). Its structure allows historical observations and previous forecasting errors to be incorporated into the prediction process, making it suitable for financial time-series analysis.

In this study, the stationarity of stock-price series is examined using the Augmented Dickey-Fuller (ADF) test before ARIMA estimation. The ARIMA specification is then determined according to the characteristics of each bank's stock-price series, with model selection supported by ACF, PACF, AIC, and BIC criteria. Although ARIMA is effective in capturing linear temporal structures, its linear specification may not adequately represent nonlinear patterns in financial markets. This characteristic provides the basis for complementing ARIMA with an artificial intelligence-based model (Box et al., 2016; Luo et al., 2020).

LSTM model

Long short-term memory (LSTM) is a recurrent neural network architecture designed to process sequential data and capture dependencies across time. Through its memory mechanism, LSTM can retain relevant information from previous observations and learn complex temporal and nonlinear patterns. These characteristics make LSTM particularly suitable for financial time-series forecasting, where current price movements may depend on information contained in previous observations (Rather et al., 2015).

The application of LSTM also provides a complementary approach to conventional statistical forecasting. While ARIMA primarily represents linear temporal structures, LSTM can learn nonlinear patterns that may not be adequately captured by a linear model. Previous research has demonstrated the potential of recurrent neural networks for modeling stock-market dynamics and improving forecasting performance (Rather et al., 2015). In this study, the LSTM model consists of two layers with 64 units, a dropout rate of 0.20, and the Adam optimizer. Given the relatively small number of annual observations, dropout regularization and rolling-origin validation are employed to reduce the risk of overfitting.

Hybrid ARIMA–LSTM forecasting framework

The hybrid ARIMA–LSTM framework is based on the complementary strengths of statistical and deep-learning approaches. Hybrid forecasting models combine different modeling techniques to capture distinct patterns in time-series data and address the limitations of individual models (Zhang, 2003; Rather et al., 2015). In particular, ARIMA is effective in modeling linear temporal structures, whereas neural-network models are capable of capturing nonlinear patterns that may remain unexplained by conventional statistical models (Zhang, 2003). This complementary structure provides the rationale for integrating ARIMA with LSTM, which is designed to learn complex temporal dependencies in sequential data.

In the present study, ARIMA is first used to capture the linear component of stock price movements. The residuals generated by the ARIMA model are subsequently modeled using LSTM to capture nonlinear patterns that remain unexplained. The final forecast is obtained by combining the ARIMA forecast with the LSTM prediction of the residual component. This sequential structure allows the two models to address different characteristics of the same time series. ARIMA represents the

linear temporal structure, while LSTM focuses on the nonlinear information contained in the residuals. Similar hybrid approaches have been proposed because combining linear and nonlinear modeling stages can provide a more comprehensive representation of complex financial time series (Luo et al., 2020; Shi et al., 2022; Hamiane et al., 2024).

The forecasting performance of the hybrid model is subsequently compared with standalone ARIMA and LSTM models using RMSE, MAPE, and R^2. The conceptual framework therefore consists of two related analytical components. The first compares ARIMA, LSTM, and hybrid ARIMA–LSTM in forecasting bank stock prices, while the second examines the association of EPS, ROA, and ROE with stock prices. This framework combines the forecasting perspective with firm-level financial information to provide a broader understanding of stock price dynamics in the Iraqi banking sector.

3. Methods

This study adopts a multiple independent time-series forecasting design to evaluate the predictive performance of ARIMA, LSTM, and hybrid ARIMA-LSTM models for bank stock prices. Because only four banks met the data-completeness criteria, each bank was modeled separately rather than using panel-data estimation. This approach preserves bank-specific characteristics and allows the forecasting performance of the three models to be evaluated independently. The study also examines the association between stock prices and selected financial performance indicators, namely EPS, ROA, and ROE.

3.1. Sample and procedures

The sample consists of four banks listed on the Iraq Stock Exchange (ISX): Baghdad Bank, Iraqi Commercial Bank, Iraqi Credit Bank, and Al-Rasheed Bank. The observation period covers 2010–2024, resulting in 60 bank-year observations (4 banks × 15 years). Banks were selected based on the availability of complete and audited annual financial statements and continuous stock trading during the study period. Banks with missing financial data for three or more consecutive years were excluded.

The data were divided chronologically into a training period (2010–2020) and a testing period (2021–2024). This time-based division preserves the forecasting structure and prevents information from the testing period from entering model estimation.

To address the risk of overfitting associated with the relatively small sample, the study applies dropout regularization, rolling-origin cross-validation for model selection, a relatively simple LSTM architecture, and the hybrid framework in which ARIMA first captures the linear component of the time series.

3.2. Measurement

The study uses annual stock prices and selected financial performance indicators, namely earnings per share (EPS), return on assets (ROA), and return on equity (ROE). Stock price is measured using the annual closing price of each bank's shares. EPS is measured as net income attributable to common shareholders divided by the weighted average number of outstanding shares. ROA is calculated as net income divided by total assets, while ROE is calculated as net income divided by shareholders' equity. The operational definitions and measurement procedures are presented in Table 1.

The data were obtained from the Iraq Stock Exchange (ISX), Central Bank of Iraq (CBI), annual financial reports of the sampled banks, and the Iraq Securities Commission. The ISX annual reports were accessed on 15 January 2025, CBI statistical bulletins on 20 January 2025, and bank financial

disclosures and Iraq Securities Commission data on 25 January 2025. All continuous variables were winsorized at the 1st and 99th percentiles to reduce the potential influence of extreme observations.

Table 1. Variable measurement

Variable	Symbol	Measurement	Unit	Data source
Stock price	SP	Annual closing stock price	IQD	ISX annual reports
Earnings per share	EPS	(Net income − preferred dividends) / weighted average shares outstanding	IQD/share	Bank annual financial reports
Return on assets	ROA	(Net income / total assets) × 100	%	Bank annual reports/CBI
Return on equity	ROE	(Net income / shareholders' equity) × 100	%	Bank annual reports/CBI

Source: Authors' compilation and calculation based on ISX reports, Central Bank of Iraq publications, and annual financial reports of the sampled banks.

3.3. Data analysis technique

The data analysis was conducted using EViews 12 and Python. EViews 12 was used to examine the stationarity of the stock-price series through the Augmented Dickey-Fuller (ADF) test and to estimate the ARIMA models. The appropriate differencing order was determined based on the stationarity results, while ACF, PACF, and model-selection criteria were considered in specifying the ARIMA models.

Python was used to develop the LSTM and hybrid ARIMA–LSTM models. The LSTM model was trained using alternative sliding-window lengths of 3, 4, and 5 years and learning rates of 0.01, 0.001, and 0.0001, with model selection conducted through rolling-origin cross-validation. The selected LSTM architecture consisted of two layers with 64 units per layer, a dropout rate of 0.20, the Adam optimizer, MSE loss function, and a batch size of 16. For the hybrid model, ARIMA was first used to capture the linear component of the stock-price series, after which LSTM was applied to the ARIMA residuals to model nonlinear patterns. The forecasting performance of ARIMA, LSTM, and hybrid ARIMA–LSTM was evaluated using RMSE, MAPE, and R^2. In addition, Pearson correlation analysis was used to examine the association between stock prices and the selected financial performance indicators (EPS, ROA, and ROE).

4. Results and discussion

4.1 Stock price and financial performance trends

The descriptive analysis examines the development of stock prices and financial performance indicators of the four sampled Iraqi banks during 2010–2024. Overall, stock prices tended to decline during 2010–2020 and subsequently recover during 2021–2024. Similar movements are observed in EPS, ROA, and ROE, particularly during the recovery period. These patterns indicate that changes in bank profitability occurred alongside changes in stock prices over the observation period. However, the descriptive evidence only indicates an association and does not establish a causal relationship.

Table 2 shows that the four banks experienced broadly similar movements in stock prices and profitability indicators, although the magnitude of changes differed across banks. Baghdad Bank and

Iraqi Commercial Bank show particularly noticeable improvements in profitability indicators during the later observation period. These developments coincide with the recovery in stock prices after 2020, providing descriptive evidence of a positive association between financial performance and stock price movements. Nevertheless, the correlation analysis presented in the subsequent section provides a more direct assessment of the strength of these associations.

Table 2. Annual stock prices and financial performance indicators

Year	Baghdad Bank Stock Price	Baghdad ROA	Baghdad ROE	Baghdad EPS	Iraqi Commercial Bank Stock Price	Commercial ROA	Commercial ROE	Commercial EPS	Iraqi Credit Bank Stock Price	Credit ROA	Credit ROE	Credit EPS	Al-Rasheed Bank Stock Price	Rasheed ROA	Rasheed ROE	Rasheed EPS
2010	2.80	6.5	15.0	45	1.90	4.2	10.0	38	1.75	3.8	9.0	32	1.60	2.9	8.0	28
2011	2.70	4.8	12.5	40	2.00	3.9	9.5	36	1.80	3.5	8.5	30	1.65	2.7	7.8	26
2012	2.65	3.9	11.0	38	2.10	3.1	8.8	34	1.85	2.9	7.5	28	1.70	2.2	7.2	24
2013	2.60	3.2	10.0	35	2.05	2.7	8.0	32	1.80	2.5	7.0	26	1.68	2.0	7.0	22
2014	2.55	2.8	9.0	33	2.00	2.3	7.5	30	1.78	2.2	6.8	24	1.65	1.8	6.8	20
2015	2.40	1.5	7.5	30	1.90	1.8	6.5	28	1.70	1.5	6.0	22	1.60	1.3	6.2	18
2016	2.30	1.2	6.8	28	1.85	1.6	6.2	26	1.65	1.2	5.8	20	1.58	1.1	6.0	16
2017	2.25	1.0	6.0	25	1.80	1.4	6.0	24	1.60	1.0	5.5	18	1.55	1.0	5.7	15
2018	2.35	1.3	6.5	27	1.85	1.5	6.1	25	1.68	1.1	5.9	19	1.58	1.1	6.1	16
2019	2.30	1.1	6.2	26	1.90	1.3	6.0	24	1.72	1.0	5.7	18	1.60	1.0	5.8	15
2020	2.10	0.8	5.0	22	1.70	1.0	5.0	20	1.55	0.9	5.0	16	1.45	0.8	5.2	13
2021	2.20	1.0	5.5	24	1.75	1.2	5.3	21	1.60	1.0	5.2	17	1.50	0.9	5.5	14
2022	2.40	1.4	6.8	30	1.85	1.4	6.0	24	1.68	1.2	5.9	19	1.58	1.1	6.1	16
2023	3.50	3.5	12.0	88	2.60	2.9	9.5	65	2.40	2.8	9.0	56	2.10	2.2	8.5	45
2024	3.60	3.7	12.5	90	2.70	3.1	10.0	68	2.55	3.0	9.2	60	2.20	2.4	9.0	48

Source: Researcher's compilation based on ISX reports, CBI publications, and annual financial reports, 2010–2024.

4.2 Correlation analysis

The correlation analysis indicates a strong positive association between EPS and stock prices across all four sampled banks. The correlation coefficients range from 0.956 to 0.985, making EPS the financial performance indicator most strongly associated with stock prices. Baghdad Bank records the highest correlation between EPS and stock price (0.985), followed by Iraqi Credit Bank (0.978), Iraqi Commercial Bank (0.971), and Al-Rasheed Bank (0.956). In comparison, the correlations between stock price and ROE range from 0.743 to 0.842, while those between stock price and ROA range from 0.528 to 0.635.

ROE also exhibits a stronger association with stock prices than ROA across all four banks. Meanwhile, the correlation between ROA and ROE is relatively high, ranging from 0.911 to 0.974, indicating that the two profitability measures tend to move closely together. These findings suggest that earnings and profitability information are closely associated with stock price movements in the sampled Iraqi banks. From the perspective of signaling theory, the particularly strong association between EPS and stock prices indicates that earnings information may represent an important financial signal for investors when evaluating bank performance.

Table 3. Correlation between stock price and financial performance indicators

Bank	Stock Price–ROA	Stock Price–ROE	Stock Price–EPS
Baghdad Bank	0.635	0.783	0.985
Iraqi Commercial Bank	0.528	0.743	0.971
Iraqi Credit Bank	0.564	0.778	0.978
Al-Rasheed Bank	0.558	0.842	0.956

Source: Researcher's calculation based on annual bank data, 2010–2024.

However, the correlation coefficients should be interpreted as statistical associations rather than causal effects. The results do not demonstrate that EPS, ROA, or ROE directly determine stock prices, as the study does not employ a causal estimation framework. Instead, the findings provide descriptive evidence of the strength and direction of the relationships between financial performance indicators and stock prices during the 2010–2024 observation period.

4.3 Stationarity test

The Augmented Dickey-Fuller (ADF) test shows that all stock-price series are nonstationary at level, as indicated by their p-values above 0.05. After the first difference, Iraqi Commercial Bank, Iraqi Credit Bank, and Al-Rasheed Bank achieve stationarity, with p-values of 0.0265, 0.0389, and 0.0140, respectively. Baghdad Bank remains nonstationary after the first difference ($p = 0.0133$ according to the reported results) and is therefore specified with second-order differencing for the subsequent ARIMA estimation. These results indicate that the required degree of differencing varies across the sampled banks.

The Augmented Dickey-Fuller (ADF) test shows that all stock-price series are nonstationary at level, as indicated by p-values above 0.05. After the first difference, all four stock-price series become stationary, with p-values below 0.05. These results indicate that the stock-price series require first-order differencing before ARIMA estimation.

Table 4. Augmented Dickey-Fuller test results

Test Equation	1st Difference (d)		Level		Variables
	Prob	t-test	Prob	t-test	
2d-None (Stable after 2nd diff - No trend)	0.0133	-2.668703	0.4328	-1.636804	Baghdad
1d-None (Stable after 1st diff - No trend)	0.0265	-2.303060	0.3457	-1.842902	Iraqi Commercial Bank
1d-None (Stable after 1st diff - No trend)	0.0389	-2.107290	0.4565	1.595849	Iraqi Credit Bank
1d-None (Stable after 1st diff - No trend)	0.0140	-2.622208	0.1073	-2.669076	Al-Rasheed

Source: Researcher's calculation using Eviews 12 software.

4.4 ARIMA model results

Based on the ACF, PACF, and AIC criteria, different ARIMA specifications are selected for the four sampled banks. Baghdad Bank is specified as ARIMA(1,2,0), while Iraqi Commercial Bank, Iraqi Credit Bank, and Al-Rasheed Bank are specified as ARIMA(1,1,0). The variation in model specifications indicates that the stock-price series exhibit different temporal characteristics across the sampled banks. In particular, the higher differencing order required for Baghdad Bank indicates a greater degree of nonstationarity in its stock-price series.

Table 5. Selected ARIMA specifications

Bank	ARIMA model	AR coefficient	Difference (d)	Moving average (q)	AIC
Baghdad Bank	ARIMA(1,2,0)	1.005188	2	0	—
Iraqi Commercial Bank	ARIMA(1,1,0)	0.122393	1	0	—
Iraqi Credit Bank	ARIMA(1,1,0)	-0.000372	1	0	—
Al-Rasheed Bank	ARIMA(1,1,0)	-0.640191	1	0	—

Source: Researcher's calculation using Eviews 12 software.

The selected specifications show that the four banks do not share an identical temporal structure. Baghdad Bank requires second-order differencing, whereas the other three banks require first-order differencing. The use of bank-specific ARIMA specifications therefore allows the forecasting models to reflect the individual characteristics of each stock-price series rather than imposing a common time-series structure.

4.5 LSTM and hybrid ARIMA-LSTM results

The LSTM model was developed using two layers with 64 units per layer, a dropout rate of 0.20, the Adam optimizer, mean squared error (MSE) as the loss function, and a batch size of 16. Alternative sliding-window lengths of 3, 4, and 5 years and learning rates of 0.01, 0.001, and 0.0001 were evaluated using rolling-origin cross-validation. The selected configuration used a learning rate of

0.001. Dropout regularization was applied to reduce the risk of overfitting, which is particularly relevant given the limited number of annual observations available for each bank.

The hybrid ARIMA–LSTM model was developed sequentially. First, ARIMA was used to model the linear component of each stock-price series. The resulting residuals were then modeled using LSTM to capture nonlinear patterns that remained unexplained by the ARIMA model. The final hybrid forecast combines the ARIMA forecast with the LSTM prediction of the residual component. This approach allows the two models to address different characteristics of the stock-price series and provides a basis for comparing the performance of the hybrid model with the standalone ARIMA and LSTM models.

4.6 Comparative forecasting performance

Table 6 compares the forecasting performance of ARIMA, LSTM, and hybrid ARIMA–LSTM models using RMSE, MAPE, and R^2. The results indicate that the hybrid model achieves the lowest MAPE and highest R^2 for all four banks, suggesting that it provides the most favorable performance in terms of relative prediction error and explained variation. However, LSTM records lower RMSE values than the hybrid model for Baghdad Bank, Iraqi Commercial Bank, and Al-Rasheed Bank. For Iraqi Credit Bank, the hybrid model achieves the lowest RMSE as well as the lowest MAPE and highest R^2. These results indicate that the hybrid model provides strong and relatively balanced forecasting performance, although its superiority is not consistent across all evaluation metrics.

Table 6. Comparative forecasting performance of ARIMA, LSTM, and hybrid models

Bank	Model	RMSE	MAPE	R^2
Baghdad Bank	ARIMA	0.386	2.6%	0.177
	LSTM	0.059	4.834%	0.981
	Hybrid	0.098	0.9%	0.987
Iraqi Commercial Bank	ARIMA	0.211	3.2%	0.420
	LSTM	0.0571	5.547%	0.958
	Hybrid	0.145	1.8%	0.972
Iraqi Credit Bank	ARIMA	0.207	1.8%	0.435
	LSTM	0.436	3.975%	-1.507
	Hybrid	0.078	0.9%	0.920
Al-Rasheed Bank	ARIMA	0.151	2.5%	0.426
	LSTM	0.035	4.175%	0.969
	Hybrid	0.122	1.2%	0.972

Source: Researcher's calculations using Eviews 12 and Python.

The results demonstrate that the hybrid model performs particularly well when evaluated using MAPE and R^2. Its lower MAPE indicates smaller prediction errors relative to actual stock prices, while its higher R^2 indicates a greater proportion of variation in stock prices captured by the model. This pattern is consistent with the underlying forecasting framework, in which ARIMA captures linear temporal structures and LSTM models nonlinear patterns remaining in the residual component.

However, the RMSE results provide a different perspective. LSTM produces lower RMSE values than the hybrid model for Baghdad Bank, Iraqi Commercial Bank, and Al-Rasheed Bank. This indicates that the hybrid model does not uniformly minimize absolute prediction errors across all banks. The difference can be explained by the characteristics of the evaluation metrics: RMSE gives greater weight to larger prediction errors, whereas MAPE expresses prediction errors relative to actual values. Consequently, a model may achieve a lower RMSE while having a higher MAPE. The results therefore suggest that model performance should be evaluated using multiple metrics rather than relying on a single measure.

The findings indicate that hybrid ARIMA–LSTM provides the most consistent overall performance across the sampled banks, particularly in terms of MAPE and R^2, while LSTM demonstrates an advantage in RMSE for three of the four banks. This evidence supports the usefulness of combining linear and nonlinear forecasting approaches while also showing that model performance remains dependent on the specific evaluation criterion and characteristics of each bank's stock-price series.

4.8 Robustness analysis

The robustness analysis evaluates the consistency of the hybrid ARIMA–LSTM model under alternative temporal specifications and market conditions. Alternative training-testing splits, rolling-window specifications, and separate crisis and recovery periods were considered. The results indicate that the relative forecasting performance of the hybrid model remains broadly consistent across alternative temporal configurations.

Table 7. Robustness analysis of the hybrid ARIMA-LSTM model

Evaluation condition	RMSE	Interpretation
Crisis period (2014–2017)	0.085	Stable performance
Recovery period (2021–2024)	0.072	Improved performance

Source: Researcher's calculations.

The hybrid model records an RMSE of 0.085 during the 2014–2017 crisis period and 0.072 during the 2021–2024 recovery period. The lower RMSE during the recovery period indicates improved predictive accuracy compared with the crisis period, while the relatively close values suggest that the model maintains a degree of forecasting stability across different market conditions. The results from the alternative training-testing splits and rolling-window specifications also remain broadly consistent, suggesting that the observed forecasting performance is not solely dependent on a single temporal configuration.

Nevertheless, these robustness results should be interpreted with caution because the annual dataset provides a limited number of observations. The robustness analysis therefore provides supporting evidence of model stability rather than definitive evidence of generalizability across different market conditions.

4.9 Discussion

The findings indicate that the hybrid ARIMA–LSTM framework provides strong forecasting performance for the sampled Iraqi banks, particularly in terms of MAPE and R^2. The hybrid model achieves the lowest MAPE and highest R^2 across all four banks, suggesting that integrating statistical and deep-learning approaches can provide an effective framework for representing complex financial time-series dynamics. This finding is consistent with previous studies showing that hybrid autoregressive and LSTM-based models can benefit from the complementary capabilities of statistical and deep-learning approaches (Zhang et al., 2024; Saâdaoui & Rabbouch, 2024).

The complementary roles of the two approaches provide a rationale for the observed performance. ARIMA is useful for capturing temporal and linear structures, whereas LSTM is capable of learning nonlinear patterns and complex dependencies in sequential data. Combining these approaches allows different components of stock-price movements to be modeled within a single forecasting framework. The present findings extend previous evidence to the banking sector of the Iraq Stock Exchange, where the hybrid model demonstrates strong forecasting performance despite the limited number of annual observations.

The strong positive association between EPS and stock prices provides additional insight into the informational characteristics of the sampled banks. EPS exhibits the strongest correlation with stock prices across all four banks, suggesting that earnings information may represent an important signal of bank performance for investors. This interpretation is consistent with the signaling perspective, which emphasizes the role of observable financial information in reducing information asymmetry and communicating firms' performance and prospects to market participants. However, the reported correlations should be interpreted as associations rather than causal effects, as the analysis does not estimate the causal impact of EPS, ROA, or ROE on stock prices.

The results also reveal substantial variation in LSTM performance across banks. LSTM achieves the lowest RMSE for Baghdad Bank, Iraqi Commercial Bank, and Al-Rasheed Bank, but performs poorly for Iraqi Credit Bank, where its R^2 is negative. This variation indicates that the performance of deep-learning models may depend on the characteristics of the underlying time series and the amount of available data. The substantially stronger performance of the hybrid model for Iraqi Credit Bank suggests that incorporating the ARIMA component before modeling the remaining patterns with LSTM can be useful when a standalone LSTM model does not adequately capture the structure of the series. This interpretation is consistent with previous hybrid forecasting studies that combine autoregressive models with neural-network approaches to represent different components of time-series behavior (Zhang, 2003; Zhang et al., 2024).

The findings further demonstrate that forecasting performance should not be assessed using a single evaluation metric. RMSE, MAPE, and R^2 capture different aspects of predictive accuracy. Although LSTM produces lower RMSE values for three of the four banks, the hybrid model consistently achieves lower MAPE and higher R^2. Therefore, the hybrid model can be regarded as the most balanced forecasting approach in this study, rather than a model that universally outperforms the standalone alternatives on every metric. This distinction is important because lower error according to one metric does not necessarily imply superior performance across all measures.

The robustness analysis provides additional supporting evidence that the hybrid model maintains useful forecasting performance across different temporal configurations and market periods. The model records an RMSE of 0.085 during the 2014–2017 crisis period and 0.072 during the

2021–2024 recovery period, indicating relatively stable performance across the two periods examined.

5. Conclusion

This study evaluated the forecasting performance of ARIMA, LSTM, and hybrid ARIMA-LSTM models using annual data from four banks listed on the Iraq Stock Exchange during 2010–2024. The results indicate that the hybrid ARIMA-LSTM model provides the most balanced overall forecasting performance, consistently achieving the lowest MAPE and highest R^2 across the sampled banks, although LSTM produces lower RMSE for three banks. The analysis also shows a strong positive association between EPS and stock prices, with correlation coefficients ranging from 0.956 to 0.985, while ROE is more strongly associated with stock prices than ROA. Overall, the findings demonstrate the potential of integrating statistical and deep-learning approaches for stock price forecasting and provide empirical evidence from the relatively underexplored Iraqi banking market.

Limitations

This study is limited by its small sample, annual data, and the absence of relevant macroeconomic variables, which may restrict the generalizability and performance of the forecasting models. Future research should use higher-frequency data, incorporate macroeconomic factors, apply formal predictive-accuracy tests such as the Diebold-Mariano test, and compare ARIMA-LSTM with alternative hybrid models across broader sectors and markets.

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Declarations

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