Deep Learning Models for Stock Price Prediction of Companies Associated with Indian Natural Gas Value Chain Underpinning Their ESG Commitments

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Keywords: ESG, Natural Gas, Deep Learning, Long Short-Term Memory, Multi-Layer Perceptron Model Recurrent Neural Network.

Abstract: Globally, stockholders are investing in companies strategizing to create a tangible, practical strategy for quantifying ESG value for investors, in tandem with decarbonization, to enhance sustainability and combat climate change. Natural Gas (NG), recognized as the preferred transitional fuel, accounts for 24.2% of the world's primary energy(PE) consumption mix. India seeks to increase the proportion of NG in the country's PE mix from 6% to 15% by 2030 to sustain decarbonized economic growth with NG transition. In this context, this article aims to forecast and compare the stock prices of eight Indian companies associated with the NG value chain, contributing to India's transition to a gas-based economy. These companies with a robust ESG framework are associated with activities like NG exploration, Liquified NG import, transmission, distribution, and retailing. The researcher applied deep learning techniques like CNN, LSTM, the RNN model, and MLP to forecast stock prices and evaluate performance using historical data with seven attributes imported from yahoo-finance get data module. LSTM model prediction is the best with the lowest RMSE value. The research novelty lies in integrating ESG commitments into the prediction framework, acknowledging the growing importance of sustainability factors in the financial market while the end consumers enhance NG consumption for a gas-based economy transition.

1 INTRODUCTION

Climate Change is a global debate, with different counties setting aspirational targets for "Net Zero" emissions to decarbonize their energy ecosystems. As a result, global investors have switched their investment decisions to companies manifesting progressive and responsible Environmental, Social, and Governance (ESG) commitments(Sarangi, 2021). India aims to achieve its Net Zero target by 2070(MoEFCC, 2022), with stiff diverse energy domain intermittent milestones for 2030. One such target is to enhance the share of Natural Gas (NG) in India's primary energy consumption mix from 6 % to 15 % by 2030 (MoPNG, 2023) to support economic growth, and decarbonization plans concurrently. NG is the cleanest fossil fuel, with 24.2 % share in the global primary energy consumption mix, while only 6.3 % in India (BP, 2022). India companies associated with the NG Value Chain strive to increase NG availability and access to the natural gas supply chain (NGSC) to enhance consumption. Oil and Natural Gas Corporation (ONGC) and Reliance Industries Limited (RIL) are upstream companies associated with domestic NG production. ONGC aims to maximize shareholder's value by enhancing domestic gas availability promising sustainable growth. RIL aims at building trust with stakeholders, consistently achieving high productivity and growth. Midstream and downstream companies like GAIL (India) Limited, operating 15,413 km of NG pipelines, intend to create stakeholder's value through affordable NG access by enhancing its spread to pipelines and penetration through City Gas Distribution (CGD) Network for gas retailing. The Petronet LNG Limited (PLL), operating India's largest Liquified NG(LNG) terminal of 17.5 MMTPA capacity at Dahej, Gujarat, builds stakeholder's trust by ensuring uninterrupted LNG re-gasification service for the continuous supply of degasified LNG(RLNG) for downstream customers. Hindustan Petroleum Company Limited (HPCL) and Bharat Petroleum Corporation Limited (BPCL), are new entrants in establishing the CGD

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projects independently. They aim to fulfill its social commitment through customer care, environmental protection, continuous improvement, and innovation. Indraprastha Gas Limited (IGL), the pioneer in India's gas retailing, adopts a customer-centric approach to improve quality of life and shareholder's value. National Thermal Power Corporation (NTPC), the largest electricity producer in India, creates shareholder's value by providing a reliable power supply in an environmentally friendly, economical, and efficient way. These companies follow their management-approved, universally accepted ESG reporting guidelines, which attract socially conscious prospective investors to invest in their companies. The guidelines underpin the requirements of the Securities & Exchange Board of India and the Ministry of Corporate Affairs, Government of India(RIL, 2022).

Companies globally are giving high importance to their ESG performance(Zumente & Bistrova, 2021). Companies set their own targets to report performance standards under various ESG criteria (Edward & Evan, 1990), reflecting responsible business growth. The environmental criteria reflect company's policies, standards, and guidelines for environmental protection, sustainability, energy management, waste management, biodiversity, etc. The social criteria manifest how the companies handle their customers, employees, suppliers, and communities within their operating domain. The governance criteria relate to the company's leadership, internal controls, audit systems, risk management, shareholder rights protection, ethics etc. On scanning the annual and sustainability report of a few of the companies above, it is seen that apart from standard financial performance parameters, economic, social, and environmental parameters are also reported. Some of these parameters are economic value generated vs distributed, health safety and environmental score, customer satisfaction index, value added per employee, procurement from government e-marketplace, energy consumption and saving, GHG emission and saving, water consumption and recycling, tree plantation, environmental expenditure, audit para status, major decisions in board meetings and AGM etc.(GAIL, 2022; RIL, 2022).

With growing concern for climate change and enhanced awareness of corporate governance, investors globally select their own set of criteria to judge ESG performance before making investment decisions for short-term and long-term profit maximization. These may be related to the growth of the top line, cost reductions, regulatory compliances, productivity, and investment decisions(Henisz et al., 2019). However, accurate prediction of future stock prices is paramount for profit maximization and shareholder value creation. In this context, this exploratory quantitative research adopts data analytics for predicting stock prices using Deep learning techniques (Hu et al., 2021; Vijh et al., 2020). The research has applied techniques such as CNN, LSTM, RNN, and MLP to predict stock prices and performance evaluation of the above-named Indian companies associated with the NGSC.

2 DEEP LEARNING TECHNIQUES

Machine learning's subfield, "Deep Learning" (DL), utilizes multilayered neural networks. These artificial neural networks aim to mimic the human brain so that computers can learn from vast datasets like humans. The following four models applied.

Artificial Neural Network (ANN) is a branch of AI that takes its cues from the brain. Computational networks inspired by the biological neural networks used in brain development are the basis for most artificial neural networks. Like the neurons in a human brain, the neurons in an ANN are connected in different layers. Nodes refer to these neurons.

A multi-layer perception (MLP) is a neural network that has multiple layers. It's a deep layer with many connections that can map one dimension to another. Neural networks are constructed by linking neurons together in such a way that the results of certain neurons are used as inputs for other neurons.

Recurrent Neural Network (RNN) is a type of neural network where the output from the previous step is fed as input to the current step. The output from the previous stage is used as input for the stage at hand in RNN. The Hidden state, which retains some data about a sequence, is RNN's primary and most crucial characteristic. Since the state recalls the Network's prior input, it is sometimes called the Memory State. All inputs or hidden layers undergo the same operation with the same parameters to generate the output.

Long Short-Term Memory Networks (LSTM) are DL, sequential neural networks that can retain knowledge. It is a subset of RNNs that solves the issue of vanishing gradients.

3 LITERATURE REVIEW

A comprehensive literature review was conducted to understand the various concepts applied to the research problem.

Hu et al., 2021 provide a detailed review from 2015 to the present on the prediction of stock price value through DL methods. The models were evaluated by analyzing the dataset through techniques such as CNN, LSTM, DNN, RNN & reinforcement learning. It also discusses the main performance metrics of all models. In this paper, the hybrid networks show promising signs for future research.

Islam & Nguyen, 2020 compares three models ARIMA, ANN & geometric Brownian model. These models could predict the stock price for the next day. In this paper, the models ARIMA and geometric Brownian model are better than the ANN model for short-term next-day stock price prediction. ARIMA model and Brownian model performed almost the same. These models are good on time-series data, and researchers and investors can examine some different models to predict the prices of each stock to find the best prediction model.

Nikou et al., 2019 used four data mining techniques to predict the close price of iShares MSCI UK. The results showed that the RNN method with an LSTM block was better than the other methods, and the SVR method had higher precision than neural networks and random forests. Recommendations were made to use the DL method, investigate different types of LSTM models, and consider the role of other influential factors in future studies.

Vijh et al., 2020 argued that predicting stock market returns is challenging due to constantly changing stock values. They created new variables to obtain higher accuracy. ANN is used for predicting the next-day closing price of the stock, and RF is for comparative analysis. Results show that ANN gives better prediction of stock prices than RF. DL models could be developed considering financial news articles and financial parameters such as closing price, traded volume, profit, and loss statements.

Kumbure et al., 2022 systematically reviewed and analyzed machine-learning literature for stock market prediction. It found that indices and stocks in the USA were the most investigated, while stocks linked to health care, information technology, and consumer discretionary were most frequently found. 2173 unique variables were used in the selected literature, with the largest type being Technical Indicator with 1348 variables. Our review found that machine learning-based prediction models for stock market forecasting were based on the ANN, SVM, and fuzzy theory. DL techniques have received much attention in the last three years, with GAs, PCA, and wavelet transforms being the most popular methods. All DL-based papers have applied improved LSTM models to predict stock market variables.

This paragraph summarizes the findings of the literature review focused on predicting stock price values using various DL and traditional models. The first paper(Hu et al., 2021) comprehensively evaluates DL models such as CNN, LSTM, DNN, RNN, and reinforcement learning. Hybrid networks show promise for future research. The second paper(Islam & Nguyen, 2020) compares three models (ARIMA, ANN, and geometric Brownian model) and concludes that ARIMA and geometric Brownian model outperform ANN for short-term next-day stock price prediction. The third paper (Nikou et al., 2019) explores four data mining techniques and finds that RNN with LSTM performs best, while SVR has higher precision than neural networks and random forest. The fourth paper (Vijh et al., 2020) focuses on predicting stock prices using ANN and RF, suggesting including financial news articles and parameters for improved accuracy. The fifth paper (Vijh et al., 2020) systematically reviews machine learning literature, highlighting the use of ANN, SVM, fuzzy theory, and DL techniques, such as improved LSTM models for stock market prediction. Overall, DL methods, especially LSTM models, demonstrate potential for accurate stock market forecasting, while traditional models like ARIMA and the geometric Brownian model also yield good results in short-term predictions.

4 METHODOLOGIES

The researcher adopted an exploratory approach with a comprehensive literature review to understand the applicability of existing models like LSTM, ANN, MLP, RNN, etc., to the research problem. The following seven steps were applied to predict the stock prices of the eight companies associated with the NG value chain. Further, from these companies' annual reports, the financial parameters like revenue, net profit, EPS, BVPS, ROE, and Debt Equity ratio were compared to plot the graphical trend for visualizing their financial performance. The methodology flow chart is in Figure 1.

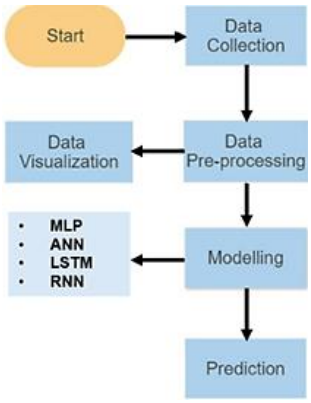

Figure 1: Methodology Flow Chart.

The seven steps are as under:

Step 1: Import the twelve Python libraries from Google Colab applied to predict stock prices.

(i) Yahoo Finance gets data
(ii) SweetViz
(iii) Matplotlib inline
(iv) NumPy
(v) Pandas
(vi) Seaborn
(vii) Matplotlib.pyplot
(viii) Plotly graph objects
(ix) TensorFlow
(x) Keras.models – sequential, Model
(xi) Keras layers - dense, LSTM, SimpleRnn, Dense, Dropout, Flatten, Conc2D, MaxPooling2D, LeakyReLU
(xii) MLP Regressor

Step 2 Data Import: The data for the eight companies were imported using the yahoo-finance get data module with dates starting 1st Jan 2005 unto 14th May 2023 having one day time interval. The Data consisted of seven attributes: Date, Open, High, Low, Close, AdjClose (adjusted close), and Volume(traded). The size of each company dataset was 4546.

Step 3 Overview of the Data: SweetViz module was used for obtaining statistical information about the data.

Step 4 Data Cleaning: The data were cleaned by removing null-valued entries/rows.

Step 5 Data Visualization: This section is divided into two parts. Part one is the relation between all the attributes, and Part two is the relation between companies' stock values. Data Visualization was done to display the relationship among attributes for a company and the relationship between stocks of different companies.

Step 6 Modelling: The modeling was done through four techniques, namely ANN, LSTM, RNN, MLP, by taking sixty data points at a time to predict the sixty-first datapoint.

The ANN consists of one input layer and eleven hidden layers. The number of neurons in each layer was 1024, 512, 256, 128, 64, 32, 16, 8, 4, 2, and the output layer had one neuron. The activation function on each layer was LeakyRelu. The loss function was mean squared error, and the optimizer Adam had a learning rate of .01. The Number of epochs was fifty.

The Multi-Layer Perceptron model had an activation function as Relu with 10x100 hidden layers.

The Recurrent Neural Network had one input layer and three hidden layers. Activation for the first three was LeakyRelu and the output layer's activation was linear. The neurons in each layer were 1, 16, 4, and 1. Optimizer used was Adam with a learning rate .01 and loss function mean squared error. The number of epochs was fifty.

The LSTM had seven layers, one input and six hidden layers. The six hidden layers had three LSTM layers and three dense layers. The loss function was a mean squared error, and optimizer Adam with a learning rate of .01 and number of epochs considered was ten.

Step 7 Prediction: The model was tested with the dataset of size 490. The results were plotted to make the predictions against each model. Comparison among the model was made based on the root mean squared model.

5 RESULTS

The researcher has discussed the various results obtained through applying the four different models, which interest prospective investors in assisting in their decision-making during investment in any of these companies' stock suiting their short or long-term investment objectives. The financial performance for FY 2021-22 plotted on a min-max scale is shown in Figure 2. The relative comparison reveals that the revenue, net profit, EPS and BVPS are highest for RIL. The ROE and Debt-Equity are the highest for BPCL and HPCL, respectively. The debt-equity is negligible for PLL.

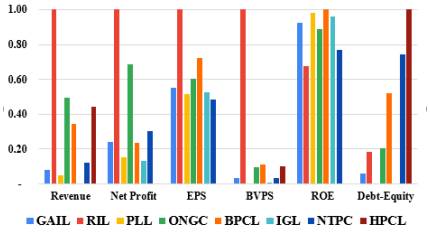

Figure 2: Financial Performance Trend.

Relation Between Attributes: The relationship between attributes for each company was obtained from seaborn and matplotlib modules. A few sample figures are shown. Figure 3 is the correlation heat map with all attributes for GAIL. Figure 4 is the residual AdjClose value for BPCL. Figure 5 is the stock price variability for GAIL. These plots help investors make an informed decision by viewing the visual images.

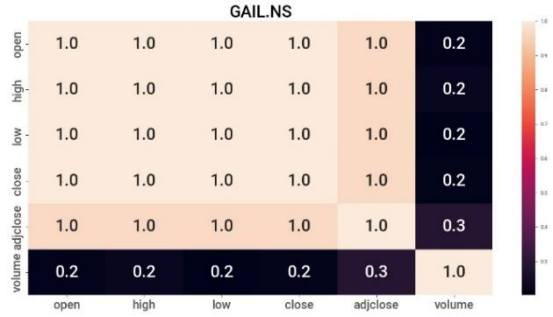

Figure 3: Correlation heat map for GAIL.

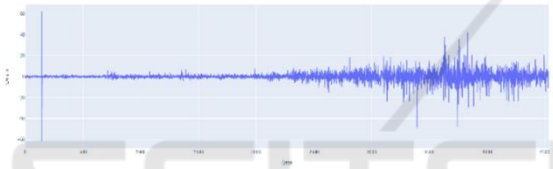

Figure 4: Residual Adj-Close for BPCL.

Figure 5: Stock price variability for GAIL.

The relationship between company's stocks is represented using matplotlib.pyplot. Each attribute has one image. Figure 6 shows the correlation of opening stock prices between companies.

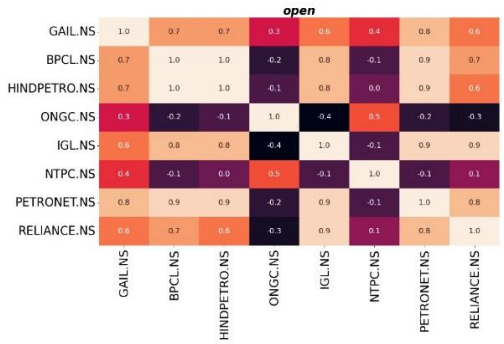

Figure 6: Correlation of opening stock prices.

Volume of stock traded for all companies from 1st Jan 2005 till 14th May 2023 is plotted using the Matplotlib.pyplot library in Figure 7. This provides real-time stock price comparison to the investors.

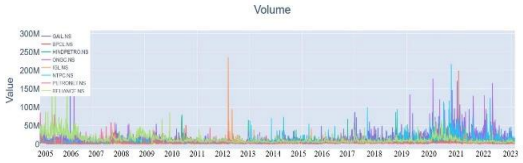

Figure 7: Volume of Stock Traded.

The stock price prediction is shown in Figure 8, plotted using Matplotlib. The pyplot model represents the predicted opening stock price for GAIL from 10th April 2022 to 14th May 2023. The Black line in the image represents the actual opening stock price, the Cyan line represents predicted values using MLP model, the Dark blue line represents the predicted values of the RNN model, the green line represents the predictions of the ANN model, and the red represents predicted values of the LSTM model. It is seen that the LSTM model predicts the stock prices with the least error since the predictions are very close to the actual values.

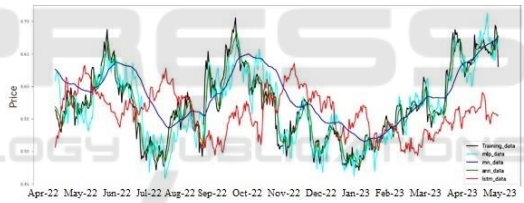

Figure 8: Predicted opening stock prices for GAIL all models.

The average RMSE of stock prices based on six attributes is in Figure 9. The RMSE obtained from MLP, RNN, and ANN models is very close and higher compared to the LSTM model, where the value is comparatively smaller. So, the application of the LSTM model by prospective investors may provide better results, positively impacting their decisions for investment.

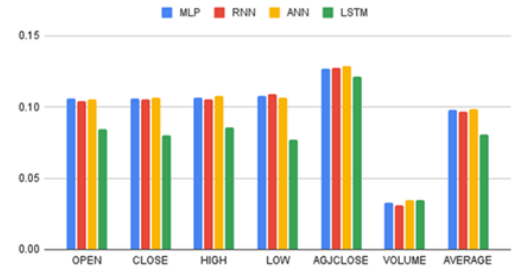

Figure 9: Average RMSE for all models on all attributes.

The Average of RMSE for LSTM model, which provides the best prediction among all models, for all companies is in Figure 10.

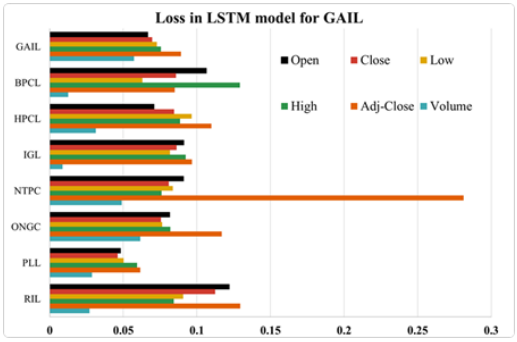

Figure 10: Average RMSE for LSTM Model.

6 DISCUSSION AND CONCLUSIONS

Increasing awareness of climate change has driven companies in the NG value chain to prioritize cleaner energy consumption and lower carbon footprints, aligning with investor preferences. This research applied DL techniques to predict the stock prices of eight Indian natural gas companies while considering their ESG commitments. The study revealed that GAIL, responsible for promoting SDG-7, exhibits relatively steady stock prices despite environmental changes. Additionally, RIL demonstrates the highest earnings per share (EPS) in 2022, while BPCL exhibits the highest return on equity (ROE). The LSTM model outperforms other models in accuracy. The findings surpass previous studies, highlighting practical applications for prospective investors. DL models for stock price prediction specifically applied to companies associated with the Indian NG value chain and their ESG commitments, hold significant practical implications for real-world investors.

Individuals traditionally rely on various methods to predict stock market movements, including fundamental, technical, and sentiment analysis. However, these conventional approaches often struggle to capture financial markets' complex and non-linear relationships. On the other hand, DL models offer a more sophisticated and effective solution for predicting stock market trends. These models leverage the power of neural networks and large-scale data processing capabilities to identify intricate patterns and correlations that might not be apparent to human analysts. These models utilize large amounts of historical stock price data and relevant ESG metrics to generate predictions about future price movements. This information enables investors to identify potential investment opportunities aligned with their ESG commitment, as it provides insights into companies' financial performance and their adherence to ESG practices. This provides a significant advantage to investors seeking to anticipate market movements, enabling them to make timely and informed investment decisions, ultimately maximizing their potential returns while minimizing risks associated with uncertainty in the stock market. By leveraging these models, investors gain access to advanced analytics that can aid in making informed investment decisions. Consequently, real-world investors can allocate their capital in a manner that supports sustainable and responsible business practices, aligning with their values and contributing to a more socially and environmentally conscious investment landscape.

The researcher found that the results obtained by applying the ANN model provided an average RMSE of 0.125, which is better than Vijh et al.,2020, which showed an average RMSE of 1.528. Further, the researcher used the 3-layer model with seven attributes for input, including hidden and an output layer which Vijh et al., 2020 did not use. The performance of models in this research are better than Islam & Nguyen, 2020 that used ARIMA(0,2,1)0 model with an RMSE of 0.14553. The researcher's model is also better than Nikou et al., 2019 due to lower RMSE value of LSTM model. Further comparing the results with Nikou et al., 2019 where the RMSE value for LSTM was 0.3065, it is seen that the current result RMSE value for LSTM is 0.090, which is better. Overall the current results are better than previous findings offering higher reliability and accuracy to prospective investors. The findings of the research suggest that ESG-integrated companies have outperformed their counterparts, indicating the financial benefits related to ROE as also recommended by Naeem et al., 2022. Further, results suggest that ESG offers long-term value creation for the shareholders, as also recommended by Zumente & Bistrova, 2021. Since investors provide capital to companies to expand and grow, resulting in surplus funds to manage environmental concerns, companies must give high importance to ESG performance to attract global shareholders(Cornell & Shapiro, 2021).

This research paper addressed the need for accurate stock price prediction in the context of companies operating in the Indian NG sector. By incorporating DL models, which have shown great promise in other domains, the research provided enhanced predictive capabilities for stock prices. Moreover, by underpinning the analysis with ESG commitments, the paper took a comprehensive approach to consider both

financial performance and sustainability factors, which are increasingly influential in investment decision-making while reducing investment risk(Hoepner et al., 2017).

7 FUTURE WORK

Several researchers have recently applied different models for predicting global companies' financial performance and stock prices in diverse sectors. The domain being contemporary, new applications with accurate forecasting is the demand of end users. Considering these, the researcher suggests future work involving the following.

- Feature Engineering: Explore new techniques to identify and extract relevant features the data. This can provide additional insights and improve models' performance.
- Applying Alternative Data Sources: An Investigation to integrate alternate data sources to capture second-period data. The Analysis will provide unique perspectives to enhance model prediction capabilities.
- Real-time Prediction: The Scope to develop models conducting real-time prediction exists by streaming real-time data using a fast interface algorithm.
- Interpretable and Explainable Models: Focus on developing interpretable and explainable models that can provide insights into the factors driving share price predictions. This is particularly important for regulatory compliance, risk management, and gaining trust from investors and stakeholders.
- Robustness and Generalization: Enhance the robustness and generalization capabilities of share prediction models to handle various market conditions, including market crashes, economic downturns, or abnormal events. Investigate techniques for model recalibration and adaptation to changing market dynamics.
- Real-world Evaluation: Validate share prediction models in real-world scenarios and compare their performance against benchmarks and industry standards. Conduct rigorous evaluation using historical data and consider factors like transaction costs, slippage, and trading volume impact.

REFERENCES

BP. (2022). BP Statistical Review of World Energy.

Cornell, B., & Shapiro, A. C. (2021). Corporate stakeholders, corporate valuation and ESG. European Financial Management, 27(2), 196–207. https://doi.org/10.1111/eufm.12299

Edward, R., & Evan, M. (1990). Corporate governance: A stakeholder interpretation. The Journal of Behavioral Economics, 19(4), 337–359.

GAIL. (2022). GAIL (India) Limited, Sustainability Reports. GAIL. https://www.gailonline.com/SBReports.html

Henisz, W., Koller, T., & Nuttall, R. (2019). Five ways that ESG creates value. McKinsey Quarterly, November, 1–12.

Hoepner, A. G. F., Oikonomou, I., Sautner, Z., Starks, L. T., & Zhou, X. (2017). ESG Shareholder Engagement and Downside Risk. SSRN Electronic Journal, November. https://doi.org/10.2139/ssrn.2874252

Hu, Z., Zhao, Y., & Khushi, M. (2021). A survey of forex and stock price prediction using deep learning. Applied System Innovation, 4(1), 1–30. https://doi.org/10.3390/ASI4010009

Islam, M. R., & Nguyen, N. (2020). Comparison of Financial Models for Stock Price Prediction. Dmouj 2006. https://doi.org/10.3390/jrfm13080181

Kumbure, M. M., Lohrmann, C., Luukka, P., & Porras, J. (2022). Machine learning techniques and data for stock market forecasting: A literature review. Expert Systems with Applications, 197(February), 116659. https://doi.org/10.1016/j.eswa.2022.116659

MoEFCC. (2022). India's Stand at COP-26. PIB, 1–2. https://pib.gov.in/PressReleasePage.aspx?PRID=1795071

MoPNG. (2023). Government has set target to increase share of gas in energy mix up to 15 per cent by 2030. PIB.

Naeem, N., Cankaya, S., & Bildik, R. (2022). Does ESG performance affect the financial performance of environmentally sensitive industries? A comparison between emerging and developed markets. Borsa Istanbul Review, 22, S128–S140. https://doi.org/10.1016/j.bir.2022.11.014

Nikou, M., Mansourfar, G., & Bagherzadeh, J. (2019). Stock price prediction using DEEP learning algorithm and its comparison with machine learning algorithms. Intelligent Systems in Accounting, Finance and Management, 26(4), 164–174. https://doi.org/10.1002/isaf.1459

RIL. (2022). Business Responsibility Report. RIL. http://www.ril.com/DownloadFiles/IRStatutory/Code-of-Conduct.pdf

Sarangi, G. K. (2021). Resurgence of ESG Investments in India: Towards a Sustainable Economy (No. 1284; ADB Working Paper Series, Issue 1284). www.adbi.org

Vijh, M., Chandola, D., Tikkiwal, V. A., & Kumar, A. (2020). Stock Closing Price Prediction using Machine Learning Techniques. Procedia Computer Science, 167(2019), 599–606. https://doi.org/10.1016/j.procs.2020.03.326

Zumente, I., & Bistrova, J. (2021). Esg importance for long-term shareholder value creation: Literature vs. practice. Journal of Open Innovation: Technology, Market, and Complexity, 7(2). https://doi.org/10.3390/joitmc7020127