

Exchange Rate Prediction: Micro and Macro Factors, Machine Learning, and Future Directions

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Abstract. This review synthesizes current research on the dynamics of exchange rates, examining the influence of microeconomic factors, such as market sentiment, and macroeconomic factors, including political stability and economic governance. It also explores the application of modern predictive techniques, notably machine learning and deep learning technologies, in anticipating exchange rate movements. The review emphasizes how these cutting-edge methods can be used to better foresee and capture intricate nonlinear interactions, while also underscoring the importance of considering both microeconomic and macroeconomic factors in developing effective prediction models. In the end, this analysis highlights significant patterns and gaps in the literature, offering insightful information to investors, politicians, and scholars attempting to understand the nuances of exchange rates. It concludes by emphasizing the need for future research to address existing limitations in data acquisition and model selection, as well as exploring new avenues for improving exchange rate prediction, such as incorporating diverse data sources and developing more robust and adaptive models.

Keywords: Exchange Rates; Machine Learning, Deep Learning; Market Sentiment; Macroeconomic Factors.

1. Introduction

In today's global economy, the concept of exchange rates holds significant importance, impacting various aspects of international trade, investment decisions, and economic policy formulation. Exchange rates, defined as the price of one currency in terms of another, serve as a crucial indicator of economic health and stability. They affect capital flows, how competitive a nation's goods and services are abroad, and even how monetary policy is formulated. A stronger currency, for example, may make a nation's imports cheaper and its exports more costly, which could result in trade imbalances.

Policymakers and investors must understand the causes influencing exchange rate fluctuations. For instance, interest rates, inflation, economic growth, market sentiment, and political stability, has a direct effect on foreign capital flows, for example, and thus influences currency demand. Higher interest rates typically attract foreign investment and boost the currency, but lower rates may have the reverse impact. Additionally, inflation rates can erode purchasing power, impacting currency value against others in the foreign exchange market.

Furthermore, market sentiment plays a pivotal role in exchange rate volatility. Psychological factors, such as investor confidence and geopolitical events, can lead to rapid shifts in currency values, often without a direct correlation to fundamental economic indicators. Political factors, including changes in government, policy stability, and geopolitical tensions, add further complexity to the exchange rate environment.

Furthermore, the equilibrium exchange rate will be impacted by shifts in foreign exchange demand brought on by actual supply and demand shocks. As a result, adjustments to the exchange rate typically coincide with modifications to the conditions of trade [1]. Fundamentally, the savings rate and investment interest rate differential are the key factors that determine financial flows in the

balance of payments. When financial capital inflows occur, it will push the real exchange rate to appreciate; while capital outflows will lead to a depreciation of the real exchange rate [2].

This review will explore exchange rate influences from three key angles: microeconomic factors, macroeconomic factors, predictive methods, existing limitations and future outlook.

Firstly, microeconomic factors such as market sentiment play a crucial role in shaping exchange rates. Investor perceptions and expectations can lead to significant fluctuations, often independent of economic fundamentals. Macroeconomic factors, including political stability and economic growth, are vital for understanding exchange rate movements. Political risks and governance quality affect investor confidence, while a stable social environment promotes economic health. Secondly, the review will examine predictive methods, specifically advancements in machine learning and deep learning methods. These methods provide innovative approaches to forecasting exchange rate movements, enhancing prediction accuracy in an ever-changing market. Lastly, based on a review of relevant research results, this article systematically sorted out the main problems currently facing this field, and combined with current development trends and technological advances, this article looked forward to future research directions.

The significance of this review lies in its integration of current studies on influencing factors and prediction methods. By synthesizing existing research, it aims to identify trends and gaps in the literature, offering insightful information to scholars, investors, and policymakers attempting to understand the nuances of exchange rates.

2. Factors Influencing Exchange Rates

2.1. Microeconomic Factors

Market sentiment plays a pivotal role in determining exchange rates, as it encapsulates the collective attitudes and emotions of investors toward a particular currency or the broader market, the findings of one study indicate that investor attitude has a favorable impact on foreign currency market [3]. This sentiment often manifests through investor confidence, which can fluctuate based on news events, economic data releases, and market trends. Since the asset approach to the exchange rate holds that an increase in the number of trades boosts the value of currency, demand for a currency usually rises when investor confidence is high, resulting in an appreciation of its value [4]. Conversely, when confidence wanes—perhaps due to negative news or economic uncertainty—investors may sell off their holdings, causing the currency to depreciate.

Rumors and speculation also significantly influence market sentiment. In foreign exchange markets, traders often react to not only confirmed news but also to whispers about potential developments, economic reports, or political changes. For instance, if rumors circulate regarding an impending interest rate hike by a central bank, investors may quickly adjust their positions based on these expectations, leading to volatility in currency values. Such behavior highlights the psychological aspect of trading, where perceptions can quickly shift and lead to large market movements, regardless of underlying economic fundamentals.

Moreover, market sentiment is often exacerbated during periods of economic stress or geopolitical turmoil. Events such as political elections, natural disasters, or conflicts can lead to heightened uncertainty and fear among investors. In such situations, risk aversion may prompt investors to flock to so-called "safe-haven" currencies like the US dollar or Swiss franc, further impacting exchange rates in significant ways. Understanding the nuances of market sentiment is therefore crucial for predicting currency movements and for developing effective trading strategies.

2.2. Macroeconomic Factors

Macroeconomic factors, particularly political stability and social governance have a profound impact on exchange rates. It has been noted that economic fundamentals, financial markets, financial

development, and government fiscal and monetary intervention are the main causes of exchange rate volatility [5]. A stable political environment typically fosters confidence among both domestic and foreign investors, encouraging capital inflows and strengthening the national currency. In countries with strong institutional frameworks, transparent governance, and consistent policy measures, investors are more likely to trust that their investments will be protected, leading to sustained demand for the currency.

Conversely, political instability, whether due to government changes, civil unrest, or policy uncertainty, can drastically weaken a currency. For example, if a country undergoes a significant political upheaval, investors may flee in anticipation of adverse economic implications, leading to a depreciation of the currency. Geopolitical risks, such as conflicts or tensions with other nations, further complicate the landscape. These risks can create an environment of uncertainty, causing investors to prefer safer assets and potentially leading to a sell-off of currencies perceived as risky.

Additionally, social stability and economic governance play essential roles in shaping investor sentiment and influencing exchange rates. Effective governance, which includes the establishment of the rule of law, transparency, and accountability, tends to promote social stability. When citizens perceive that their government is functioning effectively and addressing their needs, confidence in the currency tends to increase. In contrast, high levels of corruption, social unrest, or economic mismanagement weaken the currency as investors become wary of potential losses.

In summary, both microeconomic factors like market sentiment and macroeconomic factors such as political stability and governance are integral to understanding the dynamics of exchange rates. These elements interact in complex ways, contributing to the fluid nature of currency markets and emphasizing the importance of holistic analysis when evaluating currency movements.

3. Prediction Methods

3.1. Machine Learning-Based Prediction Methods

By producing increasingly complicated and adaptable models that can manage intricate information, machine learning (ML) has completely transformed the field of exchange rate prediction. Machine learning algorithms are capable of automatically identifying patterns and correlations from enormous volumes of historical data, in contrast to traditional statistical methods that frequently depend on certain assumptions and linear relationships. These models frequently incorporate methods, allowing analysts to account for nonlinear relationships and interactions among multiple variables that influence currency movements.

The application of machine learning in exchange rate forecasting offers several advantages, including improved accuracy and the ability to incorporate diverse data inputs, such as macroeconomic indicators, trader sentiment, and even geopolitical events. As such, ML methods have gained traction among financial analysts and researchers seeking to enhance prediction accuracy and responsiveness to market changes.

Goncu investigates the prediction of monthly average exchange rates using regression techniques based on machine learning [6]. The macroeconomic model used in the study considers the US Federal Funds rate, real interest rates, the domestic money supply, and the average exchange rate from the previous month. Using monthly data from the US dollar and Turkish lira exchange rates, the author tries a variety of machine learning methods, including Ridge regression, decision tree regression, support vector regression, and linear regression [6]. The primary finding is that Ridge regression offers investors and policymakers precise estimates with relative errors of less than 60 basis points. Goncu also shows how policymakers can utilize the model to get confidence intervals and point estimates for examining how interest rate reduction affect exchange rates. The paper emphasizes the practical implications of using machine learning in a macroeconomic framework, providing a tool for both policy analysis and investment strategies [6].

By using sentiment analysis on Twitter messages, Naeem and colleagues present a way to predict the currency exchange rate between the US and Pakistan [7]. The authors produced a dataset of USD/PKR exchange rates by gathering information from a currency website and a sample of tweets from Pakistan's business community that included money-related phrases. Natural language processing methods were applied to prepare the unprocessed dataset. The dataset was then subjected to response variable labeling, dividing the response variables into two classes: "1" indicating an increase in the exchange rate and "-1" indicating a decrease. To better represent the dataset, linear discriminant analysis (LDA) and principal component analysis (PCA) were used to visualize the data in three-dimensional vector space. Clusters obtained using a sampling approach were then used for data optimization. Five machine learning classifiers—simple logistic (SL), random forest (RF), bagging (B), and support vector machine (SVM)—were used on the set of data that had been optimized. According to the findings, the basic logistic classifier produced the best forecasting accuracy for the USD/PKR exchange rate, at 82.14%. The study shows how machine learning techniques and sentiment analysis of social media data can be combined to forecast financial indicators such as exchange rates [7].

A comprehensive analysis of these studies reveals that machine learning methods can enhance exchange rate predictions through greater adaptability and predictive power. Both studies underscore the importance of feature selection and data preprocessing in achieving accurate predictions. While Goncu focuses on macroeconomic indicators [6], Naeem et al. leverage social media sentiment [7], indicating that diverse data inputs can enhance the predictive capabilities of machine learning models. These findings suggest that machine learning represents a promising avenue for refining exchange rate forecasting techniques by accommodating complex datasets and uncovering intricate patterns.

3.2. Deep Learning-Based Prediction Methods

Deep learning, a complex version of machine learning, models complex patterns in data using neural networks with many layers. This approach has shown considerable potential in the realm of exchange rate forecasting due to its ability to learn intricate, nonlinear relationships from vast datasets that traditional models may overlook. By leveraging large quantities of historical data, deep learning models can capture temporal dependencies and multifaceted market behaviors more effectively.

A key innovation in deep learning for exchange rate prediction is the use of Long Short-Term Memory (LSTM) networks, which are specifically designed to process sequences of data and retain information over longer periods. This capability makes LSTMs particularly suitable for forecasting time series data, such as currency exchange rates.

Ensemble deep learning strategies, which combine techniques like Bagging Ridge regression with Bi-directional Long Short-Term Memory neural networks, have been shown to be effective in exchange rate prediction. These methods are used to forecast currency values against a benchmark currency across different economic periods. The prediction performance of these models is frequently contrasted with other deep learning-based algorithms and conventional machine learning algorithms to show how successful they are. In terms of prediction error, studies show that ensemble deep learning techniques can perform better than the compared models. Nonetheless, the need for prediction models in extremely volatile foreign exchange markets is highlighted by the fact that the model's performance differs greatly among currencies and economic eras. Studies conclude that by providing improved prediction performance and identifying the most affected currencies, these approaches can benefit foreign exchange traders and other stakeholders, offering opportunities for potential trading profitability and reducing the impact of increased currency risk [8].

The MVO-BiGRU model is a new forecasting framework designed to overcome the difficulties in accurately predicting exchange rates. This method enhances the training dataset by combining data augmentation approaches with variational mode decomposition, which decomposes complex signals into simpler components. The MVO-BiGRU model also uses hyperparameter optimization using techniques like Optuna to fine-tune the model's configuration and bidirectional GRU algorithms,

which are well-known for their capacity to grasp temporal dependencies in sequential data. The goal of this combination is to increase forecasting accuracy, especially for monthly foreign exchange rates. The MVO-BiGRU model's capacity to reduce overfitting, a frequent problem when working with small datasets, is one of its main advantages. The model can more effectively generalize to unknown data by carefully choosing hyperparameters and enriching the input. Research using this approach has produced encouraging findings; the MVO-BiGRU model outperformed conventional benchmark models on a number of evaluation measures and achieved excellent accuracy in out-of-sample forecasting. These results imply that the MVO-BiGRU model is a useful instrument for scholars and professionals looking to enhance exchange rate forecasts, particularly in situations involving complicated or limited data [9].

The studies reviewed indicate that deep learning techniques, particularly LSTM and its variants, present significant advantages in exchange rate forecasting by accommodating large datasets and uncovering intricate patterns. Both studies underscore the potential of deep learning techniques to capture complex nonlinear relationships and improve forecasting accuracy in exchange rate prediction. While Abedin et al. focus on the impact of the COVID-19 pandemic [8], Iqbal et al. emphasize the importance of data preprocessing and model optimization [9]. These findings suggest that deep learning represents a cutting-edge approach in the evolving landscape of exchange rate prediction.

4. Existing Limitations and Future Outlook

4.1. Existing Limitations

Current research on exchange rate prediction, while showing promising advancements, still faces several limitations that need to be addressed to improve the accuracy and reliability of forecasting models. These limitations span various aspects, including data acquisition, model selection, and the inherent complexity of financial markets.

One significant challenge is the availability and quality of data. Many studies rely on historical data, which may not fully capture future market behaviors, especially during periods of economic or political upheaval. The limited availability of high-frequency data and real-time information can also hinder the development of more responsive and adaptive models. Furthermore, the reliance on traditional macroeconomic indicators may not fully account for the influence of behavioral factors, market sentiment, and geopolitical events.

Model selection also presents a considerable challenge. While machine learning and deep learning techniques offer greater flexibility and predictive power, the selection of appropriate models and the tuning of hyperparameters can be complex and time-consuming. The risk of overfitting, where models perform well on training data but poorly on unseen data, is a persistent concern. Additionally, the lack of standardized evaluation metrics and benchmark datasets makes it difficult to compare the performance of different models and assess their true predictive capabilities.

The inherent complexity of financial markets further complicates exchange rate prediction. Exchange rates are influenced by a multitude of interacting factors, including economic fundamentals, political events, market sentiment, and global capital flows. These factors can exhibit nonlinear relationships and sudden shifts, making it difficult for models to capture the full dynamics of currency movements.

4.2. Future Outlook

Looking ahead, future research directions should focus on addressing these limitations and exploring new avenues for improving exchange rate prediction. One promising area is the incorporation of more diverse data sources, such as social media sentiment, news articles, and alternative economic indicators. The use of natural language processing (NLP) techniques to extract insights from unstructured data could provide valuable information about market sentiment and emerging trends.

Another important direction is the development of more robust and adaptive models. Ensemble methods, which combine multiple models to improve prediction accuracy and reduce variance, offer a promising approach. Additionally, the exploration of hybrid models that integrate machine learning with traditional econometric techniques could leverage the strengths of both approaches.

Furthermore, future research should focus on developing more standardized evaluation metrics and benchmark datasets to facilitate the comparison of different models and assess their true predictive capabilities. The use of rigorous statistical testing and validation techniques is essential to ensure the reliability and robustness of forecasting models.

Finally, greater attention should be paid to the practical implications of exchange rate predictions. Research should focus on developing models that can provide actionable insights for policymakers, investors, and businesses, enabling them to make more informed decisions and manage currency risk more effectively.

By addressing these limitations and exploring new research directions, the field of exchange rate prediction can continue to advance and provide valuable insights into the dynamics of global financial markets.

5. Conclusion

This review has investigated the complex relationship between exchange rate dynamics, examining the influence of microeconomic factors, such as market sentiment, and macroeconomic factors, including political stability and economic governance. It has also delved into the application of modern predictive techniques, specifically machine learning and deep learning methods, in forecasting exchange rate movements.

The integration of these diverse perspectives is crucial for a comprehensive understanding of exchange rate behavior. Market sentiment, driven by investor perceptions and expectations, can lead to significant fluctuations independent of economic fundamentals. Recent macroeconomic news releases on daily exchange rate variations are highly correlated with their ability to forecast short-term exchange rates [10]. Macroeconomic elements that affect capital flows and investor confidence include political stability and efficient governance. Additionally, the use of deep learning and machine learning techniques provides novel ways to predict changes in exchange rates, improving prediction accuracy in a market that is always shifting.

The significance of this review lies in its synthesis of current studies on influencing factors and prediction methods. This paper offers important insights for investors, scholars, and policymakers attempting to understand the intricacies of exchange rates by pointing out patterns and gaps in the literature. The paper emphasizes how deep learning and machine learning approaches can be used to better predict outcomes by capturing intricate nonlinear interactions. It also underscores the importance of considering both microeconomic and macroeconomic factors in developing effective prediction models.

Future research should focus on addressing the existing limitations in data acquisition and model selection, as well as exploring new avenues for improving exchange rate prediction. The incorporation of more diverse data sources, the development of more robust and adaptive models, and the use of standardized evaluation metrics are essential for advancing the field. By addressing these challenges, the field of exchange rate prediction can continue to evolve and provide valuable insights into the dynamics of global financial markets.

References

- [1] Stockman, A. C. (1980). A Theory of Exchange Rate Determination. *Journal of Political Economy*, 88(4), 673–698.
- [2] Tyers, R., & Golley, J. (2008). China's Real Exchange Rate Puzzle. *Journal of Economic Integration*, 23(3), 547–574.

- [3] Škrinjarić, T., Lovretin Golubić, Z., & Orlović, Z. (2021). Empirical analysis of dynamic spillovers between exchange rate return, return volatility and investor sentiment. *Studies in Economics and Finance (Charlotte, N.C.)*, 38(1), 86–113.
- [4] Ghumro, N. H., Soomro, I. A., & Abbas, G. (2024). Asymmetric effect of exchange rate and investors' sentiments on stock market performance. *Journal of Economic and Administrative Sciences*, 40(5), 1192–1204.
- [5] Nor, M. I., Masron, T. A., & Alabdullah, T. T. Y. (2020). Macroeconomic Fundamentals and the Exchange Rate Volatility: Empirical Evidence from Somalia. *SAGE Open*, 10(1).
- [6] Goncu, A. (2019). Prediction of exchange rates with machine learning. *Proceedings of the International Conference on Artificial Intelligence, Information Processing and Cloud Computing*, 1–5.
- [7] Naeem, S., Mashwani, W. K., Ali, A., Uddin, M. I., Mahmoud, M., Jamal, F., & Chesneau, C. (2021). Machine learning-based USD/PKR exchange rate forecasting using sentiment analysis of Twitter data. *Computers, Materials & Continua*, 67(3), 3451-3461.
- [8] Abedin, M. Z., Moon, M. H., Hassan, M. K., & Hajek, P. (2021). Deep learning-based exchange rate prediction during the COVID-19 pandemic. *Annals of Operations Research*, 345(2), 1335–1386.
- [9] Iqbal, F., Koutmos, D., Ahmed, E. A., & Al-Essa, L. M. (2024). A Novel Hybrid Deep Learning Method for Accurate Exchange Rate Prediction. *Risks (Basel)*, 12(9), 139-.
- [10] Erçen, H. İ., Özdeşer, H., & Türsoy, T. (2022). The Impact of Macroeconomic Sustainability on Exchange Rate: Hybrid Machine-Learning Approach. *Sustainability*, 14(9), 5357.