Econometric Modelling of USD/MYR Exchange Rate Dynamics and Key Macroeconomic Factors

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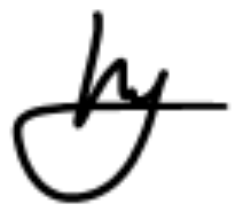
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Abstract

Stability in a country’s currency exchange rates is extremely crucial as fluctuations in the exchange rates significantly impact the international trade, investment, debt, and a country’s overall economic health. The exchanges rates are always linked to a variety of internal and external factors, among them are what we call macroeconomic factors which include money supply, inflation rates, Industrial Production Index (IPI) and others. This research seeks to explore the underlying relationship between these macroeconomic variables and the currency exchange rate of Malaysian Ringgits (MYR) by leveraging latest available data up to the year of 2024. The motivation behind this research lies in the recognition that a thorough understanding of the relationships between macroeconomic variables and currency exchange rates can be beneficial for informed policymaking and budgeting. In view of Malaysia as a developing country where its economy is evolving by leap and bounds at the present, a comprehensive analysis becomes necessary.

*Keywords: monetary economics; bilateral analysis; predictive model; machine learning*

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List of Symbols and Abbreviations

|  |  |  |
| --- | --- | --- |
| BNM | : | Bank Negara Malaysia |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| CNN | : | Convolutional Neural Network |
|  |  |  |
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|  |  |  |
|  |  |  |
| EDA | : | Exploratory Data Analysis |
|  |  |  |
|  |  |  |
|  |  |  |
| GB | : | Gradient Boosting |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
| LR | : | Logistic Regression |
| LSTM | : | Long Short-Term Memory |
|  |  |  |
| ML | : | Machine Learning |
|  |  |  |
|  |  |  |
|  |  |  |
| OOT | : | Out-of-Time |
| PCA | : | Principle Component Analysis |
|  |  |  |
|  |  |  |
| RF | : | Random Forest |
|  |  |  |
|  |  |  |
|  |  |  |
| SVM | : | Support Vector Machine |
|  |  |  |
| RMSE | : | True Negative |
| MAPE | : | True Positive |
| WHO | : | World Health Organisation |
| XGBoost | : | eXtreme Gradient Boosting |
|  |  |  |

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# CHAPTER 1: INTRODUCTION

This chapter provides a brief overview of the research. The background and problem statement of the study are discussed in Section 1.1 and Section 1.2 respectively, followed by the research questions in Section 1.3 and research objectives in Section 1.4. Section 1.5 presents the scope of the study while Section 1.6 is about the significance of the study. Lastly, the outline of the whole report is laid out in Section 1.7.

## 1.1 Introduction

As pinpointed by (Biswas et al., 2023), ever since the global economy is highly reliant on international trade, buying goods and services from a country requires an individual or an organisation to purchase them in the accepted local currency of that country. From that moment, the currency exchange rate played its part and parcel in the transactions across national borders. The currency exchange rate reflects the price of one currency against the other and it facilitates the international trade of goods and services and the capital transfer. It indicates the external competitiveness of a country’s economy (Dahal & Raju, 2022).

The currency exchange rate, as a key indicator of a nation's economic well-being, influences various aspects of its economy. The fluctuations in exchange rates potentially induce either symmetric or asymmetric effects on the trade flows. A simple proportionate link between trade volume and exchange rate volatility is implied by symmetric effects. On the other side, since various traders can have different expectations, asymmetric effects involve varying responses to changes in exchange rates. It is worth noting that these effects may differ in different industries and change over time, as discussed by (Lal et al., 2023). Within an open economy, exchange rates and the Consumer Price Index (CPI) can be intercorrelated. When the domestic currency depreciates, the import costs will certainly surge. This will consequently lead to increased CPI within the home country. Simultaneously, as the home currency weakens against foreign counterparts, it will make local products comparatively more affordable. The expenditure switching effect comes into play where it will lead to an increase in the relative demand for domestic products and home country CPI, as highlighted by (Kim et al., 2021).

Regardless of whether the exchange rate strengthens or weakens, there are always winners and losers within the domestic economy. A depreciation of the currency adversely impacts consumers of imported goods and services. It potentially leads to an overall increase in the cost of living. However, a weakened currency may boost earnings for exporters. Conversely, an appreciation benefits those involved in importing goods, services and international travel yet it can be detrimental to exporters and the domestic tourism industry. It is crucial for these exchange rate adjustments to occur in an orderly manner to facilitate continued economic activity. The primary focus of a country's exchange rate regime should not be on favouring specific sectors over others but rather on ensuring long term benefits for the overall economy, as emphasised by (BNM, 2022). (Ribeiro et al., 2020) argued that exchange rate undervaluation or depreciation can enhance the growth of nations by stimulating technological progress and knowledge spillovers. They suggest that, to promote economic growth, it is essential to avoid overvaluing the currency since this can impede the growth.

Examining the sensitivity of exchange rate volatility is valuable to identify direction of movements in exchange rates and the economic consequences. A concise understanding along with effective modelling of exchange rate movements is essential for policymakers to formulate appropriate monetary and fiscal policies tailored to a specific country's needs. It helps to guide informed policy decisions and lead the country on the right track. Gauging the sensitivity the currency exchange rates reacting to changes assists to predict their future direction and understand the potential impacts brought to the country’s economy (Thevakumar & Jayathilaka, 2022).

Article presented by (Boyoukliev et al., 2022) depicted that several main macro factors, commonly called key macroeconomic indicators such as inflation, unemployment, gross domestic product, main interest rate, foreign exchange rate, etc. determine the strength of a certain economy. These important economic indicators are often connected to each other, when one variable changes, the others change as well. Significant changes can lead to imbalances that are hard to predict and fix which in turns produce both positive and negative outcomes. Currency strength is directly dependent on the changes in the minimum of the above key macroeconomic indicators.

**(Pasionek, 2023)** reflected that in the globalised world, the exchange rates are mainly impacted by economic factors. In foreign exchange (FOREX) transactions, the exchange rate of the given currency pair is expressed as one figure, indicating a relation of the quoted currency to the notional amount. The demand and supply for the given currency pair depends on many factors. The primary economic factors that influence the short-term exchange rate volatility are macroeconomic data from the American economy. Thus, he implemented the linear regression model to assess the impact of selected macroeconomic data from the American economy on the performance of USD/PLN currency pair.

As also highlighted in the paper presented by **(Munir & Iftikhar, 2023)**, maintaining an equilibrium level of the real exchange rate is critical in which the underlying factors shall be assessed. This study used a general-to-specific method to investigate the macroeconomic drivers of the real exchange rate in Pakistan. The study adopted an ARDL technique to analyse both long-run and short-run correlations using quarterly data from Quarter 1 of 1980 to Quarter 4 of 2020. Money supply, productivity, trade openness, worker remittances, government consumption spending, terms of trade, and foreign direct investment (FDI) were all possible contributions to the real effective exchange rate in the model.

The global economic landscape is always evolving and filled with constant fluctuations and uncertainties. Malaysia with its vibrant economy is not an exception. Shifts in global trade patterns, changes in commodity prices, monetary policy adjustments and geopolitical events can all have profound effects on the value of the Malaysian Ringgit. A systematic exploration of these relationships will provide invaluable insights into the factors contributing to the MYR exchange rate movements.

This research aims to bridge existing knowledge gaps by looking into the relationship between macroeconomic variables and the USD/MYR exchange rates. By examining data up to the year 2024, a contemporary and insightful work is to be performed as a guide for the policymakers, businesses, and investors in making informed decisions in an ever-evolving economic landscape. Through the empirical analysis, this study seeks to contribute not only to the academic discourse but also to the practical understanding of the core factors shaping Malaysia's currency exchange rate dynamics.

## 1.2 Problem Statements

The exchange rate plays a crucial role in a country's international trade and economic position. Fluctuations in exchange rates can have significant consequences for policymakers, investors, businesses and consumers in making their decisions. Even though many of the researchers came up with different approaches such as VAR model (Antwi et al., 2020), ARDL model (Munir & Iftikhar, 2023; Thevakumar & Jayathilaka, 2022) and deep learning models (Biswas et al., 2023) to examine the effect of macroeconomic factors on the currency exchange rates., they were focusing the studies on their own countries. Several studies had been conducted in Malaysia (Mohamed et al., 2021; Shukri et al., 2021) to investigate the impact of economic factors on Malaysia's exchange rate volatility. However, these studies had utilised annual data which may not effectively capture the fast-paced fluctuations in currency exchange rates.

Many of the recent research undertook a variety of novel methods and models to draw relationships between macroeconomic features and the currency pairs. Nevertheless, the data they used were mostly not up to date. For instance, (Biswas et al., 2023) used data until 2019 and (Ohaegbulem & Iheaka, 2024) used data until 2021 only in their studies. This limits the relevance of their findings in the context of current economic conditions. Aside from that, most studies focus solely on the macroeconomic factors of only one country. Since currency pairs represent the relative values between two countries' currencies, we may overlook the potential mutual influence from the other country on the strength of currency pairs.

In conclusion, the existing literature furnishes substantial relationship established between the macroeconomic variables and the overall currency exchange rate of a country. Notably, this study will fill the research gap by focusing the context mainly to Malaysia instead of other countries. In addition, this study aims to also utilise the most contemporary dataset from a set of both Malaysia and US macroeconomic factors to discern the determinants of both long-run and short-run dynamics of the Malaysia currency exchange rates over the time.

## 1.3 Research Questions

The research questions of this study are stated as follows:

1. How do macroeconomic factors in the United States and Malaysia exhibit influence on their paired exchange rates?
2. Can we map macroeconomic factors and currency exchange rates of US Dollars against Malaysian Ringgits to forecast future rates?
3. How do the predictive performances of different econometric models differ in forecasting the USD/MYR exchange rate?

## 1.4 Research Objectives

This study wishes to achieve three main objectives which are:

1. To investigate the influence that each identified macroeconomic factor has on the paired exchange rates between United States and Malaysia.
2. To develop an econometric model that can predict the USD/MYR exchange rates using macroeconomic indicators.
3. To evaluate the performance of different econometric models in forecasting the USD/MYR exchange rates.

## 1.5 Research Scope

The principal of this research will be mainly focusing in building different models to trace the impacts of key macroeconomic factors such as crude oil prices, Industrial Production Index, money supplies, etc. on the currency exchange rates in Malaysia. By utilising monthly data spanning from January 2015 to July 2024, this study seeks to provide insights which can reflect the current economic conditions and align with the contemporary financial landscape. The data will be gathered from a range of reliable and reputable sources, namely Yahoo Finance, Department of Statistics Malaysia (DOSM), Central Bank of Malaysia and Federal Reserve Economic Data (FRED).

## 1.6 Research Significance

The outcome of the research is anticipated to provide more in-depth economical insights into the impacts of various macroeconomic factors on the economic growth in Malaysia which can be crucial for Malaysia to attain sustainable and steady long-term economic growth. The findings may contribute to a more informed and sound decision-making by the policy makers and government in formulating new economic policies, developing stimulus packages as well as allocating the budget for different industrial sectors. The results may also serve as a reference for the investors to foresee the future growth in Malaysia’s economy and perform decisions on whether to invest in Malaysia.

## 1.7 Report Outline

Chapter 1 introduces the overall project, which focuses on gauging the relationship between the macroeconomic variables and USD/MYR currency exchange rates. This chapter outlines the problem statements, research objectives, research questions, scope of the research and significance of the research.

Chapter 2 provides a literature review related to this study. It includes the critical review of the related works, discussions on the performance of different algorithms implemented by the previous researchers along with their benefits and limitations.

Chapter 3 details the research’s methodology. This chapter describes the proposed design and interface, including a research flowchart, model specifications as well as explanation of each step taken along with the software and tools used.

Chapter 4 presents the results and discussion based on the methodology outlined in Chapter 3. Key quantitative data is summarised with experimental outcomes, statistical analyses and evaluation metrics performance of every model used. The results are displayed in tables and graphs with discussions interpreting them.

Lastly, Chapter 5 synthesises the entire research project by providing a comprehensive summary of the key findings, implications, contributions and future direction of the study.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Introduction

This chapter mainly explains about the literature study of the previous research related to this study.

## 2.2 History of Foreign Currency Exchange Rate Systems

Prior to the establishment of formal systems, foreign currency exchange rates were determined by the relative weight and purity of the metals used in coinage. The adoption of the Gold Standard in the late 19th and early 20th centuries marked a significant shift towards a more structured system. Under the Gold Standard, each currency's value was directly linked to a fixed quantity of gold. At that time, we can observe explicitly the stability and predictability in foreign currency exchange rates. This system prevailed until the outbreak of World War I which had disrupted international trade and led countries to abandon the gold (Dahal & Raju, 2022). The interwar period between World War I and World War II caused instability and experimentation in exchange rate arrangements. Several countries including Iceland had resorted to currency controls and devaluations to address the economic challenges (Edwards & Cabezas, 2021).

In 1944, the Bretton Woods Agreement introduced a new era of fixed exchange rates, with the currencies pegged to the US dollar, which in turn was pegged to gold. This system was aimed to foster the international trade and economic stability after World War II. However, primarily due to inflationary pressures in the United States and the growing divergence in economic performance among participating countries, the Bretton Woods system ultimately collapsed in 1971 (Subacchi & Vines, 2023).

Afterwards, the Bretton Woods system gradually made transition to a floating exchange rate regime. Under the floating exchange rate system, currency values were determined by market forces of supply and demand which offers greater flexibility depending on the market conditions (Shukri et al., 2021). In the meantime, it also introduced volatility in exchange rates as currencies were now subject to market speculation, geopolitical events and economic policies (Elgahry, 2022). The great volatility became a key driver of the growth and importance of the Foreign Exchange (FOREX) market, one of the world's largest and dynamically evolving financial markets.

FOREX market basically allows virtually anyone to participate as an investor without going through any entry or exit barriers. It is known for its exceptional liquidity, dynamism and rapid turnover (Pasionek, 2023). According to BIS Triennial Central Bank Survey from the Bank for International Settlements, trading in over-the-counter FOREX market had reached average daily transaction volume of $7.5 trillion in April 2022 (a 14% rise from $6.6 trillion in 2019) as shown in Figure 2.1. Being the largest and most liquid financial market globally, the pricing of currencies is also related significantly with the relative value of domestic and foreign goods. It presents both opportunities and challenges for investors and businesses engaged in international trade and finance (Flores-Sosa et al., 2022).

A close-up of a graph

Description automatically generated

Figure 2.1 Foreign Exchange Market Turnover by Instrument

Looking back to Malaysia, the country had adjusted its fixed exchange-rate system to a regulated floating-exchange rate regime at the late July 2005 to build an open capital market and autonomy of monetary policy. The system of regulated exchange rates is a regime of international exchange rates where the exchange rate is permitted to travel freely but only on a regular basis, according to the market powers. This is believed to help the country respond to currency valuation adjustments where rates and demand can be changed if the exchange rate does not adjust (Ng & Geetha, 2020).

## 2.3 Development of Malaysia’s Economy

Starting from the pre-colonial era, Malaysia's economic development has been significantly influenced by the globalisation. Initially, the economy was heavily reliant on primary commodities such as tin and rubber (Lee, 2021). Following independence in 1957, Malaysia's economy was primarily led by agricultural industry. However, by 1980s, the focus shifted towards industrialisation, particularly in gas and petroleum production. This transition marked a significant change in economic policies and contributed to the modernisation of the trade economy (Ibrahim, 2022). Over time, Malaysia harnessed trade, foreign capital and labour to transit into an economy driven by manufactured exports. The establishment of industrial hubs and export processing zones (EPZs) during this period which aimed to attract investment and create jobs had successfully reduced unemployment and poverty rates (Rasiah & Krishnan, 2020). As a result, according to statistics from World Bank national accounts data and OECD National Accounts data files, the manufacturing sector as a share of Malaysia’s GDP had risen from 10% in 1960 to 22% in 1980 which can be clearly seen in Figure 2.2. The GDP per capita of Malaysia had also increased more than threefold from $1,266.3 thousands in 1960 to $4,184.8 thousands in 1990 as depicted in Figure 2.3.

Figure 2.2 Manufacturing, value added (% of GDP) in Malaysia from 1960 to 1980

Figure 2.3 GDP per capita (constant 2015 US$) in Malaysia from 1960 to 1990

In the early 1990s, Malaysia experienced spectacularly high growth rates. In the Sixth Malaysia Plan, the government led by Malaysia’s fourth Prime Minister, Tun Dr Mahathir had introduced the New Development Plan (NDP) for ten years and launched Vision 2020 to aspire the nation to achieve a self-sufficient industrialised nation by the year of 2020. Vision 2020 covers all aspects of life including economic prosperity, social well-being, educational world-class, political stability and psychological balance (Edrak et al., 2022). During that great time, Malaysia had the potential to position itself to be an 'Asian Tiger.' However, the Asian Financial Crisis of 1997 - 1998 severely impacted the economy and it triggered the need for structural reforms (Abidin, 2020).

Stepping into the 21st century, Malaysia aimed to transform to a knowledge-based economy which focuses more on the innovation and human capital development (Kamyshnikova, 2023). Again, the global financial crisis of 2008 further tested the economy. At this time, it prompted the government to launch the Government Transformation Programme (GTP) and subsequently the Economic Transformation Programme (ETP), both aimed to develop a more sustainable future and improve Malaysians’ quality of life. There are six pillars or National Key Result Areas (NKRAs) in the GTP which are Reducing Crime, Fighting Corruption, Improving Student Outcomes, Raising Living Standards of Low-Income Households, Improving Rural Basic Infrastructure and Improving Urban Public Transport (PMO, 2011).

In recent years, advancements in information and communication technology (ICT) have led to the era of the Industrial Revolution 4.0 and the digital economy. Digital transformation has revolutionised the business processes, economic activities and societal interactions. People are now meeting their daily needs via smartphones where purchases of goods and services can just simply be done at the fingertips within seconds. The Covid-19 pandemic further accelerated the digital economy as face-to-face interactions were discouraged. In Malaysia, digitalisation and technological investment have now been prioritised as the key drivers of economic growth. (Puspaningtyas, 2022).

Malaysia's economic development has been a complex journey marked by significant transitions. It continues to face challenges such as economic diversification, technological advancements and managing the impacts of globalisation.

## 2.4 Macroeconomic Factors

Macroeconomic factors were believed to have large impacts on economy which might comprise of factors related to economic, social and political activities. In the previous literature, researchers have identified several fundamental and technical factors that cause exchange rate volatility. Each of them will be discussed in the next sub-sections.

### 2.4.1 Crude Oil Prices

Crude oil is making up about one-third of global energy use and considered the world's core energy source. Aside from fuel, its byproducts such as gasoline, plastics and even some medicines are widely used in our everyday lives and in modern economies (Shahnazi et al., 2023). In commodity-exporting economies, the price of crude oil is a significant factor influencing exchange rates. This was proven true for countries like Canada where crude oil constitutes a considerable share of exports. Canada's crude oil exports have grown substantially in which it had reached 14.1% of total exports in 2019 and made Canada the largest supplier of crude oil to the U.S. (Pirayesh Neghab et al., 2023). As crude oil prices increase, the value of the Canadian dollars tends to rise as well since more buyers seek to purchase Canadian oil. Conversely, when crude oil prices decline, the CAD tends to weaken (Davood Pirayesh et al., 2024). This was also observed in net oil-importing countries like Bangladesh. Rising oil prices often result in currency depreciation due to increased import costs which lead to a negative impact on the exchange rates (Nandi et al., 2024).

As crude oil is a major export and import commodity for many countries, changes in its price can significantly affect their trade balances. A rise in crude oil prices can lead to a trade surplus for oil-exporting countries, further strengthening their currencies. A decline in crude oil prices can weaken their currencies due to a decrease in export revenue and a potential trade deficit. On the flip side, elevating crude oil prices can negatively impact oil-importing countries by increasing their import costs (Moshiri & Kheirandish, 2024). Indirectly, this can contribute to inflation as the increased cost of oil affects transportation costs and the prices of goods and services. Eventually, it can lead to a depreciation of their currencies as they need more of their domestic currency to purchase the same amount of oil.

For oil-exporting countries like Saudi Arabia, Russia and Iraq, higher oil prices would induce the economic growth and the vice versa for oil-importing countries. Oil price shocks can cause long-lasting volatility in exchange rates, with negative shocks resulting in greater volatility than positive ones (Nandi et al., 2024).

### 2.4.2 Stock Index

A stock index measures the performance of an entire stock market or a group of related stocks, bonds or other securities which is often associated with specific stock exchanges or industries. It serves as an indicator of market fluctuations and trends to guide investors in decision-making (Lv et al., 2022). The relationship between stock index and currency exchange rates is complex and varies across different contexts. Stock indices impact national economies by affecting the value of securities and financial instruments which in turn influence currency rates (Horbanevych & Ivanyuta, 2021).

Studies indicate that fluctuations in exchange rates and stock market performance can influence each other, particularly in emerging economies. According to (Suri et al., 2024), a stable positive relationship exists between stock markets and exchange rates in the long run, as evidenced in G20 nations. The study by (Rao et al., 2024) which examined the correlation between the SENSEX 30 returns and INR/USD exchange rate movements from 2014 to 2024 did also achieved a strong positive correlation. A 1% increase in the exchange rate corresponded to a 0.90% increase in SENSEX 30 returns. It was also discovered by (Tabash et al., 2022) that stock market indexes significantly transmit economic shocks to currency valuation during both pre and post-financial recession periods.

### 2.4.3 Exports

Exports significantly influence currency exchange rates through various mechanisms, primarily by affecting the demand for a country's currency. Theoretically when exports increase, foreign buyers need to purchase the exporting country's currency to pay for goods which can to appreciation of that currency. Conversely, a decline in exports can result in depreciation. Exports contribute positively to a nation's foreign exchange reserves, which can stabilise the currency against external shocks (Rijoly et al., 2023). The study by (A Rebello, 2018) found a positive correlation between exports and each of the exchange rates. Regression analysis showed that a 1% increase in Indian exports led to a 0.016% increase in the euro, a 0.0164% increase in the US dollar, a 0.0155% increase in the British pound and a 0.0001% increase in the Japanese yen.

### 2.4.4 Imports

When a country imports more, it needs more foreign currency to pay for these goods, which can lead to a depreciation of its own currency. This is because the demand for foreign currency increases while the demand for the domestic currency decreases (Nurjanah & Mustika, 2021; Rijoly et al., 2023).

### 2.4.5 Industrial Production Index (IPI)

The Industrial Production Index (IPI) is an economic indicator that measures the real output of various industries within a country's economy. It is often used to gauge the level of industrial activity and production performance over time. The index is expressed as a percentage relative to a base year, with the base year's production level set to 100. The Industrial Production Index (IPI) can influence currency exchange rates through its impact on economic growth, inflation, and trade balances.

An increase in the IPI often signals economic growth, which can lead to higher inflation. For instance, in Turkey, a 1% increase in the IPI leads to a 1.04% increase in the Wholesale Price Index (WPI), indicating that industrial growth can drive inflation, which in turn affects exchange rates (Sanli, 2022). Similarly, in Malaysia, changes in the real effective exchange rate are linked to changes in economic growth, suggesting that industrial production influences currency value through economic performance (Cheng et al., 2024).

### 2.4.6 Consumer Price Index (CPI)

The Consumer Price Index measures the overall change in consumer prices based on a representative basket of goods and services over time. The CPI is a widely used measure of inflation, closely followed by policymakers, financial markets, businesses, and consumers.

One of the key concepts linking CPI to exchange rates is the theory of purchasing power parity (PPP). PPP suggests that in the long run, exchange rates should adjust to equalise the price of a basket of goods and services in different countries (Ali et al., 2022). If a country experiences a higher inflation rate as reflected in a rising CPI compared to another country, its currency is expected to depreciate against the currency of the country with lower inflation. This depreciation occurs because the higher inflation erodes the purchasing power of the currency in the high-inflation country (Davood Pirayesh et al., 2024; Hasan & Islam, 2023)

Changes in CPI can influence investor confidence and consequently, currency exchange rates. A rising CPI signals higher inflation and it can lead to decreased confidence in a country's economy and its currency. Investors may perceive a high-inflation environment as risky and may move their investments out of the country, putting downward pressure on the currency (Bawuah et al., 2023). Study by (Anuar & Abu Bakar, 2022) discovered a causality relationship between exchange rate and CPI for Vietnam, that is, the exchange rate is affected by CPI. Implementing inflation targeting can reduce inflation inertia, making monetary policy more effective in stabilising CPI and, consequently, exchange rates (Kolpashnikov, 2024).

The relationship between CPI and exchange rates is complex and influenced by various factors, including inflation, global demand shocks, and import ratios. While higher inflation can lead to currency depreciation, exchange rate changes can also significantly impact CPI, especially in economies with high import ratios. Implementing policies like inflation targeting can help stabilise these interactions.

### 2.4.7 Money Supply

The money supply refers to the total amount of money available in an economy at a specific time, encompassing various forms of currency and liquid assets. It is a critical indicator of economic health, influencing inflation, interest rates, and overall economic growth. The money supply can be categorised into different measures, primarily M1 and M2. M1 includes currency held by the public and demand deposits which represent the most liquid forms of money (Bujung et al., 2024). M2 provides a broader view of money supply by including M1 and quasi-money that are less liquid such as savings accounts, time deposits and certain securities (Alif & Kurniawan, 2024).

 The money supply significantly influences currency exchange rates both short-term and long-term. In the short run, especially under quantitative easing policies, an increase in the monetary base can lead to currency depreciation. This effect is more pronounced than that of the money stock which has a limited role in short-term exchange rate dynamics (Funashima, 2020). In some regions, such as Indonesia, the short-term effects of money supply changes can lead to exchange rate overshooting, where a 1% change in money supply results in more than a 1% change in exchange rates (Syamad & Handoyo, 2023). This phenomenon was also observed in Malaysia and Thailand within the ASEAN-5 countries (Maghfiroh & Jayadi, 2024).

Over the long term, an increase in the money supply often results in currency depreciation. This is because a larger money supply can lead to higher inflation, reducing the currency's purchasing power and thus its value relative to other currencies (Sangadji et al., 2024). However, the money supply can positively impact economic growth, which may stabilise or strengthen the currency in the long run (Daoud & Al-Ezzi, 2023).

Overall, the money supply is a critical determinant of exchange rate fluctuations, with its effects varying between short and long-term scenarios. In the short term, changes in the monetary base can lead to rapid currency depreciation, while in the long term, the monetary base remains a stable predictor of exchange rate trends. Inflation and interest rates further modulate these effects which highlights the complex interplay between monetary policy and exchange rate dynamics.

### 2.4.8 International Reserves

International reserves play a significant role in influencing currency exchange rates. They are often used to intervene in foreign exchange markets and act as a buffer against economic shocks. International reserves are often used by monetary authorities to manipulate their currency stability. For instance, countries like China and Hong Kong accumulate reserves to counter currency appreciation, reflecting a mercantilist approach aimed at maintaining export competitiveness (Jiang & Yoon, 2024). In contrast, Korea and Japan exhibit a precautionary motive, using reserves to stabilise their currencies during fluctuations (Lee & Yoon, 2020). Higher levels of international reserves can lead to currency appreciation and reduce exchange rate volatility in the long run. However, short-term adjustments in exchange rate volatility occur more rapidly than changes in the exchange rate level itself (Deka et al., 2022).

Reserves can cushion the impact of terms-of-trade shocks on the real exchange rate, particularly in developing countries and those exporting natural resources. This buffering effect is more pronounced in developing countries compared to industrial ones.

International reserves significantly influence currency exchange rates by providing a tool for monetary authorities to stabilize currencies, buffer against economic shocks, and manage exchange rate volatility. The impact varies across countries and is influenced by factors such as economic development level, exchange rate regime, and the specific economic context. International reserves significantly influence currency exchange rates by affecting both their level and volatility. They can lead to currency appreciation or depreciation and help stabilize exchange rates, reducing volatility. Additionally, reserves play a crucial role in preventing currency crises, especially in flexible exchange rate regimes. These dynamics highlight the importance of strategic reserve management in maintaining economic stability.

### 2.4.9 U.S. Federal Funds Effective Rate

The Federal Funds Effective Rate (FFER) is a crucial interest rate that reflects the cost of banks borrowing funds from each other overnight and is a significant indicator of the financial system's health and stability in the United States (H et al., 2023). Fed rate hikes reduce inflation and pressure domestic economies, but also pressure foreign countries to use expansionary fiscal policy to stimulate consumption and investment (Ni, 2023). The studies from (Chen, 2023; Kang, 2023) suggested that increases in the U.S. federal funds effective rate generally lead to an appreciation of the U.S. dollar and a depreciation of other currencies such as the Chinese Yuan and Indonesian Rupiah

The U.S. federal funds effective rate significantly influences currency exchange rates against other countries, primarily through its impact on capital flows and investor sentiment. Higher interest rates offer better returns on investments denominated in dollars. As a result, it attracts foreign capital and increases demand for US dollar which typically lead to a stronger U.S. dollar. Conversely, this can lead to capital outflows from other countries, potentially weakening their currencies (Wu, 2024). The federal fund rate, the primary instrument of U.S. monetary policy, influences currency exchange rates by increasing or decreasing the money in circulation, which can affect the U.S. dollar's position as an international reserve currency and trade share (Davydov, 2020).

The anticipation of rate hikes can influence investor behaviour, leading to fluctuations in exchange rates even before the actual changes occur. This sentiment-driven movement can cause the dollar to appreciate as investors adjust their portfolios in anticipation of higher returns (Mohammed et al., 2023).

Overall, the federal funds effective rate is a critical tool in U.S. monetary policy that influences currency exchange rates by affecting capital flows, investor sentiment, and the relative attractiveness of dollar-denominated assets. This often results in the appreciation of the U.S. dollar when rates are increased, impacting global financial markets and other currencies.

### 2.4.10 Overnight Policy Rate (OPR)

According to (Bank Negara, 2024), overnight policy rate (OPR) is BNM’s sole indicator used to signal the stance of monetary policy. It is BNM’s policy interest rate that can affect banks’ lending and financing rates as well as deposit rates which will be decided and revised bi-monthly. These rates tell you how much the cost of loan is, or how much the returns are for deposits. They are applicable for both conventional and Islamic finance products.

The overnight policy rate, a key tool in monetary policy, can influence currency exchange rates, primarily through its impact on interest rates and investor behaviour. An increase in the overnight policy rate generally leads to a short-term appreciation of the national currency, as higher interest rates attract foreign capital, increasing demand for the currency (Hashchyshyn et al., 2020). **Higher interest rates attract foreign investment, increasing demand for the domestic currency and leading to appreciation.** This happens because investors seek higher returns on their investments. When a country raises its overnight policy rate, it makes its currency more attractive to foreign investors who want to take advantage of the higher interest rates. This increased demand for the domestic currency pushes up its value relative to other currencies.

**Lower interest rates can lead to depreciation of the domestic currency.** When a central bank lowers the overnight policy rate, it can make domestic investments less attractive compared to those in other countries. This can lead to capital outflows and a decrease in demand for the domestic currency, resulting in depreciation. M**oreover, when a government uses monetary policies such as cutting interest rates to stimulate the economy, this will increase the income and demand for the imported goods of a country, appreciating the currency, which will ultimately negatively affect the competitiveness of exported goods (Shen et al., 2021).**

**The relationship between interest rates and exchange rates is complex and can be influenced by other factors, including inflation, government intervention, and market sentiment.** While higher interest rates generally lead to currency appreciation, this is not always the case. Other factors, such as a country's inflation rate, political stability, and economic outlook, can also impact exchange rate movements.

Policymakers in Malaysia recognize the importance of understanding the impact of monetary variables, including interest rates, on the exchange rate, especially given the country's export-dependent economy (Ng & Geetha, 2020).

**Nepal:** Analysis of Nepal's exchange rate regime reveals that interest rates play a significant role in determining the exchange rate in the long run. However, the study also highlights the significant influence of the Indian Rupee (INR), to which the Nepalese Rupee (NPR) is pegged (Dahal & Raju, 2022).

In summary, while changes in the overnight policy rate can lead to short-term currency appreciation due to increased foreign investment, the long-term effects on exchange rates are generally weak. The effectiveness of these changes can be influenced by the central bank's communication strategy and external economic factors.

## 2.5 Modelling of Macroeconomic Variables and Currency Exchange Rates

A few research had been conducted in the past to study on how the macroeconomic factors such as unemployment rates, economic indicators by industrial sectors, gross domestic product (GDP), etc can be related to the currency exchange rate.

One of the studies is presented by (Antwi et al., 2020) focusing on applying a multivariate modelling technique of the Vector Autoregression (VAR) to assess the impact of macroeconomic variables such as broad money supply (M2), lending rate, inflation and real GDP on the exchange rate in Ghana. The empirical results depicted that real GDP, inflation, and money supply significantly influence the exchange rate in Ghana while historical values of lending rate are insignificant to make the predictions. Even though the outcome seems reasonable, yet the research utilises only limited set of macroeconomic variables in its modelling. The model has limitations as it is lack of any external variables, for instance, other exogenous factors like Foreign Direct Investment (FDI), unproductive government spending, and balance of payments for a more comprehensive analysis.

(Kim & Park, 2020) utilised a factor-augmented predictive regression technique to examine the correlation between macroeconomic variables and nominal exchange rates. They used principal component analysis (PCA) to estimate eight components from a large panel of US macroeconomic time series data in order to forecast both the short-term and long-term variations in nominal exchange rates. The study's findings demonstrated that variables obtained from US macroeconomic data have a strong ability to predict changes in the bilateral US exchange rate and can significantly increase the Purchasing Power Parity's (PPP) ability to predict changes through both in-sample and out-of-sample analyses. Nevertheless, the data ingested by the model was limited only up to year 2011, and the landscape may have changed since then.

(Pozzi & Sadaba, 2020) on the other hand focused on assessing if there are scapegoats in determining the currency exchange rate. Bayesian Gibbs sampling approach was implemented to evaluate if the macroeconomic factors, i.e., real GDP growth, the inflation rate, the long-run nominal interest rate and the current account to GDP ratio of eight selected countries contribute significantly to their currency exchange rate versus US dollar over the past years from 2002 Quarter 1 to 2014 Quarter 4. The paper asserted that nominal exchange rates are not isolated from the macroeconomic variables and their relationship fluctuates based on the time horizon and the nature of the factors involved instead. Despite a novel and rigorous testing method for the scapegoat model was introduced, the model may come to its limitation as the data used was only up to the year 2014 and this may result in not up-to-date analysis.

Another paper discussed by (Boyoukliev et al., 2022) employed ART Ensembles and Bagging method to build predictive models to forecast the EUR/USD exchange rate based on key macroeconomic indicators such as inflation, unemployment, GDP, and interest rates. The outcome of the paper concluded that achievement of accurate forecast of the future values of the foreign exchange rate cannot be made without considering the other key macroeconomic indicators. Although the models proposed can explain up to 98.8% of the data variation and have only MAPE of 1%, the paper only uses four macroeconomic indicators which may not account for other factors that influence the exchange rate, such as government debt.

(Dahal & Raju, 2022) presented the Multiple regression using OLS, Engle-Granger cointegration, and Standard Vector Autoregressive models with impulse response analysis to analyse the multivariate relationship between the USD-NPR exchange rate and major macroeconomic variables as well as the long-run relationship between Nepal and India’s exchange rate. The findings inferred that the exchange rate of India which is Nepal's main trading partner as well as other macroeconomic factors not limited to inflation, interest rates, trade balances, foreign reserves, and state debt influenced Nepal's exchange rate. While the research studied on the inter-dynamic relationship among major macroeconomic variables and apply impulse analysis to generate some policy recommendations, it was limited to make comparisons only between the currency exchange rates of India and Nepal against USD.

(Thevakumar & Jayathilaka, 2022) had proposed a combination of ARIMA and GARCH models to examine the short-run and long-run relationships between the macroeconomic variables and the exchange rate volatility of the USD/LKR currency pair. The findings of the work indicated that there is no long-run relationship between any of the macroeconomic variables and the exchange rate, however there is a short-run relationship between exchange rate lags, inflation, and merchandising trade balance. Even though the models were proved statistically reliable, however solely USD/LKR currency pair was focused, which may not reflect the exchange rate movements of other major currencies that Sri Lanka trades with, such as the Euro, the British Pound and the Indian Rupee.

Article presented by (Biswas et al., 2023) studied on developing various types of models, such as MLP, LSTM, GRU, ANN, etc. to predict and forecast the USD/BDT exchange rate using various time-sensitive macroeconomic features of both countries, such as GDP, import/export, government revenue, etc. After comparisons of all models, Time Distributed MLP provided the best results with an RMSE of 0.1984. The article deduced that the inclusion of macroeconomic factors improves the accuracy and reliability of the exchange rate forecasts. Despite usage of diverse models consolidated the research, it lacked explanations on how the models linked together the macroeconomic factors and exchange rates since deep learning models are often complex and hard to interpret.

(Hillebrand et al., 2023) conducted research in investigating how US macroeconomic factors affect US dollar exchange versus 14 currencies between May 1990 and September 2021 using a two-step maximum likelihood estimator. The paper extracts factors from the dataset using principal component analysis, and then estimates time-varying factor loadings using a Kalman filter approach. The paper concluded that exchange rates are related to macroeconomic factors but that the relationship is unstable and nonlinear due to some external factors. Even though it was discovered that the time-varying loadings model performed in this paper exhibited significantly better forecast accuracy, it may not capture the full diversity and complexity of the global currency market.

To assess the long-term and short-term correlations between the real exchange rate and a variety of macroeconomic variables, including the money supply, trade openness, worker remittances, and productivity in Pakistan, (Munir & Iftikhar, 2023) took Autoregressive distributed lag (ARDL) approach. The article concluded that money supply, trade openness, and workers’ remittances have significant short-run effects on the real exchange rate, while productivity does not. Over an extended period, the real exchange rate was positively connected with worker remittances and productivity, but adversely correlated with trade openness and money supply. Although the model's results were noteworthy, there was a restriction in that other macroeconomic factors, including inflation and interest rates, which could have an impact on the actual exchange rate, were not considered.

(Pasionek, 2023) had assessed the impact of US macroeconomic data on the short-term volatility of the USD/PLN exchange rate by applying Linear regression model with GARCH process for the random parameter. The studies implied that the exchange rate volatility was higher after the publication of the macroeconomic data, especially the data on inflation, manufacturing PMI and retail sales, during the COVID pandemic and the war in Ukraine. Even though the research was quite up-to-date, the author did not compare the results with other currency pairs or other time periods to test the robustness of the findings.

Table 2.1 summarises the key studies related by highlighting the factors considered, methodologies used, findings and limitations.

Table 2.1 Previous Works

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Reference** | **Factors** | **Techniques** | **Evaluation** | **Limitation** |
| Antwi et al. (2020) | Broad money supply (M2), lending rate, inflation, real GDP. | **Vector Autoregression (VAR)** model. Descriptive analysis (mean, median, standard deviation, skewness, kurtosis, Jacque-Bera test). | Not explicitly stated in provided excerpts but descriptive statistics and VAR model results are presented. | **VAR technique limitations**. Data limitations not explicitly discussed but limitations are noted, implying potential data issues. |
| Bawuah et al. (2023) | Terms of trade, GDP, real interest rate, fiscal deficit, inflation, nominal exchange rate, real effective exchange rate. **Estimated biases** from currency redenomination. | Structural break analysis (Bai and Perron), bias estimation, **ANCOVA**. | Statistical significance of bias estimates and macroeconomic fundamentals. | Not explicitly stated but implied due to potential limitations in data sets and model choice. |
| Biswas (2023) | Not specified in the excerpt provided. | Not specified in the excerpt provided. | Not specified in the excerpt provided. | Data cannot be shared publicly because of copyright issues. Code cannot be shared publicly due to restrictions from authors. |
| Boyoukliev et al. (2022) | Not specified in the excerpt provided. | CART-Ensembles and Bagging. | Not specified in the excerpt provided. | Not specified in the excerpt provided. |
| Davood et al. (2023) | CAD/USD exchange rate, WTI oil price, gold price, TSX composite index, S&P 500 index, 3-month LIBOR. | Machine learning (LGBM, ETR, XGB, RIDGE, LASSO, GRU), SHAP values, ablation study. | Mean Squared Error (MSE). | Not explicitly stated in provided excerpts but potential issues with data selection and model choices are implied by methodological descriptions. |
| Doojav et al. (2024) | Not specified in the excerpt provided. | SBVAR modeling. | Not specified in the excerpt provided. | Not specified in the excerpt provided. |
| Edwards et al. (2021) | Not specified in the excerpt provided. | Instrumental variables, error correction equations, structural VARs. | Short-run and long-run exchange rate pass-through (ERPT) coefficients. | Potential limitations in data and model specification are implied but not explicitly stated. |
| Farhan et al. (2022) | Real effective exchange rate volatility, GDP deflator, FDI, total exports (% of GDP), inflation rate, lending interest rate. | **GARCH** model. | Not specified in the excerpt provided. | Not explicitly stated in provided excerpts. |
| Ghauri et al. (2024) | Debt, inflation, terms of trade, market interest rate, political stability, current account balance. | ARDL model, ADF test, PPT test. | Not specified in the excerpt provided. | Some variables integrated at level, others stationary at first difference. |
| Hasan et al. (2023). | Inflation rate, interest rate, GDP growth rate, current account balance, foreign direct investment (FDI), foreign exchange reserve, trade deficit, remittances. | **Multiple linear regression**. Descriptive statistics, correlation matrix. | Adjusted R-squared, F-statistics. | Research limitations and suggestions for future research not detailed in the provided excerpts. Data restrictions are mentioned. |
| Hussain et al. (2019) | Exchange rate, GDP, (NARDL) | NARDL, CUSUM and CUSUM of squares tests, VEC Granger causality Wald tests. | Not specified in the excerpt provided. | Not specified in the excerpt provided but limitations are implied. |
| Khan et al. (2019) | GDP, exchange rate, inflation, interest rate, trade openness. | **ARDL** model. | Not specified in the excerpt provided. | Not specified in the excerpt provided. |
| Kim et al. (2020) | Exchange rates, estimated US macroeconomic factors. | Factor-augmented predictive regressions. | Adjusted R-squared. | Not specified in the excerpt provided. |
| Kim et al. (2021) | Not specified in the excerpt provided. | IRF approach, structural VAR coefficient approach. | ERPT parameter estimates. | Not specified in the excerpt provided but limitations are implied. |
| Madan et al. (2023) | Exchange rate volatility, international trade. | **Bibliometric analysis**, performance analysis, science mapping (co-citation, keyword co-occurrence, bibliographic coupling). | Publication and citation trends, identification of major contributors, key themes. | Limited by the scope of the Scopus database. |
| Mei-Li et al. (2021) | Exchange rates (USD/AUD, USD/GBP, CAD/USD, RMB/USD, USD/EUR, JPY/USD, NTD/USD), economic fundamentals. | FSPSOSVR (hybrid model combining particle swarm optimization, support vector regression, and random forest), VAR/VECM, SVR, RFR, AdaBoost. | Mean Absolute Percentage Error (MAPE), Root Mean Squared Error (RMSE). | Different sample periods for exchange rates due to data availability. |
| Munir et al. (2023) | Real effective exchange rate, money supply, productivity, trade openness, remittances, terms of trade, government consumption expenditure, FDI. | **ARDL** approach, ADF and PP unit root tests. | Not explicitly detailed in the provided excerpts but ARDL model results are mentioned. | Not explicitly stated but limitations are implied by the model and data choice. |
| Ng et al. (2020) | Exchange rate, inflation rate, interest rate, foreign exchange reserve. | E-Views 11 (econometric analysis). | Not explicitly stated in provided excerpts but results from E-Views are presented. | Inverse relationship found between variables differs from prior research. Sample size limitations, data source limitation are noted. |
| Nor et al. (2020) | Unregulated exchange rate (SOS/USD), domestic price, imports, money supply, hot money. | Not specified in the excerpt provided. | Not specified in the excerpt provided. | Not specified in the excerpt provided but data limitations are implied. |
| Ohaegbulem et al. (2024) | NGN exchange rate, external reserve, inflation rate, GDP growth, public debt, unemployment rate. | Multiple regression analysis, correlation analysis. | Adjusted R-squared, standard error, ANOVA, F-test, t-test. | Not explicitly stated in provided excerpts but potential limitations are implied. |
| Pasionek et al. (2023) | Not specified in the excerpt provided. | Not specified in the excerpt provided. | Not specified in the excerpt provided. | Not specified in the excerpt provided but limitations are implied. |
| Saidia et al. (2019) | GDP, inflation, interest rate, FDI, money supply, trade balance, terms of trade. | Not specified in the excerpt provided. | Not specified in the excerpt provided. | Not specified in the excerpt provided but limitations are implied. |
| Savina et al. (2018) | Real export, real import, exchange rate volatility, real exchange rate, GDP, foreign economic activity. | Simple linear model, semi-log linear model. | Not specified in the excerpt provided. | Not specified in the excerpt provided but limitations are implied. |
| Shukri et al. (2021) | Nominal exchange rates, domestic inflation rate, domestic real interest rate, domestic national income growth rate. | ARDL modelling, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. | Not explicitly stated in provided excerpts but ARDL model results are presented. | Not explicitly stated in provided excerpts but limitations are implied. |
| Suhana et al. (2021) | Foreign exchange rate, gross domestic product, unemployment rate, inflation rate. | Multiple regression analysis, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, correlation test. | R-squared, adjusted R-squared, F-test, t-test, Durbin-Watson statistic. | Not explicitly stated in provided excerpts. |
| Thevakumar et al. (2022) | Exchange rate volatility, inflation, interest rate, remittances, gross official reserves, money supply growth, merchandise trade balance. | ARDL model, bound testing, VAR, error correction, Johansen cointegration. | Not explicitly stated in provided excerpts but ARDL model results are presented. | Not explicitly stated in provided excerpts but limitations are implied. |
| Uz-akdogan et al. (2023) | Real exchange rate (RER), terms of trade (TOT), relative price of non-traded to traded goods (TNT), relative productivity (RP), stock of net foreign assets (NFA). | Panel smooth transition regression (PSTR), Johansen cointegration test, multivariate residual diagnostics. | Not explicitly stated in provided excerpts but PSTR model results are presented. | Potential limitations in data and model specification are implied but not explicitly stated. |

## 2.6 Summary

While existing research has examined in how the macroeconomic variables can potentially influence the currency exchange rates in short and long run, a notable gap remains. Many recent studies continue to use outdated data in perform their modeling and primarily concentrate on the authors’ own countries other than Malaysia. This gap emphasises the need for a updated study that not only considers the latest data but also the unique economic dynamics of Malaysia. Addressing this research gap is crucial to understand the factors influencing currency exchange rates of Malaysia and for the development of robust forecasting models

# CHAPTER 3: RESEARCH METHODOLOGY

## 3.1 Introduction

In this chapter, the methodology for modelling the macroeconomic factors with currency exchange rates fluctuations is explained and illustrated using flowchart. The data pre-processing steps and the models adopted for training are also discussed in this chapter. Additionally, the methods and evaluation metrics are explained in detail.

## 3.2 Variables and Data Sources

There are a total of 18 variables utilised in this study to map the relationship between the macroeconomic factors and USD/MYR currency exchange rates. All the data is secondary data obtained from a range of reliable source, namely Yahoo Finance at [https://finance.yahoo.com/,](https://finance.yahoo.com) Malaysia’s official open data portal at [https://data.gov.my/](https://data.gov.my), Central Bank of Malaysia (BNM) at <https://www.bnm.gov.my/>, United States Census Bureau at <https://www.census.gov/> and Federal Reserve Economic Data (FRED) at [https://fred.stlouisfed.org/](https://fred.stlouisfed.org). The data obtained is of monthly time series data which spans the period from January 2015 until July 2024. Table 3.1 below provides the summary and short description of each of the variable.

Table 3.1: Data Variables Descriptions

| **No.** | **Variables** | **Abbreviations** | **Unit** | **Descriptions** | **Sources** |
| --- | --- | --- | --- | --- | --- |
| 1 | USD/MYR Currency Exchange Rates | ER | USD/RM | Price of Ringgit Malaysia for every 1 United States Dollar | Yahoo Finance |
| 2 | Crude Oil Prices | CRUDE | USD/barrel | Price of every barrel of crude oil from Brent, Dubai and West Texas Intermediate (WTI) | Yahoo Finance |
| 3 | Dow Jones Industrial Average | DJ | USD | Price-weighted index that tracks 30 large, publicly owned U.S. companies trading on NYSE and NASDAQ | Yahoo Finance |

Table 3.1 continued: Data Variables Descriptions

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
| 4 | Kuala Lumpur Composite Index | KLCI | RM | Market-valued-weighted stock market index made up of the thirty largest companies on the Bursa Malaysia | Yahoo Finance |
| 5 | Malaysia Exports | EXPMY | RM (million) | The value of goods and services exported from Malaysia | Malaysia Open Data |
| 6 | Malaysia Imports | IMPMY | RM (million) | The value of goods and services imported into Malaysia | Malaysia Open Data |
| 7 | Malaysia Industrial Production Index | IPIMY | Index | Measurement of production of industrial commodities in the mining, manufacturing and electricity sectors in real terms | Malaysia Open Data |
| 8 | Malaysia Consumer Price Index | CPIMY | Index | Measurement of the cost of purchasing a constant, representative 'basket' of goods and services | Malaysia Open Data |
| 9 | Malaysia Money Supply M1 | M1MY | RM (billion) | Currency in Circulation + Demand Deposits | Malaysia Open Data |
| 10 | Malaysia Money Supply M2 | M2MY | RM (billion) | M1 + Narrow Quasi-Money | Malaysia Open Data |
| 11 | Malaysia Overnight Policy Rates | OPR | Percentages | BNM’s policy interest rate that influences, among others, banks’ lending and financing rates, as well as deposit rates. | BNM |
| 12 | U.S. Exports | EXPUS | USD (million) | The value of goods and services exported from the United States | U.S. Census Bureau |
| 13 | U.S. Imports | IMPUS | USD (million) | The value of goods and services imported into the United States | U.S. Census Bureau |
| 14 | U.S. Industrial Production Index | IPIUS | Index | Measurement of the real output of industrial commodities in the mining, manufacturing, and electricity sectors | FRED |
| 15 | U.S. Consumer Price Index | CPIUS | Index | Measurement of the cost of purchasing a constant, representative 'basket' of goods and services | FRED |
| 16 | U.S. Money Supply M1 | M1US | USD (billion) | most liquid forms of money, such as cash, checking deposits, and other highly liquid accounts. | FRED |
| 17 | U.S. Money Supply M2 | M2US | USD (billion) | M1 plus savings accounts, small time deposits, and retail money market funds | FRED |
| 18 | U.S. Federal Fund Effective Rates | FFER | Percentages | Interest rate at which depository institutions (banks and credit unions) lend reserve balances to each other overnight. | FRED |

Based on Table 3.1, while Variable 1, i.e., USD/MYR currency exchange rates will be selected as our dependent variable, macroeconomic factors from Variable 2 until 18 namely crude oil prices, stock indexes, exports, imports, consumer price indexes, industrial production indexes, money supplies, overnight policy rates and federal fund effective rates are acting as independent variables in this study. The stock market indexes of Malaysia and the United States, namely the FBMKLCI and the DJ, are incorporated as new variables in this study. FBMKLCI is made up of largest 30 companies from various industries on Bursa Malaysia’s Main Board while DJ tracks the performance of 30 large, publicly owned companies listed on stock exchanges in the United States. Hence, both stock indexes can serve as indicators of economic conditions and reflect investor confidence in their respective countries. In the meanwhile, the other macroeconomic variables are selected based on the previous research (Biswas et al., 2023; Dahal & Raju, 2022; Hasan & Islam, 2023; Nor et al., 2020; Pasionek, 2023).

## 3.3 Tools Used

This research was conducted using Visual Studio Code (VS Code) as the main development platform which is an integrated development environment (IDE) known for its versatility and extensive support for Python. VS Code's debugging tools, syntax highlighting, and extensive library of extensions offer significant flexibility for managing the different stages of data exploration, modelling, and result interpretation. The IDE also supports a streamlined workflow for organizing complex projects, allowing for seamless transitions between data manipulation, modelling, and visualization.

The primary programming language for this research is **Python**, chosen for its extensive ecosystem of libraries that facilitate advanced data science and econometric analysis. Key libraries such as **Pandas** and **NumPy** were employed for data preprocessing, transformation, and exploratory analysis, ensuring data readiness for subsequent modeling stages. Predictive modeling was implemented using **scikit-learn** and **XGBoost**, both of which offer optimized machine learning algorithms aligned with the project’s focus on performance and interpretability. The **statsmodels** library was utilized for econometric modeling, specifically for the implementation of Autoregressive Distributed Lag (ARDL) models, which are well-suited to investigating dynamic relationships within time series data. Collectively, these libraries provide a comprehensive analytical toolkit, supporting in-depth examination of the interactions between macroeconomic variables and currency exchange rates through different models.

To facilitate an interactive and visual presentation of the results, **Streamlit** was used to create intuitive dashboards. This open-source Python framework allowed for the development of a dynamic, web-based interface where key findings, model predictions, and data visualizations could be presented interactively. Streamlit’s ease of use and compatibility with Python made it an ideal choice for sharing insights in real-time and enhancing the research’s accessibility for both technical and non-technical audiences.

The complete code repository for this research is available on GitHub: <https://github.com/ooihiangee/Econometric-Modelling-of-USD-MYR>.

## 3.4 Research Design

A diagram of a software development process

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Figure Research Design Flow

Figure 3.1 above illustrates the flow of analysis of this study. The process of analysis starts by testing the unit root or stationarity of each time series variable. If unit root is found to be present or the data is not stationary, data transformation is applied until stationary data is obtained. Once all the time series variables are stationary, the lag length is selected based on AIC and BIC that are having the smallest values before entering the cointegration tests. If all the time series variables are having the same order of integration, Johansen cointegration rank test is applied, whereas, if there is mixture of integrating order, ARDL bound test is employed. Cointegration tests are used to determine the presence of the long-run relationship between the variables of interest. For Johansen cointegration rank test, VECM approach is followed if and only if cointegrating relationship exists. Contrarily, if there exist no cointegrating relationship between the variables, VAR approach is employed when the variables are stationary at level form, or first difference VAR approach is applied when the variables are stationary at first order. Diagnostic tests of heteroscedasticity, normality and serial correlation of the error terms from VECM or ARDL model is then carried out to test the robustness of the model formed whether it fulfils the assumptions, where VAR approach is exempted from the tests. After diagnostic tests are passed, it can be continued with Granger causality tests to identify the directions of short-run causal relationships between the variables. Therefore, the objectives of the study are achieved with the analysis as mentioned above.

## 3.5 Exploratory Data Analysis

Exploratory data analysis (EDA) serves as an important step in understanding the underlying structure and characteristics of the dataset used for detecting suicidal ideation. This phase involves summarising the main features of the data, often with visual methods, to identify patterns and potential relationships.

## 3.6 Data Preprocessing

Once the data is gathered, data quality assurance (DQA) is crucial to avoid producing misleading, inaccurate and biased insights. DQA involves tasks such as handling outliers, removing duplicates and addressing missing values either by imputations or removals.

Since data from different sources with different time spans were integrated, the time spans to be studied in this research was trimmed to be from January 2015 to June 2024 depending on the available data. In addition, to standardise all data in monthly format, daily USD/MYR currency exchange rates for each month will be aggregated to compute the average. Next, different datasets shall be combined into a unified and cohesive structure. This involves aligning common data fields and handling discrepancies in naming conventions to ease us in feeding the data into the models more conveniently.

Furthermore, the data was then log-transformed to stabilise the variance of a time series and address issues of skewness and heteroscedasticity as what similar previous studies by (Dahal & Raju, 2022; Munir & Iftikhar, 2023; Ohaegbulem & Iheaka, 2024) had suggested. With log transformation, it can lead to a better fit of the econometric model. Introduction of lagging variables to capture temporal dynamics and trends was carried out to enhance model performance for currency exchange rates forecasting.

Prior modelling, data will be split into 7:3 to train the models and evaluate the performance of the models in out-of-sample predictions. The training data will span period from Jan 2015 to Sep 2021 while the testing data will cover period from Oct 2021 to Jul 2024.

## 3.6 Unit Root and Stationary Tests

Unit root test is used to assess whether a time series data possess stationarity. It is an important step in most studies (Ali et al., 2022; Bawuah et al., 2023; Boyoukliev et al., 2022; Ghauri et al., 2024; Munir & Iftikhar, 2023) since estimators that are not stationary may yield false and inaccurate results. The data is considered as non-stationary and having unit root if the mean and variance are not constant. Before proceeding to any analysis related to time series data, the first step is to test for the presence of unit root and stationarity. Hence, Augmented Dickey-Fuller (ADF) test developed by David Dickey and Wayne Fuller in 1979 was conducted. To examine the robustness of ADF test result, alternative methods, Phillips-Perron (PP) test proposed by Peter Phillips and Pierre Perron in 1988 as well as Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test proposed by Denis Kwiatkowski, Peter Phillips, Peter Schmidt, and Yongcheol Shin in 1992 were used. (Afriyie et al., 2020) pointed that KPSS test as the most robust performer among the three due to its consistent accuracy across various sample size and model specifications.

The test estimation formulae by three tests are stated in Equation (3.1), (3.2) and (3.3).

ADF test:

(3.1)

PP test:

𝑦𝑡 = 𝛽0 + 𝛽1𝑡 + 𝛿2𝑦𝑡−1 + (3.2)

KPSS test:

𝑦𝑡 = 𝛽t + (3.3)

where,

∆ = first difference operation,

𝑦 = all time series variables including dependent and independent variables, t = time trend variable, m = number of lags, 𝛼 = coefficient on time trend for ADF test, 𝛿1 = parameter on time trend for ADF test, 𝛽 = coefficient on time trend for PP test, 𝛿2 = parameter on time trend for PP test, = number of observations, = random walk, 𝛽t = deterministic trend, = error term.

.

Three tests are interested in the estimate of the parameter and the p-values for the hypothesis test to determine the presence of unit root for each time series. The hypothesis tests are stated as follow:

ADF test: 𝐻0: Presence of unit root which indicates non-stationary

𝐻𝐴: Absence of unit root which indicates stationary

PP test: 𝐻0: Presence of unit root which indicates non-stationary

𝐻𝐴: Absence of unit root which indicates stationary

KPSS test: 𝐻0: Absence of unit root which indicates stationary

𝐻𝐴: Presence of unit root which indicates non-stationary

For both the ADF and PP tests, if the p-value is less than the chosen significance level (), such as 0.05, the null hypothesis is rejected at the 5% significance level. This implies there is only a 5% risk of incorrectly concluding that the time series is stationary when it is not. In this case, the series is deemed stationary and integrated of order zero, I(0). Conversely, if the p-value is greater than the significance level, the null hypothesis is not rejected and it indicates that the time series is non-stationary. To achieve stationarity in such cases, differencing the series is necessary.

For the KPSS test, the logic is reversed. If the p-value is greater than the chosen significance level, the null hypothesis is not rejected and it indicates the series is stationary. However, if the p-value is less than the significance level, the null hypothesis is rejected and it implies that the time series is non-stationary.

## 3.7 Granger’s Causality Test

**Granger’s** C**ausality** Test can be used to identify the relationship between variables prior to model building. This is important because if there is no relationship between variables, they can be excluded and modeled separately. Conversely, if a relationship exists, the variables must be considered in the modeling phase.

The test in mathematics yields a p-value for the variables. If the p-value exceeds 0.05, the null hypothesis must be accepted. Conversely, if the p-value is less than 0.05, the null hypothesis must be rejected.

## 3.8 Models

### 3.8.1 Autoregressive Distributed Lag (ARDL)

The Autoregressive Distributed Lag (ARDL) model is another econometric technique used to analyse the relationship between variables in time series data. It can deal with the condition when the variables have different orders of integration i.e., some variables are stationary while others are non-stationary. The ARDL model is particularly useful for estimating both short-run and long-run relationships between variables and is widely used in the context of cointegration analysis.

An ARDL model captures the dynamics between a dependent variable and one or more independent variables by including lags of both the dependent and independent variables. It is flexible in accommodating variables that are integrated of different orders i.e., I(0) and I(1)). This feature makes it more robust compared to traditional cointegration techniques like the Engle-Granger method.

The long-run model can be written as follows.

In the equation above,, , , and are USD/MYR exchange rates, domestic CPI, domestic IPI, domestic PPI, domestic M1 money supply, domestic M2 money supply and domestic national reserves respectively. An asterisk (\*) denotes the corresponding foreign variables for United State of America. , and denote time, constant and disturbances term, respectively. Any disequilibrium in the model is reflected in the term, which includes both short term influences and random disturbances; whilstare vectors of coefficients.

The general time series regression model extends the ADL model such that multiple regressors and their lags are included. It uses pp lags of the dependent variable and qlql lags of ll additional predictors where l=1,…,kl=1,…,k:

Yt=β0+β1Yt−1+β2Yt−2+⋯+βpYt−p+δ11X1,t−1+δ12X1,t−2+⋯+δ1qX1,t−q+…+δk1Xk,t−1+δk2Xk,t−2+⋯+δkqXk,t−q+utYt=β0+β1Yt−1+β2Yt−2+⋯+βpYt−p+δ11X1,t−1+δ12X1,t−2+⋯+δ1qX1,t−q+…+δk1Xk,t−1+δk2Xk,t−2+⋯+δkqXk,t−q+ut

For estimation we make the following assumptions: 1. The error term utut has conditional mean zero given all regressors and their lags:

E(ut|Yt−1,Yt−2,…,X1,t−1,X1,t−2…,Xk,t−1,Xk,t−2,…)

The selection of lag lengths in AR and ADL models can sometimes be guided by economic theory. However, there are statistical methods that are helpful to determine how many lags should be included as regressors. In general, too many lags inflate the standard errors of coefficient estimates and thus imply an increase in the forecast error while omitting lags that should be included in the model may result in an estimation bias.

The order of an AR model can be determined using two approaches:

[RPubs - Modeling and forecasting time series using the ARDL model](https://rpubs.com/HassanOUKHOUYA/Modeling_and_forecasting_time_series_using_the_ARDL_model)

To circumvent the issue of producing too large models, one may choose the lag order that minimizes one of the following two information criteria:

* The *Bayes information criterion* (BIC):

BIC(p)=log(SSR(p)T)+(p+1)log(T)TBIC(p)=log⁡(SSR(p)T)+(p+1)log⁡(T)T

* The *Akaike information criterion* (AIC):

AIC(p)=log(SSR(p)T)+(p+1)2TAIC(p)=log⁡(SSR(p)T)+(p+1)2T

Both criteria are estimators of the optimal lag length pp. The lag order pˆp^ that minimizes the respective criterion is called the *BIC estimate* or the *AIC estimate* of the optimal model order. The basic idea of both criteria is that the SSRSSR decreases as additional lags are added to the model such that the first term decreases whereas the second increases as the lag order grows. One can show that the the BICBIC is a consistent estimator of the true lag order while the AIC is not which is due to the differing factors in the second addend. Nevertheless, both estimators are used in practice where the AICAIC is sometimes used as an alternative when the BICBIC yields a model with “too few” lags.

Bounds Test was performed to check for the presence of a long-run relationship between the variables. The null hypothesis is that no long-run relationship exists. If the F-statistic from the Bounds Test is greater than the upper critical value, null hypothesis will be rejected which indicates cointegration i.e., a long-term relationship. After cointegration was confirmed, Error Correction Model (ECM) was used to capture the short-run dynamics and the speed of adjustment back to the long-run equilibrium.

In the context of economics, ARDL model can capture both the immediate impacts of sudden economic shocks and the gradual adjustment towards long-term equilibrium.

### 3.8.2 Support Vector Machine (SVM)

### 3.8.3 Random Forest (RF)

Random Forest regression is an ensemble learning algorithm that combines the strength of multiple decision trees to predict continuous numerical outcomes. The algorithm constructs a "forest" of decision trees with each trained on a random subset of the data and features. Unlike a single decision tree, Random Forest mitigates overfitting and enhances predictive accuracy by aggregating predictions of multiple trees to come up with the results at the end. Using the training and testing data we had split earlier at a ratio of 7:3, the response variable (currency exchange rates of USD/MYR) and highly correlated predictor variables (macroeconomic variables with correlation coefficients ≥ 0.7 or ≤ −0.7) of the training data will be fed into the random forest model. We will apply grid search to systematically fine-tune parameters, such as the number of trees and the number of features considered at each split, which at the end identify the combination that yields the best model performance.

### 3.8.4 XGBoost

### 3.8.5 LightGBM

### 3.8.6 LSTM

LSTM is a trendy model for time series forecasting. Due to the ability to process the entire sequence of data and the potential to learn long-term observation, this model has become a trending choice for researchers. LSTM can learn long-term patterns, such as yearly patterns, and the model can learn short-term patterns, such as monthly or weekly patterns. Three parts comprise an LSTM network cell: a cell state, a hidden state, and three gates. Cell states are used to pass information through the network. Those are concerned with the entire input passed through so far. The input gate is used to add information to the cell states. The input gate regulates what values need to be added by using a sigmoid function. This acts like a filter for all the information starting from h(t-1) to x t . The hidden layer creates a vector of all possible values by using the tanh function. Finally, the regulated value is multiplied by the vector and added to the cell states. The forget gate removes information from the cell state to reduce redundancy. This gate takes two inputs:

h (t-1) and x t the entire process c i t t ¼f h t t � c t 1 ¼o t þi t � c t t � tanhðc ¼sðw i ½h t 1 ; x t Þ � þb i Þ . The following equations do ð4Þ ð5Þ ð6Þ PLOSONE|https://doi.org/10.1371/journal.pone.0279602 February 7, 2023 9/ 24 ft ¼sðwf ½ht 1 ;xt �þbf Þ ð7Þ ot ¼sðwo ½ht 1 ;xt �þbo Þ ð8Þ Where,it,ft,ot,representstheinputgate,forgetgateandoutputgateandct,ht,representsthe activationvectorswherewandbareweightmatrixandbias. Asourdatasetcontains16featureswithaDatecolumn.Forthatreason,wehaveusedmul tivariateLSTM.FortrainingourLSTMmodel,wehaveusedatotalnoof3500featuredrec ordsstartingfrom15thFebruary2000.Byapplyinghyperparameteroptimization,Wehave tunedtheactivationfunctionofthedenselayer,dropoutratio,andlearningrate.Formonitor ingtheprogress,wehaveusedthevalidationloss.Wefoundthatthesoftplusactivationfunc tionperformedbetterthanallotheractivationfunctions.Forthedropoutratioof0.1anda learningrateof6e-6,ourmodelsuitsthedatabetterthananyadditionaldropoutratioand learningratevalue.ThenweimplementedtheLSTMmodelbyusingthosehyperparameters, andotherhyperparametersweresetasdefault.

## 3.9 Evaluation Metrics

We have forecasted the USD/MYR exchange rates by using various models and the outputs of those models are continuous values. To determine each model's accuracy, we will analyse the resulted inaccuracy in predicting the USD/MYR exchange rates on the testing set. To assess our models' prediction performance, we opt for the Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) which are widely used in the fields of regression research and forecasting. We will also calculate the R-square value () to gauge how effectively our models align with the underlying data. provides a measure of the proportion of the variance in the dependent variable that is explained by the independent variables in the model. It in turn offers a valuable indicator of goodness of fit.

where is the actual value of the USD/MYR exchange rates, is the predicted value of the USD/MYR exchange rates, and N denotes the total number of predictions or actual values. The model is better when the RMSE and MAPE are lower, and the model is bad when the RMSE and MAPE are high. The value of is between 0 to 1. The closer the value of to 1, the better the model is.

## 3.10 Summary

# CHAPTER 4: RESULTS AND DISCUSSIONS

## 4.1 Introduction

## 4.2 Exploratory Data Analysis

A graph of a stock market

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Figure 4.1 USD/MYR Currency Exchange Rates (Jan 2015 – Jun 2024)

The time-series plot graph observes a general upward trend in the exchange rate over the years with numerous times of fluctuations and periods of volatility. Starting from the lowest point, around 3.5 MYR per USD in early 2015, the rate experienced a sharp increase that year and nearly surpassed 4.0 MYR per USD. Over the subsequent years, the exchange rate oscillated between approximately 3.9 and 4.5. A significant spike occurred in 2022 where it briefly exceeded 4.5. The exchange rate recorded its highest value at 4.79 in February 2024

A screenshot of a table

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## 4.3 Model Evaluation

A screenshot of a computer code

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A graph of a graph showing the price of a stock market

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A graph of a graph showing the price of the stock market

Description automatically generated with medium confidenceA graph with red and blue lines

Description automatically generatedA graph showing the exchange rate

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A graph of a graph showing the price of a stock market

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|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Models** | **RMSE** | **NRMSE** | **MAE** | **MAPE (%)** | **R²** | **Training Time (sec)** |
| **ARDL** | 0.05977 | 0.09952 | 0.04425 | 0.98253 | 0.9081 | 30872.70 |
| **SVM** | 0.05915 | 0.09848 | 0.04291 | 0.95049 | 0.9100 | 1.59 |
| **RF** | 0.05716 | 0.09517 | 0.04555 | 1.01273 | 0.91596 | 175.26 |
| **XGB** | 0.05699 | 0.09488 | 0.04290 | 0.94695 | 0.91647 | 49.95 |
| **LGBM** | 0.0566 | 0.09424 | 0.04513 | 0.99875 | 0.91759 | 17.95 |
| **LSTM** | 0.05823 | 0.09696 | 0.04376 | 0.96639 | 0.91277 | 92.97 |

## 4.4 Discussions

## 4.5 Summary

# CHAPTER 5: CONCLUSIONS

## 5.1 Introduction

## 5.2 Revisiting the Objectives

1. To investigate the influence that each identified macroeconomic factor has on the paired exchange rates between United States and Malaysia.
2. To develop an econometric model that can predict the USD/MYR exchange rates using macroeconomic indicators.
3. To evaluate the performance of different econometric models in forecasting the USD/MYR exchange rates.

## 5.3 Implication of Results

## 5.4 Lessons Learned

## 5.5 Future Works

**Chapter - 1** - Introduction - Objective, Problem statement, Research question, motivation, significance, scope of the research, thesis organization.

**Chapter - 2** - Literature Review - Introduction, Critical analysis on the existing works - up to 20 articles, analysis on the similar application, summary tables, evaluation approach, one page on selected software tools.

**Chapter - 3** - Research Methodology - Introduction, Research Design, Data Science Research Methodology, Dataset selection justification, Dataset description, EDA analysis and with explanation, Model Development or Conceptual Framework.

The body of the text should be typed with double spacing. Single-spacing is only permitted in tables, long quotations, footnotes, citation and in the bibliography.

Beginning of the first line of each paragraph should have 0.5cm indentation.

References

A Rebello, S. (2018). Impact of Exports and Imports on USD, EURO, GBP and JPY Exchange Rates in India. *International Journal of Enhanced Research in Management & Computer Applications*, *7*(2), 381-386.

Abidin, I. S. Z. (2020). Evaluating the Malaysian economy 2009-2018: growth, development and policies. <https://doi.org/10.32890/9789672363149>

Afriyie, J., Twumasi-Ankrah, S., Gyamfi, K., Arthur, D., & Pels, W. (2020). Evaluating the Performance of Unit Root Tests in Single Time Series Processes. *Mathematics and Statistics*, *8*, 656-664. <https://doi.org/10.13189/ms.2020.080605>

Ali, M., Syed Mohamad, S., Yusof, A., Ismail, S., & Ibrahim, N. (2022). A GARCH Study on Exchange Rate Determinants: A Case of Malaysia. *Journal of Statistical Modelling and Analytics*, *4*, 72-84. <https://doi.org/10.22452/josma.vol4no1.6>

Alif, V. A., & Kurniawan, M. L. A. (2024). Analysis of Macroeconomic Variables on Demand for Money in Indonesia. *INCOME: Innovation of Economics and Management*, *4*(1), 30-34. <https://doi.org/10.32764/income.v4i1.4983>

Antwi, S., Issah, M., Patience, A., & Antwi, S. (2020). The effect of macroeconomic variables on exchange rate: Evidence from Ghana. *Cogent Economics & Finance*, *8*(1), 1821483. <https://doi.org/10.1080/23322039.2020.1821483>

Anuar, N. A., & Abu Bakar, A. S. (2022). *The Relationship of Consumer Price Index, Exchange Rate, Gross Domestic Product and Population Growth in ASEAN Countries using Vector Autoregressive Model*.

Bank Negara, M. (2024). Monetary Stability - Bank Negara Malaysia. [*www.bnm.gov.my*](www.bnm.gov.my). <https://www.bnm.gov.my/monetary-stability>

Bawuah, B., Agyei-Ampomah, S., Owusu-Ansah, A., & Atsu, F. (2023). Currency reform, currency biases and Ghana’s forex market fluctuations: Beyond the macroeconomic fundamentals. *Cogent Economics & Finance*, *11*(2). <https://doi.org/10.1080/23322039.2023.2276364>

Biswas, A., Uday, I. A., Rahat, K. M., Akter, M. S., & Mahdy, M. R. C. (2023). Forecasting the United State Dollar(USD)/Bangladeshi Taka (BDT) exchange rate with deep learning models: Inclusion of macroeconomic factors influencing the currency exchange rates. *PLOS ONE*, *18*(2), e0279602. <https://doi.org/10.1371/journal.pone.0279602>

BNM. (2022). *The Exchange Rate and the Malaysian Economy*. <https://www.bnm.gov.my/documents/20124/10150308/ar2022_en_box1.pdf>

Boyoukliev, I. V., Kulina, H. N., & Gocheva-Ilieva, S. G. (2022). Modelling and Forecasting of EUR/USD Exchange Rate Using Ensemble Learning Approach. *Cybernetics and Information Technologies*, *22*(4), 142-151. <https://doi.org/10.2478/cait-2022-0044>

Bujung, R. E. Y., Rotinsulu, T. O., & Th. B. Maramis, M. (2024). Analysis of the Influence of Non-Cash Payment Systems, Inflation and Interest Rates on the Money Supply (M1) 2013-2022. *Formosa Journal of Applied Sciences*, *3*(1), 81-96. <https://doi.org/10.55927/fjas.v3i1.7843>

Chen, Y. (2023). The Impact of the Interest Rates Raised by Federal Reserve System on the Exchange Rate of the US Dollar Against the Chinese Yuan. *Advances in Economics, Management and Political Sciences*. <https://doi.org/10.54254/2754-1169/56/20231054>

Cheng, S., Birau, R., Popescu, J., T, P., Pricină, G., & Pricină, C. M. (2024). Exchange rate fluctuations and industrial production in Malaysia: evidence from dynamic simulated ARDL analysis. *Industria Textila*. <https://doi.org/10.35530/it.075.05.2024128>

Dahal, S. K., & Raju, G. R. (2022). An Analysis of the Exchange Rate Regime of Nepal: Determinants and Inter-Dynamic Relationship with Macroeconomic Fundamentals. *Journal of Asian Finance Economics and Business*, *9*(7), 27-39. <https://doi.org/10.13106/jafeb.2022.vol9.no7.0027>

Daoud, H. E. D., & Al-Ezzi, R. (2023). The Cointegration Relationship Between Money Supply, Exchange Rate and Economic Growth In Iraq (2004-2020). *Business Series*, *2*(1), 9-35. <https://doi.org/10.59759/business.v2i1.112>

Davood Pirayesh, N., Mucahit, C., Wahab, M., & Basar, A. (2024). Explaining Exchange Rate Forecasts with Macroeconomic Fundamentals Using Interpretive Machine Learning. *Computational Economics*. <https://doi.org/10.1007/s10614-024-10617-1>

Davydov, A. (2020). U.S. Monetary Policy: International Results. *Russia and America in the 21st Century*. <https://doi.org/10.18254/s207054760011672-6>

Deka, A., Ozdeser, H., Cavusoglu, B., Seraj, M., & Tursoy, T. (2022). Exchange rate stability in the emerging economies: does renewable energy play a role—a panel data analysis. *Environmental Science and Pollution Research*, *30*(9), 23668-23677. <https://doi.org/10.1007/s11356-022-23911-y>

Edrak, B., Nor, Z. M., & Shaik, A. R. (2022). The Readiness of Malaysia Digital Economy: A Study of Three Government Policies from 1991 to 2020. *International Journal of Economics and Finance*, *14*(12), 84. <https://doi.org/10.5539/ijef.v14n12p84>

Edwards, S., & Cabezas, L. (2021). *Exchange Rate Pass-Through, Monetary Policy, and Real Exchange Rates: Iceland and the 2008 Crisis*.

Elgahry, B. A. (2022). Floating versus fixed: How exchange rate regimes affect business cycles comovement between advanced and emerging economies. *Cogent Economics & Finance*, *10*(1), 2116789. <https://doi.org/10.1080/23322039.2022.2116789>

Flores-Sosa, M., Avilés-Ochoa, E., & Merigó, J. M. (2022). Exchange rate and volatility: A bibliometric review. *International Journal of Finance & Economics*, *27*(1), 1419-1442. <https://doi.org/https://doi.org/10.1002/ijfe.2223>

Funashima, Y. (2020). Money stock versus monetary base in time–frequency exchange rate determination. *Journal of International Money and Finance*, *104*, 102150. <https://doi.org/https://doi.org/10.1016/j.jimonfin.2020.102150>

Ghauri, S., Ahmed, R., Streimikiene, D., Brohi, H., & Hayat, A. (2024). Macroeconomic Factors Driving Exchange Rate Volatility and Economic Sustainability: Case Study of Pakistan. *Amfiteatru Economic*, *26*, 612–628. <https://doi.org/10.24818/EA/2024/66/612>

H, D., J, L., & M, P. (2023). Reviewing the Efficacy of Federal Reserve Bank Reserve Policies through a Time Series Analysis of the Effective Federal Funds Rate. *International Journal of Research and Innovation in Social Science*. <https://doi.org/10.47772/ijriss.2023.7472>

Hasan, S. M., & Islam, R. (2023). Influence of macroeconomic variables on exchange rate: a study on Bangladesh. *International Journal of Accounting & Finance Review*, *14*(1), 1-10.

Hashchyshyn, A., Marushchak, K., Sukhomlyn, O., & Tarasenko, A. (2020). How Does the Interest Rate Influence the Exchange Rate? *Visnyk of the National Bank of Ukraine*. <https://doi.org/10.26531/VNBU2020.250.01>

Horbanevych, V., & Ivanyuta, P. (2021). Features Application of Stock Index in the Operations with Securities and Financial Instruments. *Economic scope*.

Ibrahim, M. A. (2022). Malaysia's Trade and Economy Transition between the Era of Tunku Abdul Rahman and Tun Mahathir, 1960s -1990s. *SEJARAH*. <https://doi.org/10.22452/sejarah.vol31no1.7>

Jiang, Z., & Yoon, S.-M. (2024). Interdependence between foreign exchange rate and international reserves: Fresh evidence from China. *Research in International Business and Finance*, *69*, 102255. <https://doi.org/https://doi.org/10.1016/j.ribaf.2024.102255>

Kamyshnikova, D. (2023). Malaysia. Characteristics of the Economy in the Context of the Transition to a Knowledge-Based Model. *Asia and Africa Today*. <https://doi.org/10.31857/s032150750027156-3>

Kang, Y. (2023). The Impact of the Federal Funds Rate Hike on Chinese and U.S. Financial Markets. *Advances in Economics, Management and Political Sciences*. <https://doi.org/10.54254/2754-1169/19/20230156>

Kolpashnikov, А. (2024). Assessment of the Impact of Inflation Targeting on the Exchange Rate Pass-Through and Inflation Inertia. *DEVELOPMENT OF TERRITORIAL SOCIO-ECONOMIC SYSTEMS: QUESTIONS OF THEORY AND PRACTICE*. <https://doi.org/10.17059/mkmu2024-14>

Lal, M., Kumar, S., Pandey, D. K., Rai, V. K., & Lim, W. M. (2023). Exchange rate volatility and international trade. *Journal of Business Research*, *167*, 114156. <https://doi.org/https://doi.org/10.1016/j.jbusres.2023.114156>

Lee, C. (2021). Globalisation and economic development: Malaysia's experience. *Globalisation and its Economic Consequences*. <https://doi.org/10.4324/9781003138501-6>

Lee, Y., & Yoon, S.-M. (2020). Relationship between International Reserves and FX Rate Movements. *Sustainability*, *12*(17), 6961. <https://doi.org/10.3390/su12176961>

Lv, P., Wu, Q., Xu, J., & Shu, Y. (2022). Stock Index Prediction Based on Time Series Decomposition and Hybrid Model. *Entropy*, *24*(2), 146. <https://www.mdpi.com/1099-4300/24/2/146>

Maghfiroh, U., & Jayadi, A. (2024). The Effect of Money Supply on Exchange Rate in ASEAN-5: Empirical Test of Dornbusch Overshooting Model. *Jurnal Ilmu Ekonomi Terapan*, *9*(1), 11-25. <https://doi.org/10.20473/jiet.v9i1.51854>

Mohamed, S., Abdullah, M., Noh, M. K. A., Isa, M. A. M., Hassan, S. S., Ibrahim, W. M. F. W., & Nasrul, F. (2021). Impact of Economic Factors Towards Exchange Rate in Malaysia. *International Journal of Academic Research in Economics and Managment and Sciences*, *10*(1).

Mohammed, K. S., Obeid, H., Oueslati, K., & Kaabia, O. (2023). Investor sentiments, economic policy uncertainty, US interest rates, and financial assets: Examining their interdependence over time. *Finance Research Letters*, *57*, 104180. <https://doi.org/https://doi.org/10.1016/j.frl.2023.104180>

Moshiri, S., & Kheirandish, E. (2024). Global impacts of oil price shocks: the trade effect. *Journal of Economic Studies*, *51*(1), 126-144. <https://doi.org/10.1108/JES-08-2022-0455>

Munir, K., & Iftikhar, M. (2023). Macroeconomic determinants of the real exchange rate in Pakistan. *International Journal of ADVANCED AND APPLIED SCIENCES*, *10*(8), 12-18. <https://doi.org/10.21833/ijaas.2023.08.002>

Nandi, B. K., Kabir, M. H., & Nandi, M. K. (2024). Crude oil price hikes and exchange rate volatility: A lesson from the Bangladesh economy. *Resources Policy*, *91*, 104858. <https://doi.org/https://doi.org/10.1016/j.resourpol.2024.104858>

Ng, M. C., & Geetha, C. (2020). The Impact of Monetary Variables on Exchange Rate in Malaysia from 2013 until 2015. *Malaysian Journal of Business and Economics (MJBE)*, *7*(2), 215. <https://doi.org/10.51200/mjbe.vi.2893>

Ni, H. (2023). The Global Effect of Fed Rate Hikes: Stocks, Bonds, and Foreign Exchange Markets. *Advances in Economics, Management and Political Sciences*. <https://doi.org/10.54254/2754-1169/30/20231461>

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), 215824401989884. <https://doi.org/10.1177/2158244019898841>

Nurjanah, R., & Mustika, C. (2021). The influence of imports, foreign exchange reserves, external debt, and interest rates on the currency exchange rates against the United States Dollar in Southeast Asia Countries. *Jurnal Perspektif Pembiayaan dan Pembangunan Daerah*.

Ohaegbulem, E. U., & Iheaka, V. C. (2024). The Impact of Macroeconomic Factors on Nigerian-Naira Exchange Rate Fluctuations (1981-2021). *Asian Journal of Probability and Statistics*, *26*(2), 18-36. <https://doi.org/10.9734/ajpas/2024/v26i2589>

Pasionek, J. (2023). Reaction of the USD/PLN currency pair exchange rate to the published macroeconomic data. *Financial Internet Quarterly*, *19*(1), 1-7. <https://doi.org/10.2478/fiqf-2023-0001>

Pirayesh Neghab, D., Cevik, M., & Wahab, M. I. M. (2023). Explaining Exchange Rate Forecasts with Macroeconomic Fundamentals Using Interpretive Machine Learning. arXiv:2303.16149. Retrieved March 01, 2023, from <https://ui.adsabs.harvard.edu/abs/2023arXiv230316149P>

PMO. (2011). *Government Transformation Programme Annual Report 2010 Executive Summary*. PMO. <http://lib.perdana.org.my/PLF/GOVERNMENT%20PUBLICATION/Government%20Transformation%20Programme/8f5f9018-a839-44ac-bf57-f3695f0d2502.pdf>

Puspaningtyas, M. (2022). The Role of Technology and Investment in Digitalization and The Economy in Malaysia. *Tamansiswa Management Journal International*. <https://doi.org/10.54204/tmji/vol412022006>

Rao, B. R., Kundekar, G., Pallavi, V. P., Rakshana, S., Smruthi, K., Mridu, V., R., A. P., Samarth, G. K., & Sumanth, S. (2024). The Correlation Dynamics Between Sensex 30 Returns and INR/USD Exchange Rate Movements. *International Journal of Scientific Research in Engineering and Management*. <https://doi.org/https://doi.org/10.55041/IJSREM37610>

Rasiah, R., & Krishnan, G. (2020). Industrialization and Industrial Hubs in Malaysia. <https://doi.org/10.1093/oxfordhb/9780198850434.013.36>

Ribeiro, R. S. M., Mccombie, J. S. L., & Lima, G. T. (2020). Does real exchange rate undervaluation really promote economic growth? *Structural Change and Economic Dynamics*, *52*, 408-417.

Rijoly, J. C. D., Louhenapessy, D. J., & Panggabean, J. A. (2023). The Autoregressive Analysis of Indonesian National Foreign Exchange Reserves 2000-2019 Period. *Media Trend*, *18*(1), 164-177.

Sangadji, R., Maramis, M., & Tumangkeng, S. (2024). The Influence of Foreign Direct Investment (PMA), Inflation, and Money Supply (M2) on the Exchange Rate (IDR/USD) in Indonesia for the Period 2016:Q1-2022:Q4. *Formosa Journal of Applied Sciences*, *3*(7), 2861-2874. <https://doi.org/10.55927/fjas.v3i7.10338>

Sanli, O. (2022). Impact of Exchange Rate Fluctuations On Inflation: The Case of Turkey. *ODÜ Sosyal Bilimler Araştırmaları Dergisi (ODÜSOBİAD)*. <https://doi.org/10.48146/odusobiad.1082470>

Shahnazi, R., Sajedianfard, N., & Melatos, M. (2023). Import and export resilience of the global oil trade network. *Energy Reports*, *10*, 2017-2035. <https://doi.org/https://doi.org/10.1016/j.egyr.2023.08.065>

Shen, M.-L., Lee, C.-F., Liu, H.-H., Chang, P.-Y., & Yang, C.-H. (2021). An Effective Hybrid Approach for Forecasting Currency Exchange Rates. *Sustainability*, *13*(5), 2761. <https://www.mdpi.com/2071-1050/13/5/2761>

Shukri, J., Habibullah, M. S., Ghani, R. A., & Suhaily, M. (2021). The macroeconomic fundamentals of the real exchange rate in Malaysia: Some empirical evidence'. *Jurnal Ekonomi Malaysia*, *55*(2), 81-89.

Subacchi, P., & Vines, D. (2023). Fifty years on: what the Bretton Woods System can teach us about global macroeconomic policy-making. *Oxford Review of Economic Policy*, *39*(2), 164-182. <https://doi.org/10.1093/oxrep/grad016>

Suri, R., Gauba, S., & Chandran, A. (2024). Co-movements between Stock Markets and Exchange Rates: Empirical Evidence from the G20 Nations. *International Journal of Finance Research*, *5*, 252-269. <https://doi.org/10.47747/ijfr.v5i3.1934>

Syamad, & Handoyo, R. D. (2023). The Effects of Money Supply on Exchange Rate: Evidence of Dornbusch Overshooting Model in Indonesia (2000-2021). *Jurnal Ilmu Ekonomi Terapan*, *8*(1), 144-156. <https://doi.org/10.20473/jiet.v8i1.45177>

Tabash, M. I., Asad, M., Khan, A. A., Sheikh, U. A., & Babar, Z. (2022). Role of 2008 financial contagion in effecting the mediating role of stock market indices between the exchange rates and oil prices: Application of the unrestricted VAR. *Cogent Economics & Finance*, *10*(1), 2139884. <https://doi.org/10.1080/23322039.2022.2139884>

Thevakumar, P., & Jayathilaka, R. (2022). Exchange rate sensitivity influencing the economy: The case of Sri Lanka. *PLOS ONE*, *17*(6), e0269538. <https://doi.org/10.1371/journal.pone.0269538>

Wu, H. (2024). Analyzing the Relationship Between the Fed Interest Rates and Foreign Exchange Markets. *Frontiers in Business, Economics and Management*. <https://doi.org/10.54097/77ugvxbo>

Appendix

Appendix A: Data