Forecasting Exchange Rates Using Artificial Neural Networks: An Applied Study on the Arab Republic of Egypt

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Abstract

The exchange rate is considered one of the most important economic factors that affect the overall economy of any country. The importance of the exchange rate is represented in international trade, inflation, unemployment, foreign investments, and Monetary policies

The study seeks to predict the exchange rate in Egypt using artificial neural networks.

The prediction results show that artificial neural networks have high accuracy in predicting the exchange rate in the Arab Republic of Egypt, and the most important factors that affect the exchange rate of the Egyptian pound are: The total stock of external debt (outstanding and disbursed debt, in current US$), GDP (in constant US$), gross capital formation (% of GDP), and the current account balance (balance of payments, in current US$), Inflation, and prices paid by consumers (% annually) - United States of America.

***Keywords**: Exchange Rates, Artificial Neural Networks, Monetary Policies, Forecasting Models.*

Introduction

Artificial Neural Networks (ANNs) are modern models used for analyzing, interpreting, and forecasting economic phenomena. One of the key variables analyzed in economic phenomena is the exchange rate. By forecasting future trends of this variable, many problems for the national economy can be avoided through proactive planning to mitigate adverse effects such as exchange rate volatility, currency devaluation, or increased costs of domestic and imported goods. Thus, exchange rate forecasting can contribute to stabilizing the exchange rate and preventing many issues. In recent years, particularly after the January 25, 2011, revolution, the Egyptian economy has experienced exchange rate instability. This instability is reflected in various phenomena such as the rise in commodity prices due to currency devaluation, increased cost of living, and higher poverty rates, among other effects. In this context, this study aims to forecast the exchange rate using artificial neural network models.

Previous Studies

Zhang (2024), addressing the issue of fluctuations in the Chinese yuan (CNY) exchange rate against the US dollar (USD) and how to forecast these fluctuations, especially in light of global economic tensions and events such as the trade war between China and the United States. This research aims to utilize typical Neural Network Models and Long Short-Term Memory Model (LSTM) models to analyze and forecast the Yuan-to-Dollar exchange rate over a one-year period. The research methodology involves collecting

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monthly data on the yuan-to-dollar exchange rate from the FRED website. The data was divided into a training set (from January 2006 to September 2022) and a testing set (from September 2022 to August 2023). Forecasting models used include the neural network model NNAR: 2,1,2), which relies on lagged values and provides forecasts with 95% confidence intervals, and the LSTM model, where the delay was set to 2 and the number of units in the LSTM layer was set to 32. The LSTM model was trained for 10 epochs with a data split ratio of 200/12 (200 for training and 12 for testing). The results showed that the LSTM model outperformed the Neural Network Model in terms of forecasting accuracy for the exchange rate. The Mean Squared Error (MSE) for the LSTM model was lower than that of the Neural Network Model, indicating higher accuracy in forecasts with the LSTM. model.

Pacelli (2012). The research problem lies in identifying the most effective and accurate mathematical model for forecasting the daily exchange rates of euro to US dollar. This research aims to compare the predictive performance of Artificial Neural Network (ANN) models against ARCH and GARCH models to identify which of these models can provide more accurate forecasts in a financial market characterized by high volatility and incomplete information efficiency. According to Pacelli (2012), the research hypotheses include the notion that financial market pricing processes are not random and that information efficiency in financial markets is not strong. Daily data on the Euro to US dollar exchange rate was collected from January 1, 1999, to December 31, 2009. The data included a range of input variables such as the NASDAQ index, spot gold price, average government bond yields, and crude oil price. The analysis aimed to identify the most influential variables while avoiding those that might inflate or distort the results. After evaluating the correlation and impact of these variables on the exchange rate, seven variables were selected. The objective of this research was to analyze and compare the forecasting ability of different mathematical models, such as Artificial Neural Networks (ANNs) and ARCH/GARCH models, for forecasting daily EUR/USD exchange rates. The study sought to determine which of the applied models produced the most accurate forecasts. Pacelli (2012)'s study relied on the following variables: (Nasdaq Index - Daily Exchange Rate) Euro/USD; Spot Gold Price in the United States; Average yield on 5-year government bonds in the United States; Average yield on 5-year government bonds in the Eurozone; Crude oil price; Previous day's Euro/USD exchange rate. The results indicated that ARCH and GARCH models, particularly in their static forms, perform better than ANN in analyzing exchange rate dynamics and forecasting the exchange rate.

Carriero et al. (2009), The research problem of this study lies in the difficulty of building an economic model that can forecast exchange rates with greater accuracy than the "Random Walk" model, particularly in the short term. Notably, Carriero's research aims to propose a model for forecasting exchange rates using a Large Bayesian VAR model that relies on a broad set of global exchange rates to US dollar. The research methodology involves using a Bayesian VAR model with the assumption of a "Random Walk with no drift" on a large dataset that includes 33 exchange rates as well as assessing its performance in forecasting by comparing its results to those of the Random Walk model. The results showed that the Bayesian VAR model systematically outperformed the Random Walk model for most currencies and across all forecasting horizons, with forecasting accuracy improving by an average of 2%-3%, and enhancements reaching 6%-9% in cases such as the Euro-USD and GBP-USD currency pairs.

Leung et al. (2000), Leung's research problem includes: the challenges faced by traditional economic models in accurately forecasting exchange rates, as these models have demonstrated unsatisfactory performance compared to the "Random Walk" model. These challenges represent a significant issue for multinational corporations that heavily rely on accurate exchange rate forecasts to achieve greater profits. The research aims to evaluate the effectiveness of General Regression Neural Networks (GRNN) in forecasting monthly exchange rates for three major currencies: the British Pound (GBP), the Canadian Dollar (CAD), and the Japanese Yen (JPY). Furthermore, Leung et al. (2000) sought to compare the performance of General

Regression Neural Networks GRNN with other types of neural networks and economic models to determine their effectiveness in financial forecasting. Their research methodology relied on monthly exchange rate data covering the period from January 1974 to July 1995, with the data divided into training and test sets for the models. The performance of GRNN was compared with other neural networks, such as Multi-Layer Feedforward Networks (MLFN), and multivariate transition function models, as well as the "Random Walk" model as a benchmark for comparison. The results indicated that GRNN outperformed the other models, providing more accurate and less biased forecasts, especially when compared to the Multi-Layer Feedforward Network and traditional economic models. This research serves as evidence of the capabilities of GRNN in complex financial forecasting, such as forecasting exchange rate movements.

Carriero et al. (1996), Their research addresses the problem of forecasting foreign exchange rates, a complex issue due to the non-linearity and high noise characteristic of these markets. Noteworthy, there is ongoing debate among traders and academics about whether exchange rates follow the "Random Walk" theory, which suggests that changes in exchange rates are independent and unpredictable. Carriero et al. (1996)'s research aims to assess the effectiveness of Recurrent Neural Networks (RNNs) in forecasting foreign exchange rates, particularly the Deutsche Mark. Additionally, their study seeks to develop trading strategies based on these forecasts and evaluate their profitability by employing three different architectures of RNNs and comparing them in terms of forecasting accuracy and profitability of the resulting trading strategies. These networks were trained and tested using Deutsche Mark exchange rate data from January 1990 to December 1994. The RNNs were used in forecasting price changes, and their performance was evaluated based on forecasting accuracy and profitability of the trading strategies across multiple datasets (training, testing, validation). The results indicated that the second recurrent neural network (RNN2) was the most effective in terms of overall profitability and its ability to generalize across various datasets. Additionally, trading strategies based on this network demonstrated the capability to achieve high returns, although the second strategy was more accurate in forecasting large price movements.

Research Gap

There is a noticeable scarcity of research on exchange rate forecasting in Egypt using Artificial Neural Networks (ANNs).

Research Problem

Egypt continues to face fluctuations in exchange rates that impact the national economy and the associated problems, highlighting the necessity of forecasting exchange rates. In this respect, accurate forecasting through economic models is crucial. The main issue with using economic models for forecasting is the accuracy of the model itself. Artificial neural networks, with their various types, are considered modern models that can be employed for forecasting. This raises several questions:

What is the accuracy of using artificial neural networks for forecasting exchange rates? What are the key economic variables in determining exchange rates using Artificial Neural Networks (ANNs)?

And what is the relative importance of the key variables affecting exchange rates?

Significance of the Study

The significance of the research is highlighted by the following points:

- Artificial Neural Networks (ANNs) are modern methodologies for analyzing, interpreting, and forecasting economic phenomena.
- Exchange rates are considered a crucial economic variable that both affect and are affected by many

other economic factors, especially in the context of exchange rate instability following the January 25, 2011, revolution.

- ANNs can contribute to the provision of a robust and accurate tool for forecasting exchange rates, which can be used for planning and decision-making to help stabilize the exchange rate of the Egyptian pound.

Research Objectives:

This research aims to:

- Understand Artificial Neural Networks (ANNs), including their models, components, and the steps for their implementation.
- Develop a predictive model for the exchange rate in Egypt using Artificial Neural Networks (ANNs).
- Evaluate the performance of the Artificial Neural Networks (ANNs) model for forecasting the exchange rate.
- Identify the key economic variables affecting the exchange rate through artificial neural networks.

Research Hypotheses:

Its an expected that Artificial Neural Networks (ANNs) have high accuracy in forecasting the exchange rate of the Egyptian pound.

Research Methodology

The research relies on an analytical methodology by collecting data and previous studies, as well as analyzing the exchange rate and its key influencing factors. This includes theoretical analysis based on prior studies on the topic and using econometric tools, specifically ANNs through SPSS software.

Scope of the Study:

Geographical Scope: Arab Republic of Egypt

Temporal Scope: Based on World Bank data for the period 1977-2022 to provide a sample sufficient for training and assessing ANNs.

Contents of the Study:

This research consists of the following sections:

1- Exchange Rate.

2- Forecasting.

3- Artificial Neural Networks (ANNs).

4- Econometrics Study.

Exchange Rate:

Definition of Exchange Rate:

Exchange rate is the value of a currency when exchanged for another currency. It is the number of units of a foreign currency that can be obtained in exchange for one unit of the domestic currency. (Krugman et al., 2018)

Importance of the Exchange Rate:

Exchange rate is one of the most crucial economic factors affecting the macroeconomy of any country. According to Madura (2021), the significance of exchange rate lies in the following factors:

1- **International Trade**: The exchange rate affects the cost of imported and exported goods and services. A lower exchange rate boosts exports by making them cheaper in the international market, while a higher exchange rate reduces the competitiveness of exports. Additionally, a lower exchange rate increases the cost of imports and reduces demand for them, whereas a higher exchange rate decreases the cost of imports and also reduces demand for them.

2- **Inflation**: The exchange rate can impact inflation rates. A decline in the exchange rate increases the cost of imports and raises their prices, leading to higher domestic prices (imported inflation), and vice versa.

3- **Unemployment**: Exchange rate stability contributes to increased domestic investment, which in turn lowers unemployment rates. Conversely, exchange rate instability can lead to reduced domestic investment.

4- **Foreign Investments**: Exchange rates affect investment decisions. Stable exchange rates enhance confidence among foreign investors, leading to increased foreign direct investment, whereas severe fluctuations can reduce foreign direct investment.

5- **Monetary Policies**: Central banks use exchange rates as a tool of monetary policy to achieve economic objectives such as controlling inflation and stimulating economic growth.

Types of Exchange Rates

- **Fixed Exchange Rate:** A system in which the government or central bank sets the value of the currency and defends it by intervening in the foreign exchange market (Krugman et al., 2018)
- **Floating Exchange Rate:** A system in which the value of the currency is determined by supply and demand in the foreign exchange market without government intervention (Mankiw, 2019).
- **Managed Float Rate:** A system in which the central bank intervenes occasionally to stabilize the exchange rate within certain ranges without committing to a fixed rate (Carbaugh, 2019).
- **Multiple Exchange Rates:** In this system, the country uses several exchange rates for the same currency depending on the type of financial transactions (such as commercial, tourist, investment, etc.) (Pilbeam, 2018).
- **Forward Exchange Rate:** It refers to the rate agreed upon now for exchanging currency at a specified future date (Hull, 2018).
- **Official Exchange Rate:** It refers to the rate set by the government and used in official transactions such as customs (Feenstra et al., 2017).
- **Real Exchange Rate:** It refers to the exchange rate that takes into account the difference in price levels between two countries. It reflects the purchasing power of the currency. Mankiw (2019).
- **Parallel Exchange Rate:** It is the rate that forms in the unofficial market, where currency is traded informally and unregulated, often in countries that impose foreign exchange restrictions. (Dornbusch et al., 2018).
- **Nominal Exchange Rate:** It refers to the rate at which one currency can be exchanged for another in the current market, without adjusting for differences in price levels between countries (Krugman et al., 2018).
- **Nominal Effective Exchange Rate:** It refers to the average nominal exchange rate of a specific currency to a basket of foreign currencies, weighted by trade shares with each country (Pilbeam, 2018).
- **Real Effective Exchange Rate:** It refers to the average real exchange rate of a specific currency to a basket of foreign currencies, weighted by trade shares with each country (Feenstra et al., 2017).

Factors that Influence Exchange Rates:

Several factors influence exchange rates, varying in their strength and impact depending on economic, political, and social conditions. Below are the main factors affecting exchange rates: (Caves et al., 2007).

- **Inflation**: A higher inflation rate in a country leads to a decrease in the value of its currency compared to other currencies, thereby weakening the exchange rate (Mankiw, 2019).
- **Future Expectations**: Expectations regarding future economic performance or monetary policies can affect the demand for a currency and its value (Mishkin, 2019).
- **Balance of Payments**: A surplus in the balance of payments leads to an appreciation of the currency, whereas a deficit results in a depreciation of its value (Carbaugh, 2019).
- **Political Stability**: Political stability enhances confidence in the currency and increases its value, while political instability leads to currency depreciation (Pilbeam, 2018).
- **Economic Growth**: Strong economic growth boosts the value of the currency by increasing demand for it due to foreign investment and trade (Feenstra et al., 2017).
- **Government Intervention**: Interventions in the foreign exchange market through the buying or selling of foreign currencies can directly affect the exchange rate (Dornbusch et al., 2018).
- **Fiscal Policy:** Elements of fiscal policy impact the exchange rate (Frenkel et al., 1987).
- **Public Revenues:** An increase in public revenues through taxes can lead to an appreciation of the local currency if the proceeds are used to reduce the fiscal deficit or improve infrastructure. Conversely, it may have the opposite effect and depreciate the currency if it negatively impacts the level of investment in the country.
- **Public Expenditures:** An increase in public Expenditures may lead to inflation if it is not effectively targeted, which could result in a depreciation of the currency. Conversely, if spending is effectively directed towards increasing investment, it may lead to an appreciation of the currency.
- **Monetary Policy**: Monetary policy components affect the exchange rate (Krugman et al., 2018).
- **Interest Rates:** A rise in interest rates attracts foreign indirect investments, leading to increased foreign capital inflows, which strengthens the currency and makes it more attractive to investors, thereby increasing its value relative to other currencies. However, higher interest rates can also lead to reduced investment due to increased capital and loan costs, which can affect economic growth rates and consequently decrease the exchange rate.
- **Money Supply:** An increase in the money supply without a corresponding rise in production can lead to inflation and a depreciation of the currency.
- **Central Bank Open Market Interventions:** The selling of buying of local currency can directly influence the exchange rate.
- **Balance of Payments: The balance of payments affects the exchange rate:** (Krugman et al., 2018).
- **Current Account:** A surplus in the current account increases demand for the local currency, thereby strengthening its value.
- **Capital Account:** Inward capital flows enhance the value of the currency, while outward capital flows lead to a depreciation of the currency.
- **Official Reserves:** An increase in official reserves boosts confidence in the local currency and supports the exchange rate.
- **Unemployment:** An increase in official reserves boosts confidence in the local currency and supports the exchange rate (Blanchard et al., 2013).

- **Individual Behavior, Attitudes, and Social Interaction**: Individual Behavior, Attitudes, and Social Interaction attitudes, and social interaction, can lead to increased economic confidence or a shift towards investing in foreign assets. These changes can affect the exchange rate by altering the demand for both the local and foreign currencies (Akerlof et al., 2010).

Exchange Rate Theories:

1- **PPP - Purchasing Power Parity :(**Marsh et al., 1994)

Purchasing Power Parity **(**PPP) Theory is an economic theory used to determine the exchange rate between two currencies based on the relative price levels in the two countries. In essence, PPP theory is based on the assumption that identical goods should cost the same in all countries when their prices are adjusted by the current exchange rate. In other words, the exchange rate between two currencies should be equal to the ratio of the price levels in the two countries.

Theoretical Basis of PPP Theory: PPP theory is based on the *Law of One Price*, which states that identical goods should be sold at the same price in different markets when prices are expressed in the same currency. However, if price differences arise, arbitrage operations will drive the prices toward equilibrium.

Types of Purchasing Power Parity (PPP)

- **Absolute PPP:**
  - It states that the exchange rate between two currencies is equal to the ratio of the price levels in the two countries.
  - The equation is $S = \frac{P1}{P2} S = \frac{P1}{P2}$
  - Where S is the exchange rate, and P1 and P2 are the price levels in the two countries.
- **Relative Purchasing Power Parity (Relative PPP):**
  - Relative PPP states that the rate of change in the exchange rate between two currencies reflects the difference in inflation rates between the two countries.
  - The equation is $\Delta S/S = \frac{\Delta P1}{P1} = \frac{\Delta P2}{P2} \Delta S/S = \frac{\Delta P1}{P1} = \frac{\Delta P2}{P2}$
  - Where ΔS is the change in the exchange rate, and ΔP1 and ΔP2 are the changes in price levels in the two countries.

Challenges and Criticisms

The Purchasing Power Parity (PPP) theory faces several challenges, including:

- **Transportation Costs and Tariffs:** These factors impede the application of the Law of One Price.
- **Differences in the Basket of Goods:** The basket of goods used to calculate price levels may vary between countries.
- **Heterogeneity of Goods:** The quality and preferences for goods can differ between countries.

2- **Interest Rate Parity (IRP) Theory: Chinn et al. (2004)**

IRP Theory is an economic theory used to determine the relationship between interest rates and the spot and forward exchange rates between two currencies. This theory assumes that the difference in interest rates between two countries is equal to the difference between the spot and forward exchange rates of the currencies.

Theoretical Basis of IRP Theory:

Theoretical Basis of IRP Theory: IRP theory is based on the concept that investors will seek higher returns. If returns in one country are higher than in another, investors will move their funds to the country of-

fering higher returns. This movement of funds leads to changes in exchange rates until the expected returns are balanced between the two countries.

Types of Interest Rate Parity

- **Uncovered Interest Rate Parity - UIP:**
  - UIP states that the difference in interest rates between two countries is equal to the expected change in the exchange rate between the two currencies.
  - The equation is: $\frac{E(e)}{e} = f(i) - d(i) \frac{E(e)}{e} = f(i) - d(i)$
  - Where $d(i)\, d(i)$ is the domestic interest rate, and $f(i) f(i)$ is the foreign interest rate, and $E(e) E(e)$ is the expected future exchange rate, and ee is the current spot exchange rate.
- **Covered Interest Rate Parity - CIP:**
  - CIP states that the difference in interest rates between two countries is equal to the expected change in the exchange rate between the two currencies.
  - The equation is $\frac{F-S}{S} = f(i) - d(i) \frac{F-S}{S} = f(i) - d(i)$
  - Where *F* is the forward exchange rate and *S* is the spot exchange rate.

3- **Balance of Payments (BOP) Theory:** (Krugman et al., 2021)

(BOP) Theory is considered one of the fundamental theories in determining exchange rates between currencies. According to this theory, the exchange rate is determined by the balance between the demand and supply of foreign currencies in the international currency market, which is influenced by factors such as international trade, foreign investments, and financial transfers.

Core of BOP Theory:

The theory suggests that the exchange rate is directly affected by the surplus or deficit in the current account and capital account of the balance of payments. If there is a surplus in the balance of payments, the value of the local currency will rise due to increased demand for the local currency by foreigners. Conversely, if there is a deficit, the value of the local currency will fall due to an increased supply of the local currency in exchange for foreign currencies.

4- **Market Efficiency Theory: Fama (1970)**

Market Efficiency Theory is considered one of the fundamental theories in determining exchange rates between currencies. This theory states that exchange rates are determined based on the information available to all market participants, and that these rates reflect all information currently accessible. In other words, any changes in exchange rates result from new information coming to light.

Core of Market Efficiency Theory:

Market Efficiency Theory is founded on the hypothesis that financial markets, including the foreign exchange market, are efficient, meaning that exchange rates quickly adjust to new information. If markets are fully efficient, it is impossible to achieve abnormal profits through currency trading because all information related to prices is available to all traders simultaneously.

Evolution of Exchange Rates in Egypt:

Over the recent decades, the exchange rate in Egypt has experienced significant changes. During the 1970s and 1980s, Egypt followed a fixed exchange rate system, with the Egyptian pound pegged to the US dollar. The government began gradually liberalizing the exchange rate in the late 1970s and early 1980s. In the 1990s, Egypt further liberalized the exchange rate, leading to substantial fluctuations in the value of the pound. In 1991, an agreement was signed with the International Monetary Fund (IMF) that included implementing economic policies aimed at improving the Egyptian economy. In the early 2000s, the exchange rate

was fully liberalized in 2003, resulting in a significant depreciation of the pound. This trend continued with notable fluctuations due to political and economic events. After the January 25, 2011, revolution, Egypt witnessed considerable volatility in the exchange rate due to political and economic upheavals, with the central bank frequently intervening to stabilize the market. In November 2016, the Central Bank of Egypt decided to float the pound, leading to a significant decline in its value to foreign currencies. This decision was part of an economic reform program in collaboration with the IMF (Al-Mashat et al., 2007).

Forecasting:

Definition of Forecasting:

Forecasting is the process of estimating future events or outcomes based on current or past data and information. It is used in a variety of fields such as economics, management, planning, and science to make informed decisions and achieve desired objectives (Armstrong, 2001).

Types of Forecasting:

Each type of forecasting has its distinct applications based on the nature of the available data and the forecasting horizon. Forecasting methods can be categorized based on the following types:

1- **Types of Forecasting Based on Data Type and Methodology:**

Qualitative Forecasting: Qualitative forecasting relies on personal estimates and expertise rather than quantitative data.

It depends on subjective judgment, experience, and specialized knowledge, and is used when quantitative data is unavailable or insufficient. This type of forecasting includes techniques such as focus groups, personal interviews, and the Delphi Method. It is employed when historical data is either unavailable or unreliable, such as in the (Delphi Method), where estimates from a group of experts are collected repeatedly until a consensus is reached (Linstone et al., 1975).

Quantitative Forecasting: Quantitative forecasting relies on historical data and mathematical models to analyze trends and forecast future outcomes. For example, Time Series Analysis: Uses historical data to forecast future values based on seasonal patterns and trends. Regression Models: Analyze the relationship between a dependent variable and one or more independent variables to predict future values. Economic Models: Utilize economic theories and mathematical models to analyze and forecast economic relationships. This type of forecasting is considered more accurate and is frequently used for forecasting demand, sales, and production (Athanasopoulos, 2018).

2- **Types of Forecasting Based on Time Horizon: (Hatfield, 2000).**

- **Short-Term Forecasting:** Short-term forecasting refers to forecasts that cover a brief period, typically from days to a few months. This type of forecasting is useful for daily operational planning and immediate decision-making.
- **Medium-Term Forecasting:** Medium-term forecasting covers periods ranging from several months to two years. It is used for tactical planning, inventory management, and budgeting.
- **Long-Term Forecasting:** Long-term forecasting encompasses periods extending beyond two years, potentially reaching a decade or more. It is employed for strategic planning and forecasting long-term trends and future directions.

3- **Forecasting Based on Future Outlook: Fildes et al. (2012)**

- **Optimistic Forecasting:** Optimistic Forecasting Optimistic forecasting assumes positive scenarios and is used to plan for the best possible outcomes.
- **Pessimistic Forecasting:** Pessimistic forecasting considers the worst possible scenarios and is used to prepare for potential challenges and risks.

- **Realistic Forecasting:** Realistic forecasting aims to strike a balance between optimism and pessimism, providing estimates based on current data and historical trends.

Forecasting Hypotheses:

Forecasting Hypotheses are a set of hypotheses used to estimate future outcomes based on current data and analyses. According to these hypotheses include (Makridakis et al., 1998):

- **Continuity of Historical Patterns**: This hypothesis assumes that trends and patterns observed in historical data will continue into the future.
- **Economic and Political Stability**: This hypothesis assumes that the economic and political environment will remain stable and not change significantly, which could affect the forecasted data.
- **No Major Technological Changes**: This hypothesis assumes that there will be no sudden technological developments that significantly impact the data or trends.
- **Consistent Consumer Behavior**: This hypothesis assumes that customer or consumer behavior will not change drastically in the future.
- **Availability of Accurate Data**: This hypothesis assumes that the data used for forecasting is accurate and complete.
- **No Catastrophic Events**: This hypothesis assumes that no natural or human-induced events will cause significant and unexpected changes in the data.
- **Assumption of Uncertainty in Forecasting:** This hypothesis refers to the recognition that all forecasts carry a degree of uncertainty due to unforeseen factors that may affect future outcomes. Evidently, this hypothesis is based on the understanding that forecasts are not 100% accurate and there is always a possibility of unexpected events altering the predicted results.
- **The Flexibility Hypothesis in Forecasting:** This hypothesis refers to the ability of the forecasting model to adapt to changes in data or underlying conditions. A flexible forecasting model can respond to new developments and adjust forecasts based on the latest available information.

Factors Influencing Forecasting:

The forecasting process is influenced by various factors, depending on the context and type of forecast required (Makridakis et al., 1998) suggested some key factors that can affect the accuracy of forecasts as follows:

- **Data Quality**: The quality and accuracy of the data used in the forecasting process significantly affect the results.
- **Model Selection**: Choosing the appropriate model for analysis and forecasting is a critical factor. There are various models, such as linear models, machine learning models, and neural network models.
- **Historical Data Analysis**: A thorough analysis of historical data and understanding past patterns helps improve the accuracy of forecasts.
- **External Factors**: External factors, such as economic, political, and technological changes, may impact the accuracy of forecasts.
- **Human Biases**: Analyses and forecasts can be influenced by human biases and incorrect information.
- **The Nature of the Variables**: The nature of the variables used in the forecasting process is an important factor in determining the accuracy of the forecast. Variables can be quantitative (e.g., sales, profits) or qualitative (e.g., customer satisfaction, product quality). Quantitative variables are often easier to measure and forecast using mathematical models, while qualitative variables may require more complex techniques such as qualitative statistical models or psychological analysis (Chatfield, 2000).
- **Time Horizon**: The time horizon of the forecasting process significantly impacts its accuracy. Short-term forecasts are typically more accurate because they rely on recent data and the

influencing factors tend to be more stable. In contrast, long-term forecasts may be less accurate due to increased uncertainty and changes in influencing factors.

- **Cost**: The costs associated with the forecasting process include the expense of data collection, the cost of tools and software used, and the cost of analysis and interpretation. High-precision forecasts may require higher costs, but this expense should be weighed to the potential benefits of accurate forecasting (Armstrong, 2001).
- **Ease of Application**: The ease of applying forecasting techniques depends on the complexity of the model used and the availability of necessary human and technical resources. Simple models may be easier to implement but might not achieve the same level of accuracy as more complex models. It is important to choose a model that strikes a suitable balance between ease of use and accuracy (Armstrong, 2001).

Forecasting Methods

1- **Qualitative Forecasting Methods:** (Armstrong, 2001)

a- **Expert Judgment:** This method relies on the knowledge and expertise of specialists in the relevant field. Opinions and estimates from these experts are gathered to form a view of the future.

b- **Delphi Method:** This method involves collecting opinions from a panel of experts through a series of iterative questionnaires until a consensus is reached.

c- **Focus Groups**: This method gathers qualitative information from a selected group of people to discuss specific topics and derive trends or forecasts.

2- **Quantitative Forecasting Methods:**

- **Causal Models (Regression Models):** These models rely on analyzing the relationship between two or more variables to forecast the values of the dependent variable based on the values of independent variables.
- **Economic Models:** These models are based on known economic relationships between variables, such as supply and demand models and economic growth models.
- **Econometric Models Used in Forecasting**: These models apply statistical methods to economic data to forecast future trends and relationships:
- **Linear Regression Model:** The linear regression model is one of the simplest and most widely used econometric models. It is employed to analyze the relationship between a dependent variable and one or more independent variables. Regression can be simple (with one independent variable) or multiple (with several independent variables). Wooldridge (2016)
- **Autoregressive Distributed Lag Model (ARDL):** The ARDL model is used to analyze dynamic relationships between variables, particularly when the variables are not stationary over time. It helps in identifying the long-term relationship between variables (Pesaran et al., 2001).
- **Error Correction Model (ECM):** The ECM model is used to analyze non-stationary time series data. It aims to integrate short-term relationships with long-term relationships between economic variables (Engle et al., 1987).
- **Autoregressive Integrated Moving Average (ARIMA) Model**: The Arima model is used to analyze time series and forecast future trends based on historical data. The model consists of three components: Autoregression (AR), Moving Averages (MA), and Integration (I) (Box et al., 2015).
- **Vector Autoregression Model (VAR):** The VAR model is used to analyze the interrelationships between multiple time series variables, treating each variable as both a dependent and an independent variable simultaneously (Lutkepohl, 2005)

- **Generalized Autoregressive Conditional Heteroskedasticity (GARCH) Model:** The GARCH model is used to analyze and forecast conditional variance in financial time series, such as stock price volatility (Engle et al., 2001).

Artificial Neural Networks (ANNs)

Definition of Neural Networks

Neural networks are computational models inspired by the structure and functioning of the human brain. They aim to learn from data by adjusting the weights between simple units, known as neurons. Neural networks are used in a variety of applications, including forecasting, classification, and processing images and texts.

Structure of Neural Networks

The structure of neural networks is based on a layered architecture, where the network consists of:

- Input Layer: This layer receives the raw data to be processed.
- Hidden Layers: These layers are located between the input layer and the output layer. They process the data through a network of interconnected neurons.
- Output Layer: This layer produces the final result or forecast based on the processed data.

Basic Components of Neurons:

- Weights: These determine the strength of the connections between neurons.
- Activation Function: Transforming Aggregated Inputs into Outputs.
- Bias: A constant value added to the inputs to adjust the final output.

Types of Neural Networks

There are several types of artificial neural networks, including Feedforward Neural Networks:

- The simplest type of neural network, where data flows in one direction from the input layer to the output layer.
- Recurrent Neural Networks (RNNs): These include loops that allow information to pass through, taking into account the temporal sequence of the data.
- Convolutional Neural Networks (CNNs): CNNS are primarily used in image and video processing, where convolutional operations are used to extract features from visual data.
- Generative Adversarial Networks (GANs): GANs consist of two neural networks competing to produce new data that resembles the original data.

Steps for Using Neural Networks

There are several steps to follow when using ANNs in forecasting, including the following:

1- Data collection: Collect appropriate data for training that represents the problem the model aims to solve.

2- Data Processing: Clean and normalize the data to make it suitable for use in the neural network.

3- Data Grouping: Divide the data into training, testing, and validation groups.

4- Model Design: Choose the appropriate network architecture, including the number of layers and neurons in each layer.

5- Model Training: Use training data to adjust the weights through iterative learning processes such as backpropagation.

6- Model Assessment: Assess the model's accuracy and effectiveness using the test data.

7- Model Optimization: Adjust the model's architecture or training settings to enhance performance.

8- Forecasting: Use the trained model to make predictions based on new data.

Econometrics Study

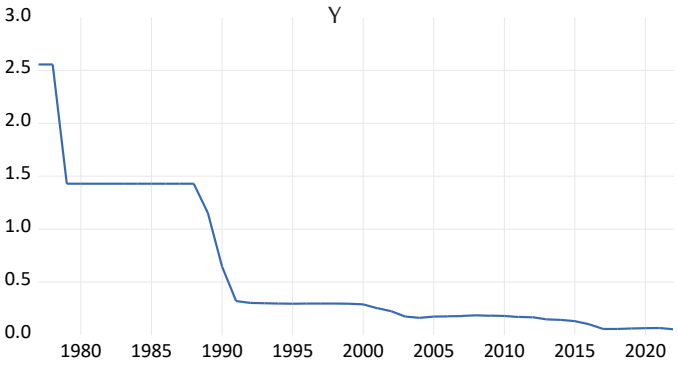
Data Sources

The researcher collected data through a literature review of research and studies discussing forecasting exchange rates using Artificial Neural Networks (ANNs) . The data includes statistics on the official exchange rate (the number of local currency units equivalent to one U.S. dollar), current account balance (% of GDP), current account balance (balance of payments, at current U.S. dollar prices), inflation (consumer prices % annually) – United States, total external debt (debt outstanding and disbursed, at current U.S. dollar prices), and gross capital formation (% of GDP), and GDP (at constant dollar prices), based on World Bank data for the period 1977-2022.

Study Variables

The study relied on World Bank data from 1977 to 2022, and the following variables were analyzed:

Name	Indicator
Official Exchange Rate (Number of local currency units per US Dollar)	Ln_Y
Current Account Balance (% of GDP)	Ln_X5
Current Account Balance (Balance of Payments, Current US Dollars)	Ln_X7
Inflation, Consumer Prices (% annual) – United States of America	Ln_X11
Total External Debt Stock (Disbursed and Outstanding Debt, Current US Dollars)	Ln_X12
Gross Capital Formation (% of GDP)	Ln_X15
Gross Domestic Product (GDP) at Constant Prices in USD	Ln_X17



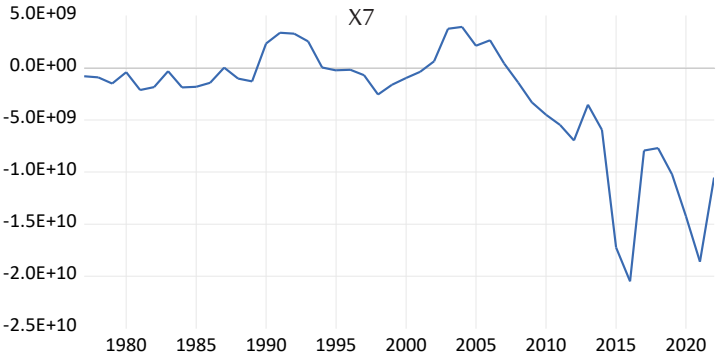
Source: EVIEWS program outputs based on World Bank data for the period 1977-2022 Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023)

Figure (1): Exchange Rate of the Egyptian Pound during the Period (1977-2022)

According to figure (1), a continuous decline in the exchange rate of the Egyptian pound is observed. Notably, during the Economic Openness period (1974-1981), the exchange rate dropped from 2.55556 USD per pound to 1.42857 USD per pound and then remained stable until 1988. In 1986, an Economic Reform Program was implemented due to pressure from international institutions for Egypt to repay its external debt, aiming to restore its creditworthiness. Al-Antry (1994). As a result, the exchange rate began to fluctuate, reaching 1.153846 USD per pound in 1989, then gradually declined to 0.29452912 USD in 1999 due to the implementation of the Economic Reform Policy during that period. It then stabilized around 0.17 USD until 2010, followed by a decline due to the January 25th Revolution in 2011. After the Economic Reform Policy was applied in 2016, the exchange rate fell to 0.0997 USD per pound and further declined to 0.05 USD per pound by 2022.

From the figure (2), it is observed that the Current Account Balance (Balance of Payments, Current US Dollars) remained relatively stable from 1977 to 1989, with a slight deficit and fluctuations close to balance. With the implementation of the Economic Reform Policy and the adoption of a contractionary demand policy through increased interest rates, the deficit turned into a surplus until 1995. The balance then shifted to a deficit from 1996 to 2000, turned into a surplus from 2001 to 2007, and returned to a deficit until 2010. According to Brahim et al., (2003), **the surplus up to 1995 is attributed to relative economic stability** where in the early 1990s, Egypt began implementing an economic reform program under the supervision

of the International Monetary Fund. This has led to improvements in some economic indicators. Furthermore, **remittances from Egyptians working abroad** were a key source of foreign currency. In addition, **tourism revenues** during the period of relative stability contributed to an increase in the number of tourists and tourism revenues. However, Rizk (2001) contends that **the shift to a deficit during the period from 1996 to 2000 had several causes, the most significant of which was the increase in imports** where Egypt's heavy reliance on imports to meet domestic needs led to increased expenditures compared to revenues. Additionally, the surplus is attributed to the **weakened exports where** a lack of diversification in the base of exports and their sensitivity to global economic fluctuations were prevailing. Another reason for the surplus was a **decline in tourism revenues** where regional security events and some terrorist incidents affected the flow of tourists. Furthermore, the surplus is attributed to the **rising external debt resulted from** the government's borrowing to cover fiscal deficits and increased interest payments abroad, along with **ineffective economic policies** that did not focus on boosting domestic production or improving the efficiency of export industries. On the other hand, according to the World Bank (2002), the most important reasons for the surplus **from 2001 to 2007 include**: the applications of a set of **economic reforms**; which ignited economic growth; the **increase in exports**, with growth in exports particularly in sectors such as natural gas and manufacturing industries; the **increase in foreign direct investment**, due to improvement in the investment climate and an increase in foreign investment flows; **the recovery of the tourism sector**, with restored confidence in the tourism industry and an increase in the number of tourists; and **the remittances from overseas workers**, as remittances from Egyptians working abroad continued to rose significantly.



Source: EVIEWS program outputs based on World Bank data for the period 1977-2022 Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023)

Figure (2):Current Account Balance (Balance of Payments, Current US Dollars)

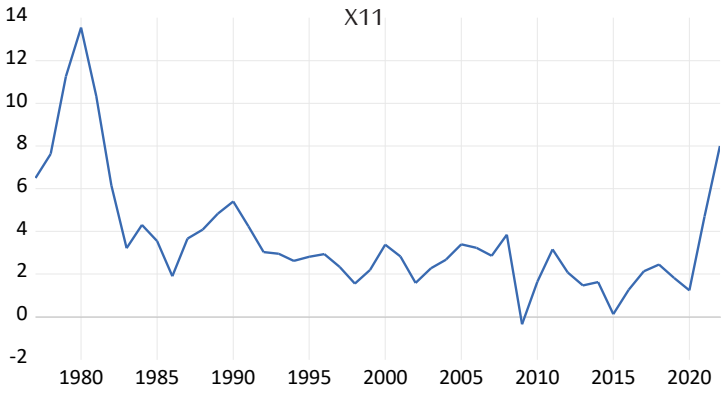
According to Zaki (2011), the reasons for the deficit from 2008 to 2010 include: **the global financial crisis of 2008**, which affected Egypt by reducing foreign investments and exports; **continued heavy reliance on imports**, with Egypt needing imports to meet domestic demand while tourism revenues declined; and **the adverse impact on the tourism sector**, with the tourism industry suffering from the global financial crisis and regional events, leading to an increase in public debt.

The current account deficit increased after 2011 due to political and social unrest (2011-2013), including: **the January 25 Revolution of 2011**, which destabilized Egypt politically and economically, reducing tourism and foreign investments; and **frequent government changes**, which caused further political instability and reduced economic confidence, with the deficit reaching its highest value in 2016. Despite economic reforms in 2016, improvements were minimal until 2022 (Amin et al., 2014).

According to figure (3) (Blanchard et al., 2013), the following can be deduced:

- The period from 1977-1989, particularly the late 1970s and early 1980s, experienced high inflation rates, often referred to as "stagflation", due to oil price shocks, wage-price spirals, and expansionary monetary policies. The Federal Reserve, led by Paul Volcker, aggressively raised interest rates in the early 1980s to combat inflation, leading to a significant economic slowdown but ultimately reducing inflation rates.

- The period from 1990-2000 was characterized by declining and relatively stable inflation due to technological advancements, globalization, and improved monetary policies by the Federal Reserve.
- The economic boom of the 1990s, particularly in the technology sector, played a crucial role in maintaining low inflation rates.
- From 2001-2010, the Federal Reserve's response included significant monetary easing and unconventional policies such as quantitative easing, which helped stabilize prices but resulted in varying inflation rates during the recovery period.



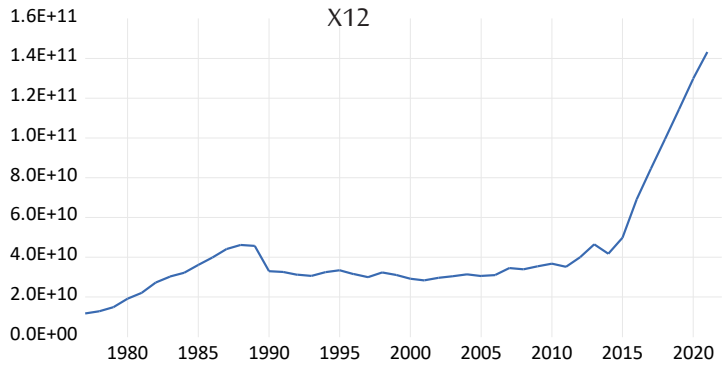
Source: EVIEWS program outputs based on World Bank data for the period 1977-2022 Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023))

Figure (3): Inflation, Consumer Prices (% annually) – United States of America

- During the period from 2011-2022, this period began with low and stable inflation due to moderate economic growth and stable commodity prices. However, the COVID-19 pandemic in 2020 caused significant economic disruptions, supply chain issues, and fiscal stimulus, leading to a sharp increase in inflation rates from 2021 onward.

from the figure (4), the following can be deduced (Abdel-Khalek, 2001):

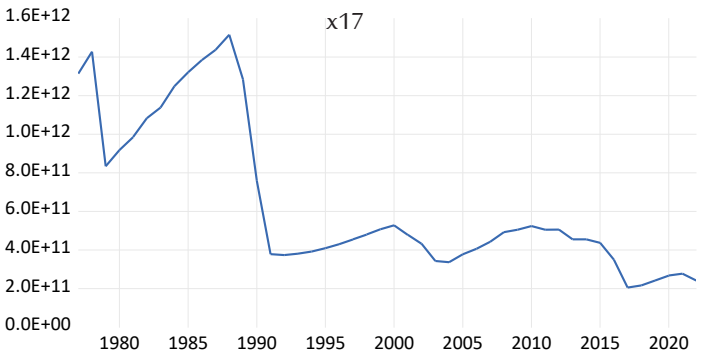
- During the period from 1977-1989, Egypt experienced an accumulation of external debt due to the Economic Openness policy, expansion in infrastructure and major projects, and the impact of fiscal and monetary policies used to finance the budget deficit.
- During the period from 1990-2000, external debt decreased as a result of the Economic Reform and Structural Adjustment Program adopted by the Egyptian government in collaboration with the International Monetary Fund. This included external debt relief (50% of the debt value in 3 phases), debt restructuring, and obtaining concessional loans.
- During the period from 2001-2010, the new millennium saw a gradual increase in external debt due to the financing of infrastructure projects and economic development. Egypt was also affected by the global financial crisis in 2008, leading to a rise in external debt levels to finance the budget deficit and support the economy.
- During the period from 2011-2021, Egypt witnessed a sharp increase in external debt due to the aftermath of the 2011 revolution, the government's need to finance a significant budget deficit and securing international loans to support the economy and development projects. Additionally, the impact of the COVID-19 pandemic led to a substantial increase in borrowing.



Source: EVIEWS program outputs based on World Bank data for the period 1977-2022 Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023))

Figure (4): Total External Debt Stock (Disbursed and Outstanding Debt, Current US Dollars)

According to figure (5), (Abdel-Khalek, 2001), from the previous figure, the following can be deduced:



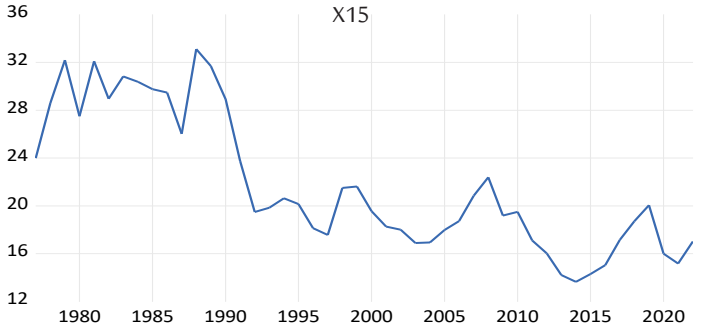
Source: EVIEWS program outputs based on World Bank data for the period 1977-2022 Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023))

Figure (5): Gross Domestic Product (GDP) at Constant Prices in USD

- During the period from 1977-1989, Egypt experienced significant growth in its **Gross Domestic Product (GDP)** at constant US dollars, driven by the economic open-door policy initiated by President Anwar Sadat. This period witnessed major infrastructure projects and increased foreign investment. Additionally, international agreements, such as the peace treaty with Israel, contributed to economic stability.
- From 1990 to 2000, **GDP at constant (US dollars)** initially declined due to the nature of the economic reform program implemented with the International Monetary Fund. However, growth rates gradually recovered and reached their peak in 2000. While this program led to gradual improvements in some economic indicators, it also had negative social impacts. Between 2001 and 2010, GDP at constant US dollars initially decreased until around 2005 but then gradually increased, reaching its peak in 2010. Egypt witnessed significant economic growth during this period, driven by economic reforms and increased foreign direct investment. Infrastructure spending and public services also improved. Despite this growth, challenges such as unemployment and poverty persisted.
- During the period from 2011-2022, there was a gradual decline in **Gross Domestic Product (GDP) at constant prices in USD** until 2016 due to the significant impact of the political events following the 2011 revolution on the Egyptian economy. This period witnessed a decrease in foreign investments and tourism, along with an increase in unemployment and poverty rates. Despite these challenges, a gradual recovery began afterward as the Egyptian government implemented new economic reforms in collaboration with the International Monetary Fund (IMF) to stimulate economic growth and improve the business climate.

According to Figure (6) (Abdel-Khalek, 2001), the following can be deduced:

- During the period from 1977-1989, the Gross Capital Formation (% of GDP) reached its highest level during this period, approximately 32%. Egypt witnessed significant investments in infrastructure and major national projects. The economic policies adopted by Egypt during this time focused on rapid growth through increased government spending and investment.
- During the period from 1990-2000, the period began with a decline in Gross Capital Formation (% of GDP). This period was influenced by the nature of the Economic Reform and Structural Adjustment Program, which started with fiscal reform and demand reduction to address the budget deficit and balance of payments



Source: EVIEWS program outputs based on World Bank data for the period 1977-2022 Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023)

Figure (6): Gross Capital Formation (% of GDP)

deficit. The rate then began to rise, fluctuating between 17% and 23%, due to the economic reform policies that Egypt implemented in collaboration with the International Monetary Fund. These policies reduced government spending, increased the role of the private sector, and financial and monetary reforms helped improve the investment environment but also reduced the volume of direct government investments.

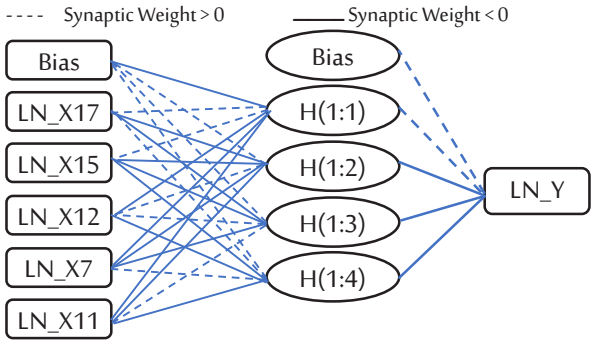
- During the period from 2001-2010, this period began with a decline in Gross Capital Formation (% of GDP) in 2001, which continued until 2004. It then gradually increased until 2007, followed by a gradual decline until 2010 (around 19%).
- This was due to an increase in foreign direct investments and improvements in infrastructure and services.
- The economic reforms that began in the 1990s continued and led to a gradual increase in investments, but global challenges like the global financial crisis emerged.
- During the period from 2011-2022, this period was affected by political events following the 2011 revolution, leading to a decline in Gross Capital Formation (% of GDP) due to reduced investments and capital flight caused by increased economic instability. This continued until the implementation of economic reforms in 2016, which resulted in an increase in Gross Capital Formation (% of GDP), reaching 20% in 2018. However, it declined again due to the COVID-19 pandemic in 2019, and then began to rise in 2021 as the pandemic subsided.

Constructing the Artificial Neural Network:

The neural network consists of three layers: the input layer, the hidden layer, and the output layer. The input layer represents the independent variables and, therefore, consists of 6 neurons corresponding to the number of independent variables plus 1 neuron representing the Buas.

The hidden layer consists of a single layer with 4 neurons plus 1 neuron representing the Buas.

The output layer has one neuron representing the estimated dependent variable.



Hidden layer activation function: Hyperbolic tangent
Output layer activation function: Identity
Source: SPSS22 program outputs based on World Bank data during the period 1977-2022
Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023)

Figure (7): Architectural Structure of the Artificial Neural Network

Training and Testing the Network

The sample size is 46 units, divided into 35 units for training the network, representing 77.8% of the sample size, and 10 units for testing the network, representing 22.2% of the sample size, with one unit missing (due to the unavailability of data for some independent variables for the year 2022)

Activation Functions:

- Activation function for the hidden layer: Hyperbolic tangent
- Activation function for the output layer: Identity

Network Accuracy

The accuracy of the neural network is determined by the following indicators:

Table (1): Training of the Artificial Neural Network:

Case Processing Summary

		N	Percent
Sample	Training	35	77.8%
	Testing	10	22.2%
	Valid	45	100.0%
	Excluded	1	
	Total	46	

Source: SPSS22 program outputs based on World Bank data during the period 1977-2022
Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023)

From table (2), it is clear that:

- The mean squared error is 0.659 in training and 0.199 in testing.
- **The mean percentage error is 0.039 in training and 0.02 in testing.**
- The mean percentage error is 0.039 in training and 0.02 in testing.

Weights

Table (3) It shows the weights between the independent variables and the hidden layer, as well as between the hidden layer and the estimated dependent variable (output layer).

Relative Importance of Variables:

From figure (8), it is evident that: Importance of Each Independent Variable in forecasting the Dependent Variable, the Exchange Rate Relative importance

- Total External Debt (due and disbursed, in current US dollars) Ln_X12 =100%
- Gross Domestic Product (at constant US dollars) Ln_X17=86.4%
- Gross Capital Formation (% of GDP) Ln_X15= 86.1
- Current Account Balance (Balance of Payments, in current US dollars) Ln_X7 =46.5%
- Inflation, Consumer Prices (% annual) — United States Ln_X11 =21.9%

Results and Findings

Artificial neural networks exhibited high accuracy in forecasting, with a mean squared error of 0.659 during training and 0.199 during testing, indicating that the network's accuracy in forecasting the actual exchange rate was approximately 96.1%.

One of the most significant factors influencing the Egyptian Pound's exchange rate is the total external debt (due and disbursed, in current US dollars), with a relative importance of Ln_X12 =100%

Table (2): Indicators of Network Accuracy

Model Summary

Training	Sum of Squares Error	.659
	Relative Error	.039
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.00
Testing	Sum of Squares Error	.199
	Relative Error	.021

Dependent Variable: LN_Y

a. Error computations are based on the testing sample.

Source: SPSS22 outputs based on World Bank Data for the period 1977-2022 (Available athttp://data.albankaldawli.org/indicator (Accessed on 15/12/2023)

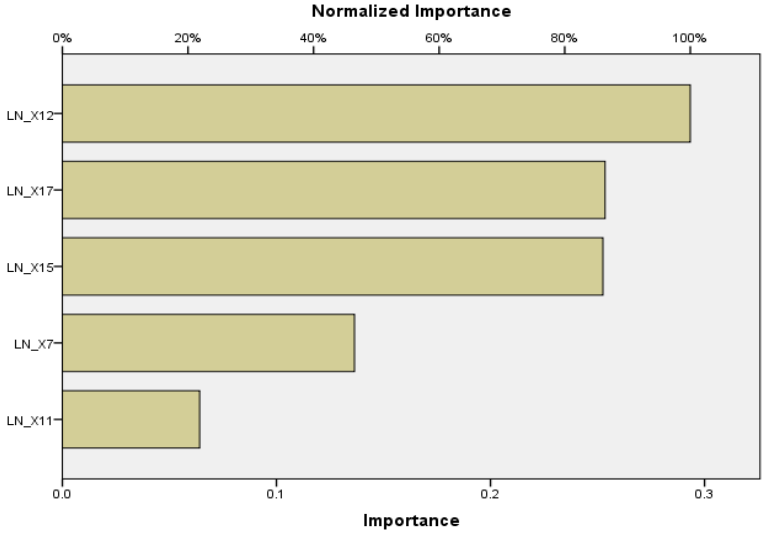
Table (3): Neural Network Weights

Parameter Estimates

		Predicted				
		Hidden Layer 1				Output Layer
Predictor		H (1:1)	H (1:2)	H (1:3)	H (1:4)	LN_Y
Input Layer	(Bias)	-.244-	.004	.082	.319	
	LN_X17	.636	-.096-	-.327-	.092	
	LN_X15	.219	-.411-	-.416-	-.214-	
	LN_X12	-.034-	.181	.597	-.239-	
	LN_X7	-.171-	-.495-	-.336-	.467	
	LN_X11	-.003-	-.028-	.138	-.411-	
Hidden Layer 1	(Bias)					.013
	H (1:1)					.385
	H (1:2)					-.125-
	H (1:3)					-1.005-
	H (1:4)					-.149-

Source: SPSS22 program outputs based on World Bank data during the period 1977-2022

Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023)



Source: SPSS22 program outputs based on World Bank data during the period 1977-2022
Available at http://data.albankaldawli.org/indicator (Accessed on 15/12/2023)

Figure (8): The Relative Importance of Independent Variables in Forecasting the Exchange Rate

Gross Domestic Product (at constant US dollars) Ln_X17 =86.4%

Gross Capital Formation (% of GDP) Ln_X15= 86.1

Current Account Balance (Balance of Payments, in current US dollars) Ln_X7 =46.5%

Inflation, Consumer Prices (% annual) – United States Ln_X11 =21.9%

Recommendations:

To improve the value of the Egyptian pound, attention must be paid to reducing the value of debts, increasing the size of the GDP at constant prices, increasing capital formation as a percentage of the GDP, improving the current account balance, and working to reduce inflation rates.

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