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# Predicting the exchange rate of the Turkish lira against the US dollar using artificial neural networks

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***Abstract*---**The study discusses how to design an artificial neural network to predict the exchange rate of the Turkish lira against the US dollar. Using monthly historical data of the exchange rate and a set of other important macroeconomic indicators (base interest rate and monthly inflation rate). The model relied on a reverse propagation algorithm to train the network, with training repeated over several cycles amounting to 10,000 cycles to ensure improved accuracy of predictions. After the model was built, its performance was evaluated using criteria such as the mean absolute error (MAE) and the square root of the mean error (RMSE) to measure the accuracy of the predictions. Finally, the model was tested. The results showed the strength of the designed neural networks in predicting the exchange rate, where the expected values of the network outputs matched significantly with the actual values, which highlights their effectiveness in providing accurate and reliable predictive insights.

***Keywords*---**exchange rate, ANN, Turkey.

## Introduction

Currency exchange rate forecasting is one of the most prominent challenges facing economists and financial analysts globally, due to its wide-ranging impact on the macroeconomics. In the context of international economic relations, the currency exchange rate plays a pivotal role in determining the strength of the domestic economy and its impact on World Trade. In particular, forecasting the exchange rate of the Turkish lira against the US dollar is of exceptional


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importance, given the geopolitical and economic importance of Turkey, and the heavy dependence on the US dollar in international trade.

Turkey, as a developing and highly developed economy, relies heavily on imports from abroad, especially in vital sectors such as energy and capital goods. Fluctuations in the exchange rate of the lira against the dollar directly affect the cost of imports, which, in turn, is reflected in the prices of goods and services within the country, and directly affects the inflation rate. This volatility also contributes to determining the monetary policy of the Central Bank of Turkey, as exchange rate stability is one of the main goals of maintaining price stability in the country.

In addition, the accurate prediction of the exchange rate of the lira against the dollar has a significant impact on domestic and international investors. Financial markets are highly affected by unexpected fluctuations in exchange rates, which can lead to the withdrawal of foreign investments or a decline in confidence in the domestic economy. On the other hand, the ability to accurately predict these fluctuations gives economic decision makers in Turkey the ability to develop more accurate financial and investment policies that contribute to reducing risks and promoting economic growth.

From a social point of view, sharp fluctuations in the exchange rate of the Turkish lira can affect living standards, as the weakness of the local currency leads to a high cost of living, especially in relation to imported goods such as fuel and food. Thus, an accurate prediction of the future of the Turkish lira exchange rate against the US dollar is an important tool not only for governments and decision makers, but also for companies and individuals who rely on the stability of the currency in planning their future expenses and investments.

In recent years, artificial neural network models have become one of the leading tools in the field of financial forecasting, including forecasting currency exchange rates. These models are characterized by their ability to process huge amounts of data and cope with complex patterns that may not be obvious in traditional analyzes. For the exchange rate of the Turkish lira against the US dollar, artificial neural networks can provide accurate forecasts by analyzing multiple variables, such as macroeconomic data, interest rates, inflation levels, and geopolitical events. These models rely on their ability to learn from previous data and discover nonlinear relationships between variables, which gives them a huge advantage in predicting fluctuations that are difficult to determine using traditional methods. This makes it an effective tool for economic decision makers and investors who seek to make informed decisions based on accurate analyzes of future changes in the exchange rate.

**The Study Problem:**

In light of the constant fluctuations witnessed by the Turkish currency, there is a need for tools and techniques capable of accurately predicting the exchange rates of the Turkish lira against the US dollar. With recent developments in the field of artificial intelligence, especially artificial neural network models, the question arises as to how effective these models are in providing accurate and applicable

predictions. The problem of the study is as follows: Can artificial neural network models accurately predict the exchange rate of the Turkish lira against the US dollar.

**Hypothesis of the study:**

The study assumes that the use of artificial neural network models can achieve higher accuracy in predicting the exchange rate of the Turkish lira against the US dollar compared to traditional methods, through their ability to analyze multiple and variable data and discover non-linear relationships between different economic variables.

**Research methodology:**

In this study, two main approaches were used: the descriptive approach and the analytical approach. The descriptive approach was based on the review and analysis of the literature on the subject of the study, the analytical approach was used to analyze economic data related to the exchange rate of the Turkish lira against the US dollar, the key interest rate, the inflation rate, with the application of artificial neural networks as a predictive model.. The first stage of the study was to list the theoretical framework, but in the applied part, historical data related to the study variables were collected from reliable sources such as the Central Bank of Turkey and financial markets data for the period from [01/01/2014-01/09/2024]. The Alyuda NeuroIntelligence program was also used. In the construction, training and testing of an artificial neural network.

**1. The theoretical framework of the currency exchange rate and its impact on the Turkish economy**

The currency exchange rate is one of the fundamental pillars of the international economic system, determining the value of the national currency against foreign currencies, which directly affects trade and financial relations between countries. For the Turkish economy, the fluctuations of the Turkish lira exchange rate against the US dollar are a decisive factor in determining the cost of imports and exports, as well as in controlling inflation rates and guiding monetary policies. These fluctuations have wide effects on the stability of the Turkish economy, which makes understanding the theoretical framework of the exchange rate necessary to analyze its effects on various economic sectors and develop strategies to reduce the risks associated with it.

**1.1 definition of the exchange rate**

The exchange rate is the rate at which the currency of a particular country is exchanged for the currency of another country, reflecting the relative value of each currency in the financial market." (Krugman, 2018). The exchange rate is defined as the ratio that determines the value of one currency against another, and is considered a key factor in determining the international competitiveness of countries (Mishkin, 2015). The exchange rate is the value on the basis of which a domestic currency is converted into a foreign currency, and reflects multiple influences such as monetary policy and economic factors (Obstfeld, 1996).

**1.2 the importance of the exchange rate in the international economy**

The exchange rate is a key element in balancing international economies, as it affects trade and investment flows, and also contributes to adjusting the monetary policies of countries, and its importance lies in the following points:
- Determination of international competitiveness: the exchange rate plays a decisive role in determining the competitiveness of countries in international trade. The low exchange rate of the national currency can make the country's exports more attractive and less expensive in foreign markets, which enhances its exports and reduces imports. By contrast, a rising currency makes imports cheaper, which can lead to a trade deficit. (Krugman P. &., 2018)
- Influence on the flow of foreign investments: the exchange rate directly affects the decisions of foreign investors. Investments become more attractive in countries with stable or undervalued currencies, since greater profits can be made when the proceeds are retranslated into the original currency of investors. Stability in the exchange rate promotes the outflow of foreign investments and increased confidence in the domestic economy. (Mishkin, Financial Markets and Institution, 2015).
Exchange rates have a prominent role in guiding foreign direct investment (FDI) flows. When the local currency is weak, foreign companies may find an opportunity to purchase local assets at relatively low prices, which encourages increased investments. In turn, exchange rate fluctuations and their instability may be a hindrance for foreign investors, as the fluctuation of currency value increases the financial risks on investments. Making investment decisions requires a thorough understanding of possible changes in exchange rates and their impact on expected returns. (Froot, 1993) .
- Adjusting the internal economic balance: the exchange rate is used as a tool to adjust internal economic imbalances, such as inflation or trade deficits. Countries experiencing high inflation may resort to adjusting the exchange rate to mitigate its effects. Similarly, flexible exchange rates can contribute to a better balance between the supply and demand of foreign currencies in financial markets. (Obstfeld M. &., 1996).

The exchange rate plays a fundamental role in maintaining the macroeconomic stability of the state. Governments often use exchange rates as a tool to stimulate the economy or control inflation. Significant changes in the exchange rate can lead to significant effects on economic growth by affecting the demand for exports and imports. In addition, countries that rely on a fixed or subsidized exchange rate can provide greater stability to the economy, while countries that rely on a flexible exchange rate are exposed to more fluctuations that may affect the local economy ((Author): Edwards, 1998).
- Facilitating international trade: the exchange rate affects the cost of exports and imports between countries, as the prices of international goods and services are determined based on the exchange rate of the local currency against foreign currencies. If the value of the local currency rises, local goods become less competitive on world markets, which leads to a decrease in demand for exports. In turn, currency depreciation enhances the competitiveness of domestic exports, increasing demand for them. On the other hand, the exchange rate also affects the cost of imports, as imported goods become cheaper or more expensive based on the strength of the local currency. (Krugman P. R., 2006)

- Impact on inflation: the exchange rate is a decisive tool in determining the level of inflation in any economy. When the value of the local currency rises, the cost of imported goods decreases, which contributes to lower inflation rates, especially in economies that rely on imports to meet their needs. In turn, a devaluation increases the cost of imports, which raises the prices of domestic goods and services. In this context, governments and central banks resort to the use of monetary policies to adjust the exchange rate in order to control inflation and ensure its stability (Taylor, 2001).
- Improving cash reserves countries with stable and strong exchange rates are usually able to accumulate large cash reserves of foreign currency, which enhances their ability to cope with financial crises. These reserves enable countries to defend their currencies in times of crisis, help them cover external debts and support domestic price stability. Moreover, the accumulation of cash reserves contributes to improving international confidence in the domestic economy, which enhances its ability to borrow at lower interest rates on world markets. (Obstfeld M. S., 2010)
- Support of monetary and financial policies the exchange rate directly affects the monetary and financial policies of the state. When the local currency is under severe downward pressure, the central bank may be forced to raise interest rates or buy the local currency to maintain its value, which may affect economic growth by reducing internal and external investments. In addition, the government can rely on multiple strategies that include controlling the supply of currency to support exchange rate stability. Countries with a stable exchange rate tend to attract more foreign and domestic investments. (Calvo, 2002)
- Strengthening international relations: the stability of exchange rates contributes significantly to the improvement of economic and trade relations between countries. When exchange rates are stable, the risks associated with financial fluctuations are minimized, which strengthens trust between countries and trading partners. In turn, exchange rate fluctuations may lead to trade tensions and instability in world markets. So, countries usually cooperate at the international level to ensure the stability of exchange rates through trade agreements and treaties aimed at minimizing fluctuations in financial markets. (Eichengreen, 2008)

## 2. Factors affecting the exchange rate of the Turkish lira against the US dollar

The exchange rate of the Turkish lira against the US dollar is influenced by several main factors, which are divided into two factors: internal factors, and external factors.

### 2.1 internal economic factors:

The most important internal factors affecting the exchange rate of the Turkish lira include:
- Inflation: inflation is one of the main factors that directly affect the exchange rate of the Turkish lira against the US dollar. High inflation rates in Turkey erodes the purchasing power of the local currency, which contributes to its depreciation against foreign currencies. High inflation makes Turkish products less competitive in world markets, as the cost of production and local prices rise,

which negatively affects the volume of exports. In turn, imported goods become more expensive, which adds more pressure to the balance of payments and weakens the Turkish lira. Moreover, high inflation reflects economic instability, which leads to the exit of foreign investments and a decline in confidence in the local currency. (Dornbusch, 2004)

- Interest rates: interest rates are one of the basic monetary tools used by countries to adjust the value of their currency. In the case of the Turkish lira, the Central Bank of Turkey raises interest rates to attract foreign investments and limit the depreciation of the currency. When interest rates are high, investors get higher returns from their investments, which increases the demand for the Turkish lira and raises its value against the dollar. However, a reduction in interest rates may lead to an increase in liquidity in the domestic market, weakening the lira. In recent years, Turkey has experienced tensions due to conflicting monetary policy, as political pressure on the central bank to cut interest has significantly exacerbated the lira's decline. ((Author): Taylor, 1993)
- Budget deficit: the budget deficit has a significant impact on the stability of the economy and the exchange rate of the local currency. In the case of Turkey, the growing budget deficit increases the risks of inflation and the weakening of the lira against the US dollar. When government expenditures are higher than revenues, the government is forced to borrow to finance the deficit, both from within and from abroad. The heavy dependence on foreign debts leads to an increase in demand for foreign currencies to pay off these debts, which puts pressure on the Turkish lira and pushes it to decline. In addition, a large budget deficit may affect the credit ratings of the state, leading to higher borrowing costs and increasing pressure on the currency. (Alesina, 1995)
- Monetary policies: the monetary policies adopted by the Central Bank of Turkey have a decisive role in determining the course of the Turkish lira exchange rate. The central bank can use a range of monetary tools, such as controlling interest rates and open market operations, to influence the value of the local currency. In cases of high inflation or budget deficits, the central bank may raise interest rates to attract foreign investment and relieve pressure on the lira. But, on the other hand, if monetary policy relies on increasing the money supply or reducing interest to support economic growth, this can lead to a depreciation of the lira. In Turkey, monetary policies have experienced significant fluctuation, which has significantly affected the stability of the currency. (Mishkin F. S., 2007).
- Foreign capital inflows: foreign capital inflows directly affect the exchange rate of the Turkish lira. When Turkey attracts foreign investments, both in the form of direct and indirect investments, the demand for the lira increases, which enhances its value. On the other hand, the exit of capital from the country may lead to a sharp depreciation of the lira. Recently, Turkey has witnessed volatile capital inflows as a result of political and economic changes, which has made the lira vulnerable to large fluctuations. Foreign investors tend to withdraw their investments in cases of political or economic instability, which leads to an increase in demand for the US dollar and a devaluation of the lira. (Calvo G. A., 1996)
- External debt: the increase in External Debt represents a significant burden on the Turkish economy and directly affects the exchange rate of the lira. With the increasing need to repay the debt in foreign currency, the demand for the US dollar is increasing, which weakens the Turkish lira. In recent years, Turkey's external debt has risen significantly, which has increased the pressure on the lira

exchange rate. In addition, rising debt may lead to a decline in international investors ' confidence in the Turkish economy, which increases capital outflows and further devalues the currency. The lira is also under further pressure when Turkey's borrowing costs rise due to a weak credit rating and increased international interest rates.. (Reinhart, 2010)

- **Political and economic conditions**: the Turkish lira is greatly affected by the internal political and economic conditions. Political instability, whether caused by elections, internal conflicts or geopolitical tensions, undermines confidence in the Turkish economy, prompting foreign and domestic investors to withdraw their investments. This leads to a depreciation of the lira against the dollar. Also, economic conditions such as high inflation, budget deficit, high unemployment lead to a weakening of confidence in the local currency. As a result, the lira is under significant pressure in global financial markets, which makes it more vulnerable to fluctuations and depreciation against the US dollar.. (Aisen, 2013)

**2.2 External factors:**

The most important external factors affecting the exchange rate of the Turkish lira include:

- US economic policies: the economic policies adopted by the United States, such as the Federal Reserve's policies on interest rates, directly affect the exchange rate of the Turkish lira. When the US Federal Reserve raises interest rates, the demand for the US dollar as a safe and profitable currency for international investors is growing. This leads to an outflow of capital from emerging markets such as Turkey to the United States, which weakens the value of the Turkish lira against the dollar. In addition, expansionary monetary policy in the United States may increase demand for Turkish goods and services, which may support the lira in the short term, but sharp increases in US interest often put pressure on foreign currencies.. (Clarida, 2010).
- World oil prices: being a large importer of oil, any fluctuations in world oil prices directly affect the exchange rate of the Turkish lira. When oil prices rise, it increases Turkey's energy import bill, which puts pressure on the balance of payments and increases the demand for U.S. dollars to pay those bills. This leads to a devaluation of the Turkish lira. On the contrary, when oil prices fall, the cost of imports decreases, which relieves pressure on the local currency. However, the high dependence on energy imports makes Turkey vulnerable to price fluctuations on world markets, which increases the sensitivity of the lira to external changes. (Kilian, 2008).
- Global trade and economic sanctions: changes in global trade and economic sanctions imposed on Turkey directly affect the exchange rate of the lira. When other countries impose sanctions on Turkey, as happened during political disputes with the United States, this leads to a decrease in demand for Turkish exports and restricted access to international markets, which reduces the flow of hard currency and weakens the lira. In addition, global trade tensions affect the lira indirectly through the decline in business activity, as the decline in global demand leads to a decline in export earnings and increases the pressure on the local currency.. (Oatley, 2019)
- Fluctuations of the global financial markets: fluctuations in the global financial markets significantly affect the exchange rate of the Turkish lira. Emerging markets such as Turkey are often affected by global capital flows, as investors

tend to buy safer currencies and assets in times of global financial crises, which leads to an outflow of capital out of Turkey and a depreciation of the lira. For example, major financial crises such as the global financial crisis in 2008 or the covid-19 crisis negatively affected the exchange rate of the Turkish lira due to the withdrawal of foreign capital, which significantly deteriorated its value against the US dollar. (Forbes, 2012)

- Geopolitical crises: geopolitical crises in the region around Turkey significantly affect the exchange rate of the lira. Turkey is located in a politically sensitive geographical region, where regional conflicts, such as the conflict in Syria or tensions with Russia, increase political and economic risks. These crises affect foreign investment flows to Turkey and lead to a decrease in confidence in financial markets, which increases the pressure on the lira. When geopolitical crises worsen, investors tend to seek safe havens such as the US dollar, which increases the demand for foreign currencies and leads to a depreciation of the lira. (Roubini, 2004)
- Monetary policy of global central banks: the monetary policies pursued by the central banks of major countries, such as the European Central Bank and the US Federal Reserve, directly affect the value of the Turkish lira. For example, when the Federal Reserve raises interest rates, investors turn to the US market in search of higher yields, which reduces the attractiveness of Turkish assets and pushes the lira to decline. In addition, the ECB's moves to ease or tighten monetary policy affect capital flows between the European markets and Turkey, given the strength of trade and investment relations between the EU and Turkey.. (Rey, 2015).
- Regional economic factors: the economic growth in the neighboring countries of Turkey significantly affects the exchange rate of the lira. Turkey is heavily dependent on exports to the EU and Middle Eastern countries, and any economic slowdown in these countries affects the demand for Turkish products, which leads to a decrease in dollar revenues. For example, the economic crisis in the European Union negatively affected Turkish exports, which increased the pressure on the lira. In addition, economic fluctuations in neighboring countries such as Iran and Syria lead to a reduction in trade and investment activity with Turkey, which further deteriorates the value of the currency. (Frankel, 1998)

## 3. The application of artificial neural networks in predicting the exchange rate of the Turkish lira against the dollar

The application of artificial neural networks in predicting the exchange rate of the Turkish lira against the US dollar is one of the effective tools based on historical data and economic patterns. These networks rely on a deep learning model to analyze data on exchange rates, as well as other economic factors such as interest rates, inflation rates, and macroeconomic data.

### 3.1 introduction to the concept of artificial neural networks

Artificial neural networks (Artificial Neural Networks) are computational systems inspired by the networks of neurons in the human brain, used to digitally simulate human mental processes. These networks consist of small computational units known as neurons or nodes, which are connected to each other via weights that can be adjusted. These cells are organized into layers: the

input layer that receives the initial data, the hidden layers that process the information, and the output layer that produces the final result. The learning of these networks is based on an algorithm called "reverse propagation" (Backpropagation) that makes weights based on the difference between the expected and real outputs. Over time, the network adapts to become more accurate in data processing and analysis. (Goodfellow, 2016)

One of the fundamental aspects that make artificial neural networks unique is their ability to adaptively learn from data without direct human intervention in programming the rules. This is what distinguishes it from traditional algorithms, in which neural networks can constantly improve themselves by gaining knowledge from the available data. These networks are able to detect patterns invisible to humans, making them a powerful tool in multiple fields, such as image recognition, natural language processing, and economic forecasting. Moreover, the ability to work with large and complex data makes it ideal for advanced artificial intelligence applications. (Schmidhuber, Neural Networks (Volume): 61)

With advances in technology, especially in cloud computing capabilities and the increasing availability of Big Data, deep neural networks have become able to solve problems that were previously considered unsolvable by traditional models. Deep neural networks contain multiple layers of neurons that allow them to learn more abstract representations of data. Thanks to these characteristics, these networks have been able to make remarkable breakthroughs in areas such as face recognition, machine translation, and self-driving cars. Thus, neural networks have become one of the key tools in the current revolution in the field of artificial intelligence. (LeCun, 2015).

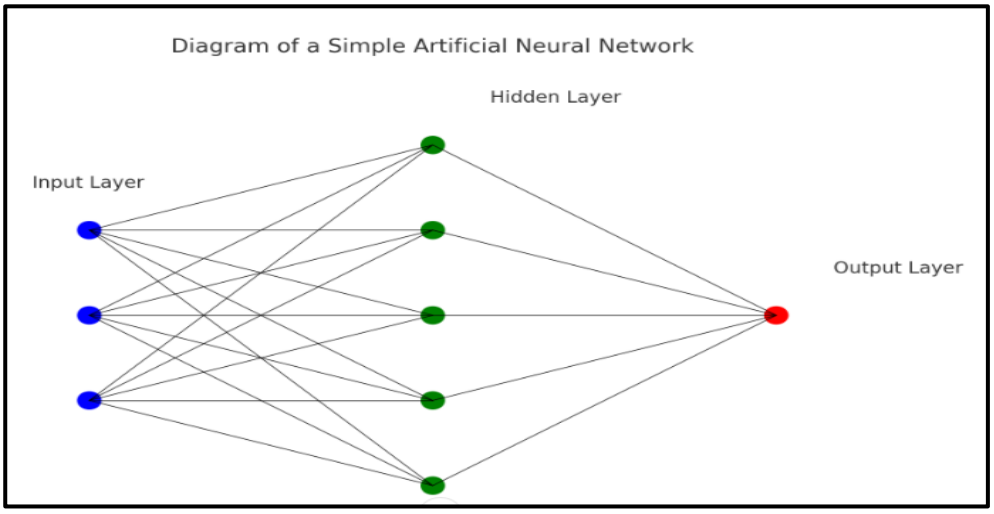



Figure No. 01: simple design of an artificial neural network
Source: Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.

The Shape of the artificial neuron can be illustrated as follows:

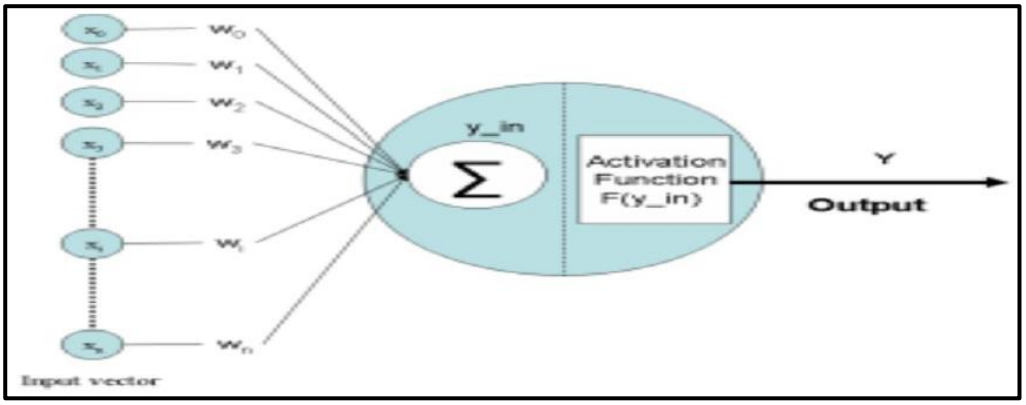



Figure No. 02: simple design of an artificial neuron
Source: Grosan, C. A. (2011). Intelligent Systems A Modern Approach. springer p 284

An artificial neuron is defined as a basic information unit that collects inputs, represented by the information it receives from the neurons connected to it, and then the collection of inputs produces a certain value called the threshold, processed by the activation function, to output the result in the form of a digital value expressing the value of the neuron's activity. (Grosan, 2011)
"The artificial neuron is formed from:
* Neuron input.
* Mesh weight."
* Activation function

### 3.2 characteristics of neural networks that make them suitable for forecasting exchange rates

Artificial neural networks have unique properties that make them suitable for predicting exchange rates, especially in the dynamic and volatile environment of financial markets. The following are three paragraphs that illustrate these characteristics, with references:
- Ability to handle large and complex data: artificial neural networks are characterized by their ability to analyze large and multidimensional data, a crucial characteristic in predicting exchange rates that are influenced by a variety of economic and political factors. These networks can recognize patterns and hidden relationships between different variables in data that are difficult to detect using traditional methods. Furthermore, neural networks are capable of processing sequential temporal data such as daily or monthly exchange rates and analyzing historical patterns to predict future prices (Schmidhuber J. , 2015).
- Flexibility and adaptation to changes in the market one of the most important characteristics of neural networks is their high flexibility, which allows them to adapt to sudden changes in financial markets. This is extremely important in the field of forecasting exchange rates, since the factors affecting the value of currencies are constantly changing, including monetary policies, economic crises, and global capital movements. Thanks to deep learning algorithms, neural

networks are able to continuously adjust the weights of connections between neurons based on new data, which enables them to improve the accuracy of forecasts and adapt to changes in real time.

- The ability to generalize and prevent over-customization

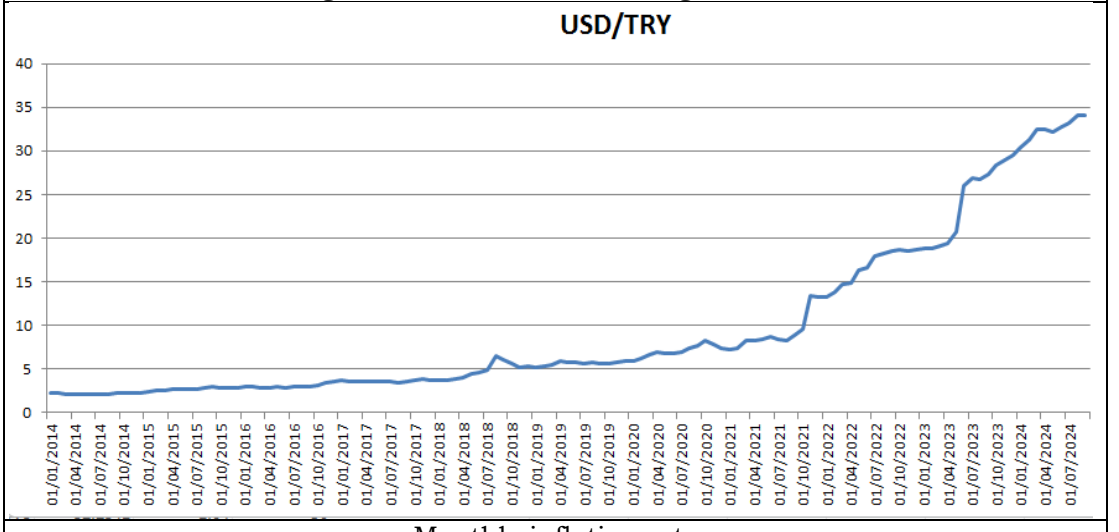
Another property that makes neural networks suitable for predicting exchange rates is their ability to generalize. Neural networks not only rely on the data on which they were trained, they are able to generalize the acquired patterns to new, invisible data. This helps in predicting future exchange rates more accurately even when economic conditions change. In addition, networks use techniques such as "regularization" to avoid the problem of over-allocation (Overfitting) that occurs when models become too sensitive to fluctuations in historical data, which increases their accuracy in predicting long-term exchange rates.

### 3.3 economic variables adopted in the model.

The following variables were relied upon to be inputs into the artificial neural network model: inflation rates, interest rates, historical exchange rate data. This is based on monthly historical data from the period 01/01/2014 to 01/09/2024, bringing the number of views to 129.

The following figure shows the evolution of the historical data of the study variables:

The exchange rate of the Turkish lira against the US dollar




Monthly inflation rate

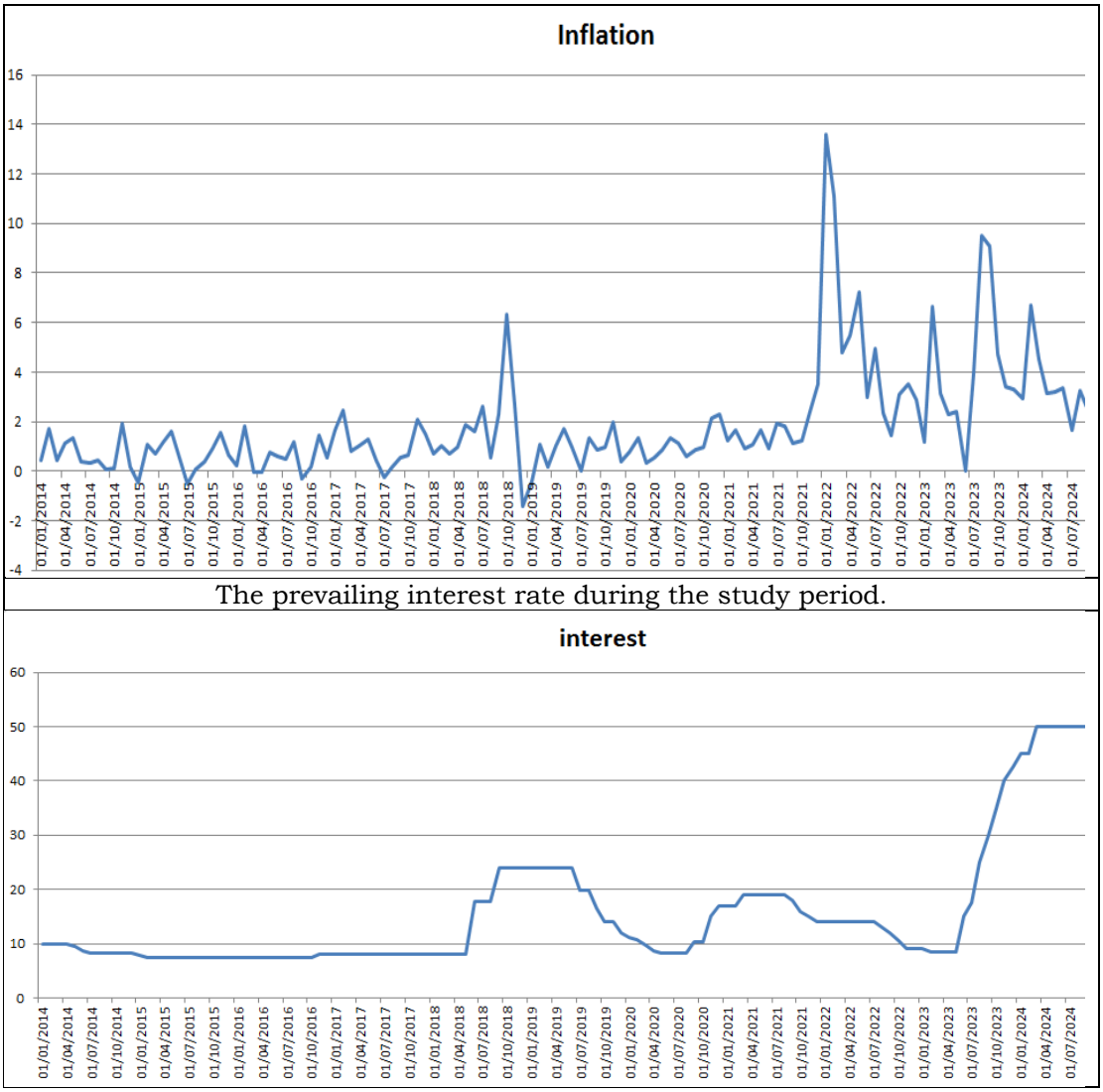



Figure No. 03: evolution of historical data for the study variables
Source - :https://sa.investing.com/currencies/usd-try

The exchange rate of the Turkish lira against the US dollar has witnessed significant fluctuations, reflecting the economic and political challenges faced by the country. We summarize this as follows:

2013-2015-in this period, the Turkish lira began to experience stresses as a result of geopolitical and economic crises. The country experienced a decline in confidence as a result of political tensions, which led to a weakening of the currency. At the end of 2014, the US dollar began to rise against the lira, the exchange rate reached about 2.3 lira per dollar.

2016 this year was decisive, as it witnessed an attempted coup in July, which led to a sharp decline in the value of the lira. The government responded with political and economic measures, but the currency continued to deteriorate, hitting record highs, approaching 3 lira per dollar at the end of the year.

2017-2018 in this period, the lira experienced further deterioration due to increased inflation rates and unconventional monetary policies. Tensions with the United States led to increased pressure on the currency, as the exchange rate exceeded 4 lira per dollar in mid-2018.
2019-2021 the COVID-19 pandemic worsened the economic situation, as the lira recorded a further decline. Turkey suffered a deterioration in foreign exchange reserves, which negatively affected investor confidence. The exchange rate reached about 8 liras per dollar by the end of 2021.
2022 - 2023: pressures on the lira continued as a result of economic challenges, including high inflation rates and declining confidence in economic policies. However, some new government measures, such as the introduction of guarantees on deposits in local currency, began to be aimed at restoring confidence.
As for inflation rates, Turkey has experienced high inflation rates, ranging from 6% to 25%, with a sharp increase in some periods. We summarize them in the following points:
2013-2015: inflation rates were relatively moderate, ranging between 7% and 8%, but began to rise gradually.
2016-2018: the country experienced significant jumps, with inflation recorded around 15% in 2017 and 18% in 2018, which affected purchasing power.
2019-2021: inflation rose sharply, exceeding 20% in 2021, as a result of the effects of the COVID-19 pandemic and repeated economic crises.
* 2022-2023: inflation continued to rise, reaching record levels of more than 70% in 2022, which significantly affected the prices of goods and services.
For interest rates have experienced significant fluctuations, as interest rate hikes have been used as a tool to counter inflationary pressures. However, inconsistent monetary policies have exacerbated economic crises and exchange rate instability. The evolution of interest rates can be summarized as follows:
2013-2015: in this period, interest rates were relatively high, ranging from 4% to 8%. In order to control inflation and support financial stability.
2016-2018: interest rates witnessed a significant increase, reaching about 16% in 2018, due to increasing inflationary pressures and political tensions. The central bank has made decisions to raise interest rates to counter the deterioration of the lira.
• 2019-2021: interest rates continued to rise, with the key interest rate reaching 19% in 2020, as the central bank tries to curb inflation and restore confidence in the currency.
2022: this year witnessed significant fluctuations, as interest rates were cut despite high inflation, which increased pressure on the lira and raised inflation rates to record levels.
2023: unconventional monetary policies continued, as interest rates were relatively low compared to inflation rates, which led to exchange rate instability and increased economic pressures.

**4. Building the appropriate artificial neural network:**

The stage of building an artificial neural network goes through specific stages, namely: the identification of inputs and outputs, the analysis stage, the design stage, the training stage, the testing stage

**4.1 identification of inputs and outputs:**

The first step in building an artificial neural network for the purpose of forecasting is to determine the inputs and outputs, where the output was determined by the exchange rate of the Turkish lira against the US dollar during the period t, and the inputs of the network are the previous prices of the exchange rate and were determined by two periods, due to the strong correlation linking the current price with previous prices, in addition to the monthly inflation rate, and the main interest rate prevailing during the period T.

**4.2 analysis stage**

At this stage, the training group, the confirmation group, and the test group are determined. Using the Alyuda NeuroIntelligence program, we obtained the following results:

Table No. 01: results of the analysis process

| | Training group | Confirmation group | The test group | Excluded anomalous values | Total data |
|---|---|---|---|---|---|
| Number | 87 | 20 | 20 | 2 | 129 |
| Percentage | 67.45% | 15.50% | 15.50% | 1.55% | 100% |

Source: prepared by the researchers based on the outputs of Alyuda NeuroIntelligence

The data based on the program Alyuda NeuroIntelligence were randomly hashed, and the data in the network were represented in binary form (0.1), for the output layer, the representation is bipolar (-1. 1) for the input layer.

4.3 design stage

At this stage, the logistic logistic function was relied on as a stimulus function in the hidden layer and the output layer, and relying on the Alyuda NeuroIntelligence program, a group of designs were nominated for forecasting and it turned out that the optimal design based on the error reduction criterion is: (4-10-10-10-10-10-10-1)

The network consists of five hidden layers, each layer contains 10 neurons, and the network is shown as follows

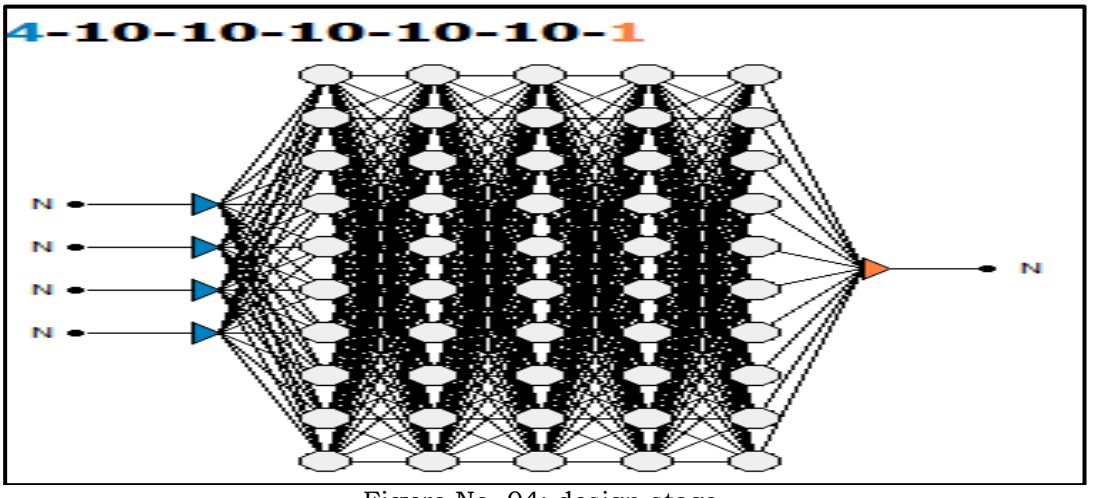



Figure No. 04: design stage
Source: prepared by the researchers based on the outputs of Alyuda NeuroIntelligence

### 4.4 training phase

The reverse propagation algorithm was relied on. This is the most common algorithm for training neural networks, as it is used to update the weights based on the error in the output. The following are the stages of the network training process

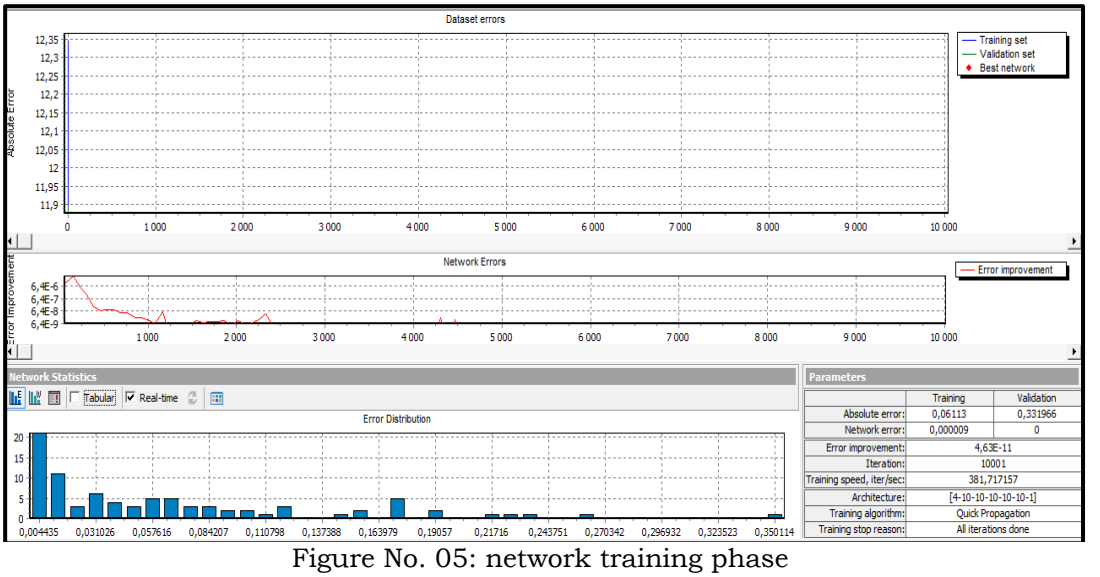



Figure No. 05: network training phase
Source: prepared by the researchers based on the outputs of Alyuda NeuroIntelligence

The results show that the network errors and their distribution decrease with an increase in the number of training repetitions, which reached a value of 10,000

times, which indicates that the designed network was well trained and reached a statistically acceptable level for prediction.

### 4.5 testing phase

The following figure shows the results of the network testing process by comparing the output values obtained from the artificial network with the real values and the results are shown in the following figure:

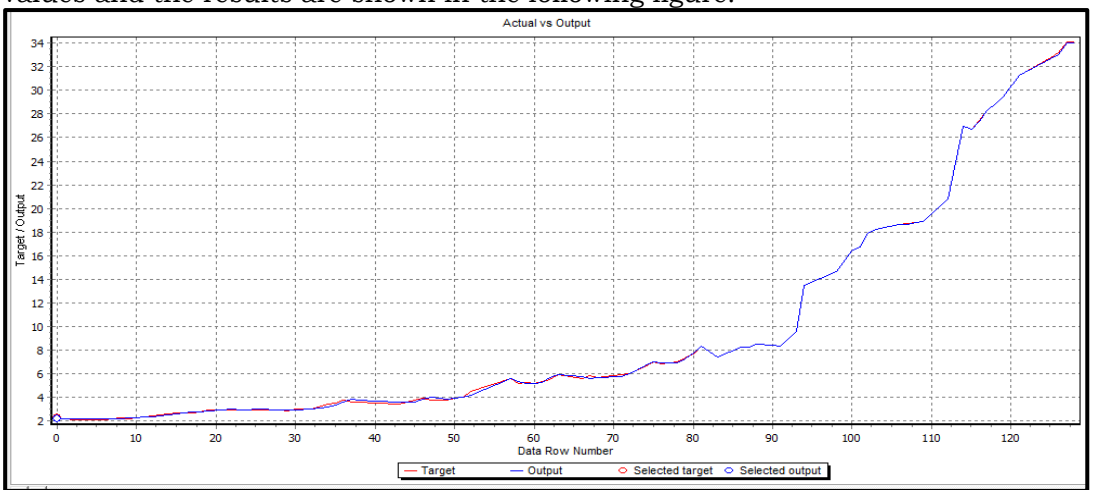



Figure No. 06: network test phase
Source: prepared by the researchers based on the outputs of Alyuda NeuroIntelligence

From the figure, we find that the output values largely coincide with the original values, as the two figures are almost identical, and from it turns out that the designed artificial neural network is good and reliable in the matter of identification.

## 5. Forecasting the exchange rate of the Turkish lira based on the designed network

Using the network designed and proven effective to predict the exchange rate of the Turkish lira against the US dollar during the subsequent period, using the expected values of both the interest rate and the inflation rate, and using the previous values of the exchange rate during two previous periods, as the Central Bank of Turkey expects rates to decline during the last third of 2024 to reach 1.5% on a monthly basis, while it will keep the key interest rate at its current levels of 50%, so based on these data, the average exchange rate of the Turkish lira against the US dollar can be expected during October of 2024 . The results are shown in the following table:

Table No. 02: Prediction phase

| Monthly inflation expected during October 2024 | Key interest rate expected during October 2024 | Exchange rate during September 2024 | Exchange rate during the month of August 2024 | Expected exchange rate during October 2024 |
|---|---|---|---|---|
| 1.5% | 50 % | 34.0711 | 33.1808 | 34.007 |

Source: prepared by the researchers based on the outputs of Alyuda NeuroIntelligence

The results show that if the forecasts of the Turkish central bank for both the interest rate and the inflation rate are true during October, the exchange rate of the Turkish lira will stabilize within 34 lira per 1 US dollar during the same month.

## 6. Conclusion

Artificial neural networks are the most advanced tools in the field of economic forecasting. This technology is considered one of the advanced applications of machine learning, which makes it capable of analyzing big data and dealing with complex relationships that may be difficult to understand by traditional methods. These models provide great flexibility in adapting to various economic variables, which makes them highly valuable in improving financial decision-making and risk management strategies.

In this study, historical data was used for both inflation and the interest rate, in addition to the previous values of the Turkish lira exchange rate during two time periods. The monthly data was used from the period 01/01/2014 to 01/09/2024, which amounted to about 129 views .As an input to the network in order to predict the exchange rate of the Turkish lira. The result was that the ideal network structure for forecasting is (1-10-10-10-10-10-4), the output of which significantly corresponded to the actual values of the exchange rate . By using the forecasts of the Central Bank of Turkey for the interest rate and inflation rate during October 2024, as well as the exchange rate for both September and August of 2024 as inputs, the network gave a forecast for the exchange rate for October of 34.007 Turkish lira to 1 US dollar, i.e. stability in the exchange rate during October . It shows that the use of neural networks can provide greater predictive accuracy in the exchange rate of the Turkish lira against the US dollar .Compared to traditional statistical models, due to their ability to learn from historical data and adapt to nonlinear changes. However, the prediction results remain influenced by many factors, such as the quality of the data used, the network design and the mathematical models adopted. Thus, there remains a lot of room for improvement and development by working on improving deep learning algorithms and combining them with other technologies such as hybrid models to improve the accuracy of predictions.

Moreover, the use of artificial neural networks in this context opens the door for further applied research, not only in the field of currency forecasting, but in a wide range of financial and economic fields. The continuous advances in artificial intelligence technologies and the increasing availability of data reinforce the

importance of these tools in enabling financial institutions and governments to make more evidence-based decisions.

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