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Modelling the Imports and Exports Data of Türkiye Employing Autoregressive Artificial Neural Networks

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Abstract*— Modelling imports and exports data is crucial for understanding and forecasting economic trends, as it helps policymakers and businesses make informed decisions on trade policies and strategies. Accurate models can reveal underlying patterns in trade flows, enabling better management of economic stability and growth. This study presents the modelling of Türkiye's total imports and exports using artificial neural networks (ANNs). The data, obtained from official sources, exhibited significant nonlinearity and non-stationarity, prompting the development of an ANN with three hidden layers, each containing ten neurons. The autoregressive ANN model utilized lagged values of imports and exports as inputs, and was trained separately for both datasets. The training process converged after 686 epochs for exports and 522 epochs for imports, demonstrating the model's effectiveness. The comparison of actual data with ANN predictions revealed a high level of accuracy, further validated by performance metrics such as the coefficient of determination, mean absolute percentage error, mean absolute error, and root mean square error. With coefficients of determination exceeding 0.85, the model's accuracy and robustness were confirmed. Notably, the same ANN architecture was employed for both imports and exports, highlighting the model's versatility. The study suggests that the developed autoregressive ANN model is applicable to other time series data characterized by strong nonlinearity.

Keywords*— Imports, exports, autoregressive, artificial neural networks, modelling.

I. INTRODUCTION

The economic landscape of Türkiye has been shaped by a complex interplay of various factors, with import and export activities standing at the core of its economic growth and development. As a nation straddling Europe and Asia, Türkiye occupies a strategic geographical position that has historically made it a vital hub for trade. Over the past few decades, Türkiye's economic policies and international trade agreements have increasingly integrated the country into the global economy, making imports and exports critical components of its economic framework. The importance of these activities cannot be overstated, as they significantly contribute to Türkiye's GDP, employment, and overall economic stability. Türkiye's journey towards becoming a prominent trading nation has deep historical roots. The country has been a key player in trade for centuries, dating back to the Silk Road era when it served as a bridge between the East and West. However, the modern structure of Türkiye's import and export activities began to take shape in the 20th century, particularly after the establishment of the Republic of Türkiye in 1923. The early years of the republic were marked by a focus on industrialization and self-sufficiency, with import-substitution policies aimed at reducing dependency on foreign goods.

Imports have played a crucial role in Türkiye’s economic development, providing the country with access to raw materials, intermediate goods, technology, and consumer products that are not available or are produced insufficiently domestically. These imports are essential for various sectors, including manufacturing, construction, and agriculture, which rely on foreign inputs to produce goods and services that meet both domestic and international demand. One of the primary reasons imports are vital to Türkiye’s economy is the country's limited natural resources. For instance, Türkiye is heavily reliant on imports for energy, particularly oil and natural gas, which are critical for its industrial sector and overall economic activities. The dependence on energy imports has shaped Türkiye’s trade policies and its relations with energy-rich countries, influencing everything from diplomatic ties to foreign investment strategies. In addition to energy, Türkiye imports a

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significant amount of machinery, electronics, and chemicals, which are necessary for its manufacturing sector. This sector is a cornerstone of Türkiye's economy, contributing to a large portion of its GDP and employment. The availability of imported machinery and technology enables Turkish manufacturers to produce high-quality goods that are competitive in international markets, thereby supporting the country's export-oriented growth model.

Consumer goods constitute another significant portion of Türkiye's imports. As the Turkish economy has grown and the standard of living has improved, the demand for foreign goods has increased. This includes everything from automobiles to electronics and luxury items, reflecting the growing consumer base and the integration of global consumer culture in Türkiye. The importance of imports is also evident in Türkiye's supply chain dynamics. Many Turkish industries operate within global supply chains, where components and raw materials are sourced from different countries, assembled or processed in Türkiye, and then exported to other markets. This interconnectedness makes imports indispensable to the functioning of these industries, highlighting the critical role that international trade plays in sustaining Türkiye's economic activities.

Exports are equally important to Türkiye's economy, serving as a key driver of economic growth, employment, and foreign exchange earnings. The diversification and expansion of export markets have been central to Türkiye's economic strategy, particularly since the 1980s. Turkish exports have evolved from primarily agricultural products in the mid-20th century to a diverse mix of goods and services, including textiles, automobiles, machinery, and electronics. The textile and apparel industry has historically been one of Türkiye's leading export sectors. Turkish textiles are renowned for their quality and have established a strong presence in European and Middle Eastern markets. This sector not only generates significant export revenue but also provides employment for millions of workers, particularly in regions where other economic opportunities may be limited.

In recent years, the automotive industry has emerged as a major contributor to Türkiye's export portfolio. Türkiye has become a key production hub for several global automobile manufacturers, producing a wide range of vehicles that are exported to markets across Europe, Asia, and beyond. The success of the automotive sector illustrates Türkiye's ability to compete in high-value industries and its integration into global value chains. In addition to goods, Türkiye has also developed a robust services export sector, particularly in tourism and construction. Tourism is one of Türkiye's most important industries, attracting millions of visitors each year to its historical sites, beaches, and cultural landmarks. The revenue generated from tourism exports is a significant source of foreign exchange, contributing to the country's economic stability. Similarly, Turkish construction companies have established a strong presence in international markets, particularly in the Middle East and Africa, where they are involved in large-scale infrastructure projects.

The importance of exports to Türkiye's economy is further underscored by the role they play in addressing the country's trade deficit. Türkiye has historically run a trade deficit, where the value of imports exceeds the value of exports. To mitigate this deficit and reduce dependency on foreign capital, successive Turkish governments have pursued policies aimed at boosting exports. This has included the promotion of export-oriented industries, the negotiation of free trade agreements, and the provision of incentives for exporters. Global trade policies and agreements have had a significant impact on Türkiye's import and export activities. As a member of the World Trade Organization (WTO) and a candidate for European Union (EU) membership, Türkiye has benefited from access to global markets and the reduction of trade barriers. The Customs Union agreement with the EU, which came into effect in 1995, has been particularly influential, allowing Turkish goods to enter the EU market without customs duties and aligning Turkish regulations with EU standards.

This agreement has facilitated the growth of Türkiye's exports to the EU, which is its largest trading partner. However, it has also posed challenges, particularly in terms of competition with EU producers and the need to comply with stringent regulatory requirements. Despite these challenges, the Customs Union has been a cornerstone of Türkiye's trade policy, contributing to the modernization of its industries and the diversification of its export base. In addition to its relationship with the EU, Türkiye has pursued free trade agreements (FTAs) with a number of countries and regions, including the European Free Trade Association (EFTA), South Korea, and the Middle East. These agreements have opened up new markets for Turkish exports and provided Turkish consumers with access to a wider range of imported goods at competitive prices. Türkiye's strategic location has also positioned it as a key player in regional trade initiatives, such as the Belt and Road Initiative (BRI) led by China. As part of the BRI, Türkiye aims to enhance its connectivity with Asia, Europe, and Africa through the development of infrastructure and trade corridors. This initiative is expected to further boost Türkiye's import and export activities by facilitating the flow of goods and services across these regions. Despite the significant

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contributions of imports and exports to Türkiye's economy, the country faces several challenges in its trade sector. One of the primary challenges is the persistent trade deficit, which has been a source of economic vulnerability. The trade deficit is driven by Türkiye's reliance on imports for energy and raw materials, as well as the competitive pressures in international markets. Managing this deficit requires a careful balance between promoting exports and controlling imports, while also addressing structural issues such as the energy dependency and the need for technological innovation. Another challenge is the volatility of global markets, which can have a significant impact on Türkiye's trade activities. Fluctuations in global demand, changes in commodity prices, and shifts in exchange rates can all affect the competitiveness of Turkish exports and the cost of imports. The global economic environment, including trade tensions between major economies, also poses risks to Türkiye's trade sector, particularly in terms of access to markets and the stability of trade relationships. However, there are also significant opportunities for Türkiye to enhance its position in the global economy through trade. One opportunity lies in the diversification of export markets. While the EU remains Türkiye's largest trading partner, there is potential for growth in other regions, particularly in Asia, Africa, and Latin America. Expanding into these markets can help reduce Türkiye's dependence on traditional markets and mitigate the impact of regional economic downturns.

Innovation and technology also present opportunities for Türkiye's trade sector. By investing in research and development (R&D) and adopting advanced technologies, Türkiye can enhance the competitiveness of its industries and move up the value chain. This can lead to the production of higher-value goods and services, which can command higher prices in international markets and contribute to reducing the trade deficit.

Considering the importance of import and export volumes of Türkiye on the economic stance, there exist vast number of studies regarding the import and export capacity of Türkiye. For example, Yilmaz and Kaya investigated the relationship among import, export and currency rates for Türkiye using a vector autoregressive approach and they have concluded that the changes in the real effective currency rate does not have meaningful effect on the trade deficit in Türkiye [1]. Kizildere *et al.* also investigated the foreign trade volume of Türkiye on the currency rate for the 1980-2010 year range employing cointegration methods and have also concluded that the currency rate does not have significant effect on the trade volume [2]. Erden and Saglam utilized autoregressive distributed lag (ARDL) error correction model for the investigation of the import and export of Türkiye for the 1989-2008 range and they have concluded that there exists negative correlation between the currency rates and the import of investment goods [3]. In another work, Tatlici and Kiziltan utilized gravity model for the analysis of Turkish export volume for the 1994-2007 range and they have shown that the gross domestic products of the trade partners have positive effect on the export volume of Türkiye [4]. Aysun *et al.* have studied the effects of the Customs Union (CU) on Turkish trade volume using 1980-2009 data and they have found out that CU agreement has positive effect on import volume and does not have insignificant effect on the export volume [5]. In another work, Aktas have used Granger causality among import volume, export volume and economic growth in Türkiye for the period of 1996-2006 and it is shown that there exists causality relationship among these variables [6]. Altintas also utilized VAR analysis and Granger causality tests for the assessment of the relationship among foreign direct investments (FDI), export and import volume of Türkiye for the period of 1996-2007 and it is concluded that there exists complementary relationship between FDI and trade volume [7]. Kocak and Ozmen performed econometric estimation of the import function of Türkiye employing Johansen maximum likelihood method and it is demonstrated that elasticity of import volume to the GDP is high [8].

Gul and Ekinci investigated the relationship between the real exchange rates and foreign trade volume using bivariate Granger causality test for Türkiye for the 1990-2006 period and it is concluded that there exists a cointegrating relationship between foreign trade and real exchange rates [9]. Gunduz and Esengun analyzed the impact of CU on the foreign trade between Türkiye and EU using statistical tests for the 1987-2003 period and it is demonstrated that the import volume of Türkiye is strongly affected by the CU compared to the export volume of Türkiye [10]. Bozdaglioglu also analysed the import and export volume of Türkiye using cointegration tests and it is shown that imports and exports do not have tendency to converge in the long term [11]. Tuncer explored the dynamic causal relationships between GDP, exports, imports, and investments in Türkiye between 1980-2000 using quarterly time series data and VAR model and their findings reveal a strong causal effect from GDP to exports and investments [12]. In a more recent study, Acaravci and Dagli investigated the effects of the volatility of real exchange rate on the foreign trade of Türkiye for the period of 2002-2020 using ARDL approach and they have concluded that there does not exist cointegration relationship between real

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imports, real domestic income, real exchange rates and real exchange rate volatility [13]. In another study, the effects of the exchange rate volatility on the imports and exports of Türkiye to the selected country groups is investigated and it is shown that the exchange rate volatilities do not have significant impact on the export to these selected country groups [14]. Sandalcilar et al. have investigated the determinants of the foreign trade of Türkiye with the next eleven countries using the gravity approach and it is demonstrated that the GDP of Türkiye has negative impact on its export and has positive effect on its import volume [15].

Akal has studied the intermediate goods import of Türkiye for the 1982-2004 period using causality analysis and it is shown that income, foreign exchange rate and relative import price affects the import demand of the intermediate goods [16]. Maden and Aljburi have investigated the trade volume between Türkiye and Iraq using augmented gravity model for the period of 1990-2016 where they have demonstrated that Türkiye's export has inter-industry trade pattern [17]. In another study, Sandalcilar have investigated the trade between Türkiye and Brazil, Russia, India and China (BRIC) countries using panel gravity model and it is concluded that the foreign trade between Türkiye and BRIC countries is positively affected by the GDP and the population of the countries [18]. Simsek and Kadilar analysed the aggregated import demand behavior of Türkiye using bounds test for the period of 1970-2002 and they have concluded that long-term elasticity of the demand function to the income and relative prices are 0.37 and 0.67, respectively [19]. In another work, Isik has studied the foreign trade volume between Türkiye and Shangai Cooperation Organization (SCO) for the period of 2004-2014 and it is demonstrated that the GDP and populations of SCO members and Türkiye have a positive impact on the foreign trade flows between them [20]. Karas and Karas have studied the effects of the real exchange rates on the imports and exports of Türkiye for the period of 2003-2017 using Johansen cointegration test where it is shown that there exists cointegrated relationships between these variables [21].

In this paper, we have attempted to model the imports and exports of Türkiye using artificial neural networks (ANNs). For this aim, the official imports and exports data of Türkiye has been taken from the electronic data distribution system (EDDS) of the Central Bank of Republic of Türkiye (CBRT). Then, an ANN is developed in Python programming language. The inputs of the ANN are the lagged values of the imports and exports data therefore the developed ANN operates as an autoregressive ANN. The developed autoregressive ANN is then trained using the 70% of the imports and exports data separately. The test results show that the developed autoregressive ANN accurately models the imports and exports data. Finally, the performance parameters namely the coefficient of determination (R^2), mean absolute percentage error (MAPE), mean absolute error (MAE) and the root mean square error (RMSE) are computed verifying the accuracy of the developed model.

II. Materials and Methods

First of all, the imports and exports data are taken from the EDDS of the CBRT for the period of 2013M11 – 2024M05 [22]. The total imports and total exports data are shown in Fig. 1. It is worth noting that the imports and exports values are monthly data with the y-axis of x1000 USD.

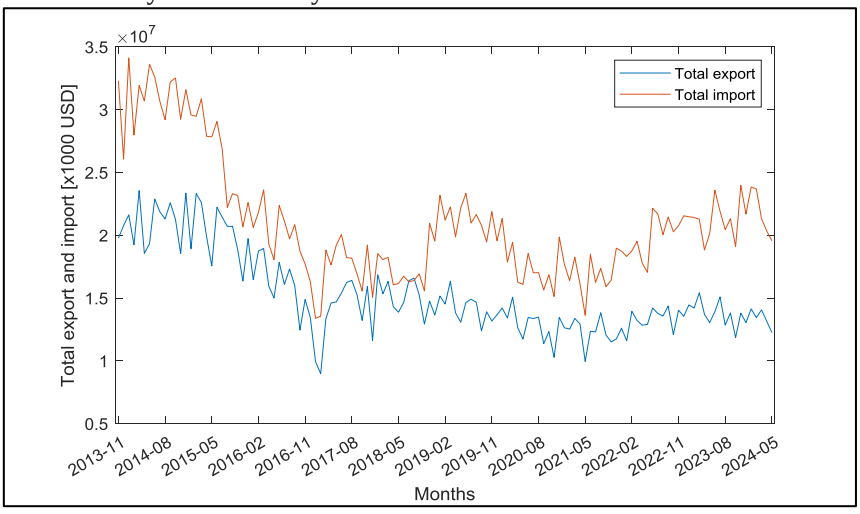

Fig. 1. Total exports and imports of Türkiye in monthly basis

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The structure of the ANN developed in this work is shown in Fig. 2. As it can be observed from Fig. 2, the inputs of the ANN is the lagged values of the imports or exports time series therefore the developed ANN operates as an autoregressive ANN. There are three hidden layers in the ANN structure each consisting of ten neurons. These values are optimized for the accuracy of the model. The autoregressive ANN is implemented in Python programming language using the MLPRegressor class [23].

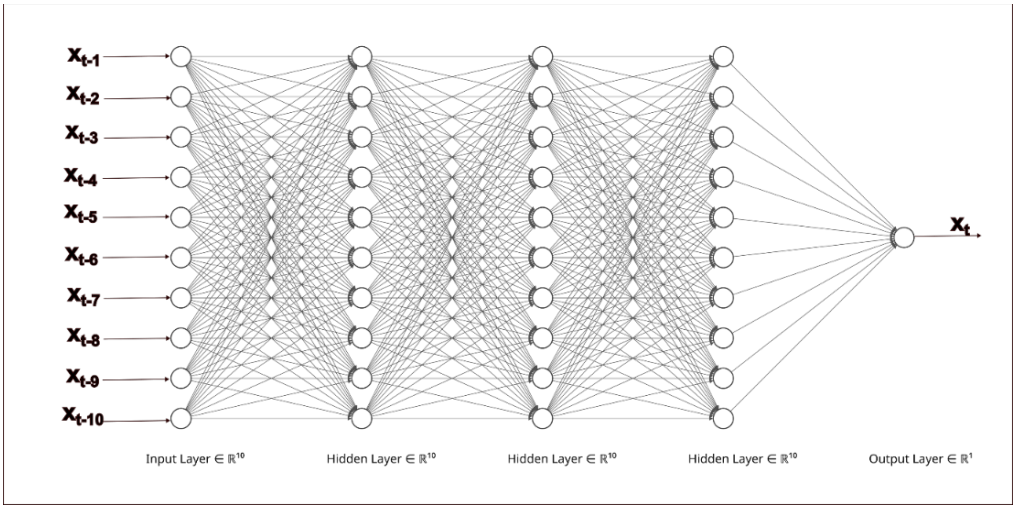

Fig. 2 The structure of the developed ANN model

The developed autoregressive ANN is trained for the imports and exports data separately. The 70% of the available data is used as the training data and the remaining 30% is taken as the test data for assessing the performance of the developed models. The loss curves regarding the training phases of the exports and imports data are given in Figs. 3 and 4 respectively. The training phases converges for 686 and 522 epochs for the exports and imports data, respectively.

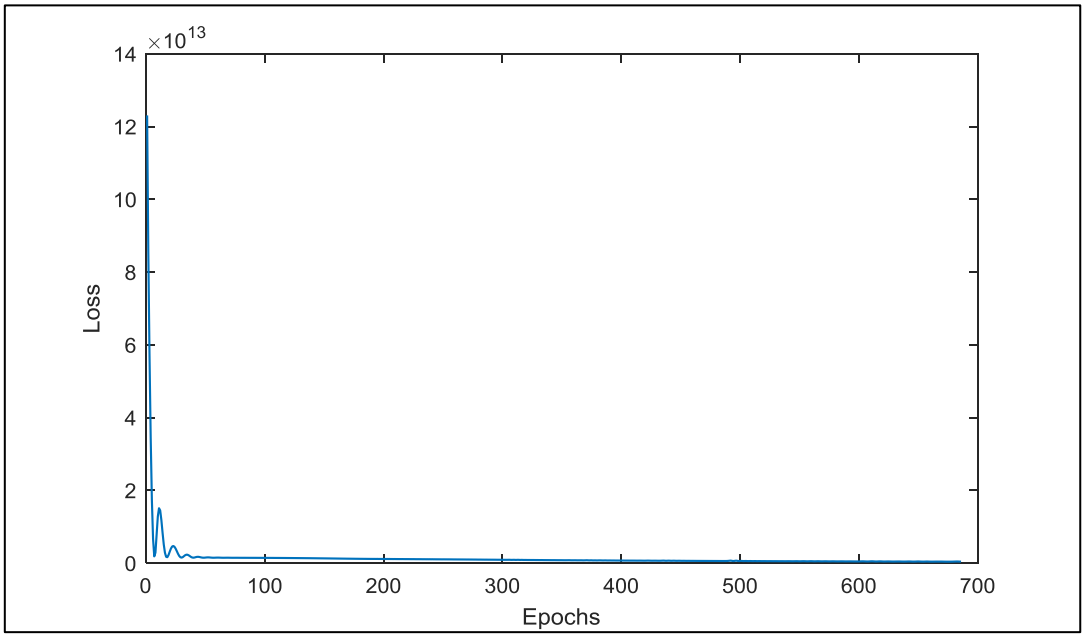

Fig. 3. Loss curve regarding the training of the developed ANN for the total export data

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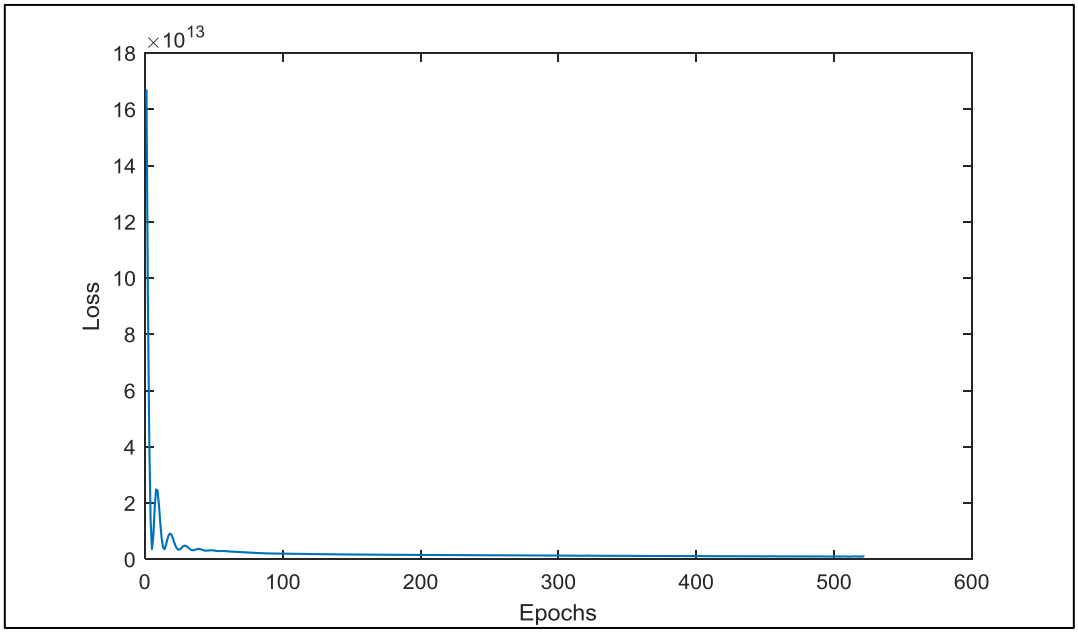

Fig. 4. Loss curve regarding the training of the developed ANN for the total import data

III. Results And Discussion

The developed autoregressive ANN is trained using the total exports data of Türkiye as the first step. The actual exports data and the results obtained from the autoregressive ANN is shown on the same axes in Fig. 5. As it can be seen from Fig. 5, the developed model can be used to express the total imports data accurately despite the lack of stationarity of the data.

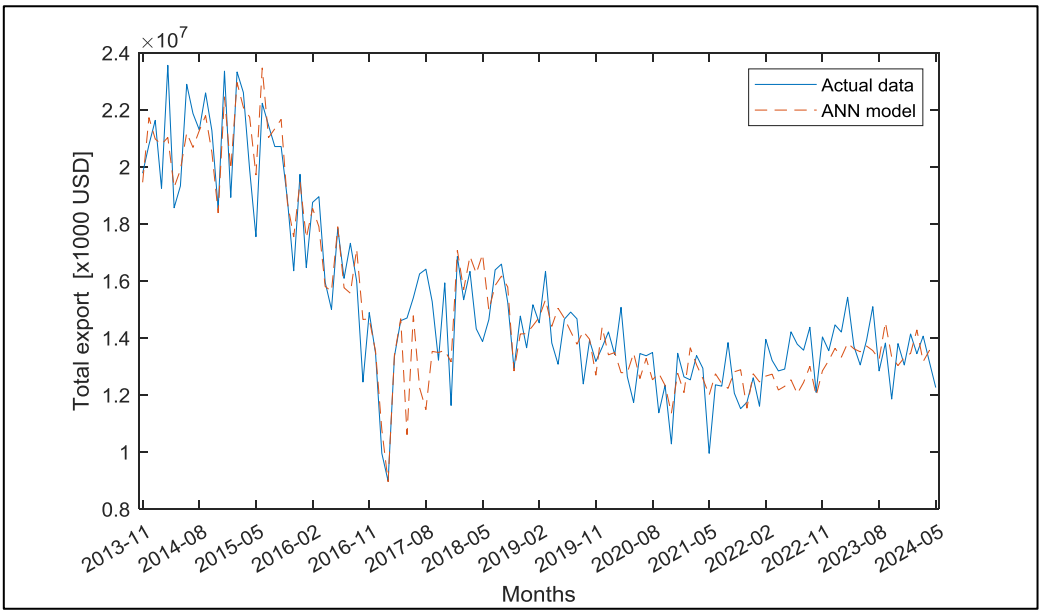

Fig. 5. Actual total export data and the result of the developed ANN model

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Similarly, the actual total imports data and the result of the developed autoregressive ANN model are shown on the same axes in Fig. 6. It can be observed from Figs. 5 and 6 that the developed network can be used to model the total imports and total exports data without any change in the network structure.

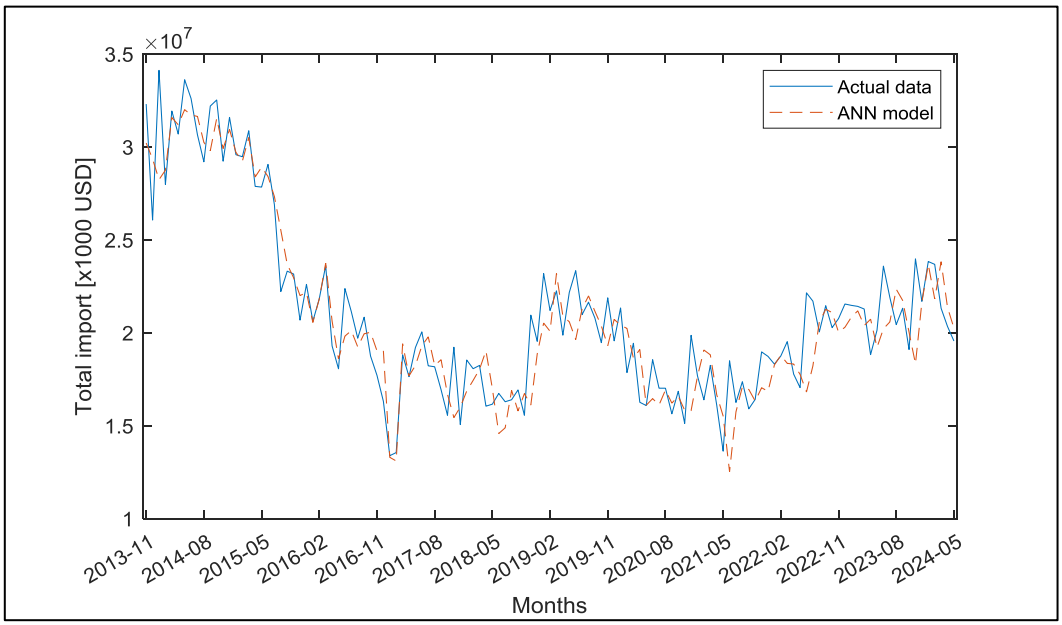

Fig. 6. Actual total import data and the result of the developed ANN model

In order to further assess the performance of the developed autoregressive ANN model, the performance metrics of the model results for the total exports and total imports data are computed. Coefficient of determination (R^2), mean absolute percentage error (MAPE), mean absolute error (MAE) and the root mean square error (RMSE) are computed using the formulas shown below [24]:

$$R^2 = \frac{\sum_1^l (O-avg(O))^2 - \sum_1^l (O-M)^2}{\sum_1^l (O-avg(O))^2} \quad (1)$$

$$MAPE = \frac{100}{l}\sum_1^l \left|\frac{O-M}{M}\right| \quad (2)$$

$$MAE = \frac{\sum_1^l |O-M|}{l} \quad (3)$$

$$RMSE = \sqrt{\frac{\sum_1^l (O-M)^2}{l}} \quad (4)$$

In the above equations, O is the actual data, M is the results data of the autoregressive ANN model and l is the size of the data. These performance parameters are computed in Python environment and the obtained values are given in Table 1 for the exports data and imports data modelling.

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Table 1. Performance metrics of the proposed ANN model for exports and imports data

	R^2	MAE	MAPE	RMSE
Exports data	0.857	14.4	0.06	12.2
Imports data	0.868	12.8	0.05	10.1

As it can be observed from Table 1, the developed autoregressive ANN can be used to model both the exports data and the imports data accurately. It is worth noting that the structure of the developed autoregressive ANN does not change for modelling exports and imports data therefore it can be argued that the developed autoregressive ANN can be used to model other time series data without any need for modifications.

IV. CONCLUSIONS

In this work, the total imports and total exports data of Türkiye have been modelled employing artificial neural networks. First of all, the imports and exports data are taken from the official sources and then plotted which show that both imports and exports data are highly nonlinear and non-stationary data. Considering this situation, an ANN is developed with three hidden layers containing ten neurons each. The inputs of the developed ANN are taken as the lagged values of the imports and exports data making the network an autoregressive ANN. Then, the developed autoregressive ANN is modelled for the exports and imports data separately. The training phases converged for 686 and 522 epochs for the exports and imports data implying the suitability of the ANN. The actual exports and imports data are plotted with the ANN model results as the next step which shows a high degree of accuracy of the model. In order to further verify the accuracy of the model, the coefficient of determination, mean absolute percentage error, mean absolute error and root mean square error values are computed for both the exports and the imports data. The coefficient of determination values are found to be higher than 0.85 for each model which verifies the accuracy of the model. It is again worth mentioning that the developed autoregressive ANN model is used for the exports and imports data without any change in the network structure which confirms the versatility of the model. It can be argued that the developed autoregressive ANN model can be used to model other time series data having strong nonlinearity.

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