Prediction of Life Quality Index Value Rankings of Countries After the COVID-19 Pandemic with Artificial Neural Networks

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***Abstract*—** As there are indicators that affect the performance criteria of businesses, countries also have some indicators that affect the quality of life. Indicators affecting the quality of life; which are property, pollution, health care, crime, traffic, and cost of living index. These indexes are created by analyzing data entered by citizens. Economic crisis, pandemics, natural events, etc. conditions affect these indexes. The COVID-19 pandemic affected all these indexes. In this study, the impact of the COVID-19 pandemic on the quality of life of countries was investigated. In this context, the artificial neural network was trained with the data of 5 countries in the European continent, consisting of a total of six indexes between 2012 and 2019. In the scenario where the COVID-19 pandemic never happened, the quality of life of the countries for 2020 was estimated and compared with the quality of life realized in 2020. It has been observed that the ANNs tested by charting the MAPE criterion and past period estimates gave successful results. As a result, it was determined that the COVID-19 pandemic caused a significant decrease in the quality of life of three countries but did not affect the quality of life of the remaining two countries.

***Keywords*—** artificial neural networks, deep learning, quality of life index, prediction, time series

1. INTRODUCTION

The most basic features of Artificial Neural Networks (ANNs) are that they can make decisions based on information while producing or trying to produce solutions to events or problems and they can produce predictions about the next events by learning the events with the information at hand. These systems enable solving problems that are almost impossible to solve manually. ANNs consist of cells that are hierarchically connected to each other, these cells, called process elements, store the information they learn in connections. The main task of an ANN is to produce an output set that can correspond to the set of inputs shown to it. In order to do this, the network should be trained with examples of related events and have the ability to generalize. These systems, which work by imitating the working principles of the human brain such as learning information, being able to derive, discover and predict new information, although they remain primitive compared to the speed of the human brain, nowadays have become quite fast. These speeds can be measured in nanoseconds [1].

With the first cases of COVID-19 seen at the end of 2019, it has been observed that countries are experiencing both social and economic changes. Due to the fact that the year 2020 includes the entire pandemic period, almost all the habits of people have changed. In this study, it will be investigated how the changes experienced affect the indexes of the countries. ANN, which will be trained with index data before the year 2020, will estimate the quality of life index for the year 2020 when there is no COVID-19 pandemic. The obtained result will be compared with the index for the year 2020, which was experienced in real. The trust of citizens in their countries after the COVID-19 pandemic and how the pandemic affects the quality of life of citizens will be investigated within the scope of this study. At the end of the study, it will be presented how countries are affected by COVID-19 pandemic. In this way, it is expected that countries will be able to identify

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their deficiencies and take precautions against extraordinary situations. At the same time, it is expected that this study will contribute to the widespread use of ANN in the field of social sciences.

2. CONCEPTUAL FRAMEWORK

2.1 *Artificial Neural Networks*

Artificial neural network cells are similar to biological nervous systems. The task of the artificial neural network, just like the biological nervous system, is to produce an output as shown in Figure 1 in response to the electrical signals it uses as input. For this to be possible, the network must be trained with certain data sets. In this way, the network reaches the level that it can generalize and determines the outputs with these capabilities [2]. At the basis of artificial neural networks are three layers, these layers are the input layer, hidden layer and output layer [3].

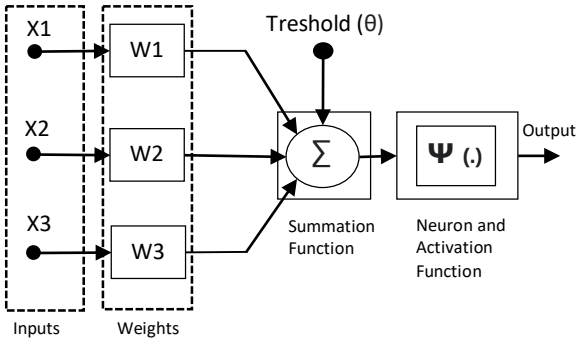


Figure 1. Artificial Nerve Cell Model

(Haykin, 1999; Sönmez Çakır, 2018)

The estimation error in ANN consists of the difference between the actual value and the estimated value for a certain period [8]. The accuracy of the information produced by the established ANN is examined with error criteria. The network should be tested with the error criteria in the literature and should be within acceptable limits. It is very important for the accuracy of the network that the error values are within acceptable limits.

The MAPE criterion generally gives more effective results than other criteria, and it is sufficient to explain the change. The criteria to be considered while examining the MAPE values are as in Table 1. [9].

Table 1. MAPE Value and Descriptions

MAPE<%10	High Accuracy
MAPE>%10 and <%20	Medium Accuracy
MAPE>%20 and <%50	Low Accuracy but acceptable
MAPE>%50	No Predictive Value

2.2. *Country Indexes*

Some measurements affect the quality of life of countries and these are defined as country indexes. These indexes are property price index, pollution index, health care index, crime index, traffic index, and cost of living index. The fact that the quality of life index highly depends on the fact that the health service index is high, while other indexes are low. Country index descriptions are as follows [5]:

When creating a property index, the ratio of house prices to incomes, the ratio of the mortgage loan to the percentage of income, the affordability ratio of the mortgage loan, the ratio of housing prices to housing rents, and the annual gross rental yield are established using the information. The pollution index is formed by an eight-question questionnaire, in which the weight is given to air pollution and water pollution. While creating the traffic index, the time spent in traffic, the inefficiency rate due to the lack of public transport use, and the carbon dioxide emission rate emitted depending on the traffic duration are used. The crime index is also determined by the results obtained by a twelve-question questionnaire. While creating the cost of living index, rent index, market index, restaurant, and cafe index, and local purchasing power are used. The cost of living index is adjusted for New York, the cost of living index for New York is 100%. If the cost of living index of a city is 140, it means that the city is 40% more expensive than New York City.

The indexes mentioned above were created by processing the data entered by the citizens by software written in the Java programming language. The quality of life index is reached by evaluating these indexes with certain weights.

3. METHOD

In this study, the 2020 quality of life indexes of Germany, France, Italy, Turkey, and Greece were estimated by ANN. YSA, which has a successful result in almost every field in which it is used; It can work with incomplete information, adapt to the problems it encounters, make decisions under uncertainties and be tolerant of errors [14]. Therefore, in this study, ANN has been preferred for the creation of an estimation model.

All ANN's installed were created using the Matlab 2019B program. At the same time, while creating the ANN, a multi-layered, feedback network type was chosen as seen in Figure 2. For the input layer, 13x6 data was used as the equivalent of six indexes collected over thirteen terms, and for the output layer, 1x13 data was used as the equivalent of the quality of life index collected over thirteen terms. Trainlm function is used as a training function, Learngdm function is used as learning function, MSE function is used as performance function, and Tansig function is used as activation function. While determining the number of

hidden neurons to be used in the hidden layer, it was decided to use 15 hidden neurons in the hidden layer by trial and error method, since it is not possible to act according to certain rules and there is no systematic approach to find the optimal number of neurons [6]. Five separate networks have been created for five countries.

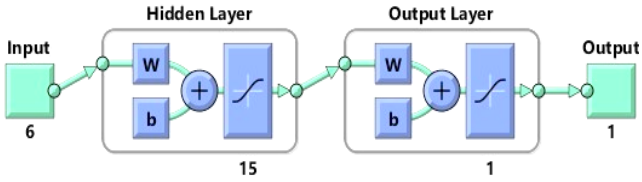


Figure 2. Artificial Neural Network Model

70% of the data was used for training, 15% was used for verification, and the remaining 15% was used for testing.

The data used for training from these stages are aimed at learning the network, the data used for verification is used to determine when the training should be terminated, while the data used for testing checks whether the network has achieved the desired performance [7].

3. Training ANN with Country Indexes and Predicting the Year 2020 when COVID-19 does not exist.

3.1. Index Data Used

As a period was chosen between 2012, the first year for which complete data was available, and 2019 when the pandemic had not yet started. The data presented once a year from 2012 to 2014 began to be presented twice a year from 2014, so there are fourteen terms of data in each index of each country. These data are property price index, pollution index, health service index, crime index, traffic index, cost of living index, and quality of life index, and these data were used in the study. For ANN trained with one-term transferred; Six thirteen term-old index data (13x6) was used as the input layer, and thirteen-periods quality of life index data (13x1) was used as the output layer.

The ANN data set up for the estimation was taken from Numbeo [5]. These data were used for training the network and for comparing its outputs.

3.2. Creation and Training of the ANN

For each country 2012, 2013, 2014, 2014-2, 2015, 2015-2, 2016, 2016-2, 2017, 2017-2, 2018, 2018-2, 2019 the six indexes of their terms are taken from Numbeo and these data are used in the input layer. Since the data are given in six-month periods after 2014, it is seen that two data are received every year since 2014. These independent variables formed the input layer of the ANN. For each country 2013, 2014, 2014-2, 2015, 2015-2, 2016, 2016-2, 2017, 2017-2, 2018, 2018-2, 2019, 2019-2 the quality of life index of their terms are taken from Numbeo and these data are used in the output layer.

4. RESULTS

Input layer data of Germany used for ANN training in Table 2 and output layer data from Germany used for ANN training in Table 3 are given.

Table 2. The Input Layer of Germany's Artificial Neural Network

Years	Property Prices	Pollu-tion	Health Care	Crime	Traffic	Cost of Living
2012	5,21	45,14	71,96	21,20	80,77	88,55
2013	4,78	28,43	73,25	23,86	74,55	91,64
2014	5,60	30,20	75,26	27,14	132,35	87,14
2014-2	6,13	30,33	76,66	29,13	102,09	86,82
2015	6,61	28,32	75,61	28,49	98,41	76,27
2015-2	7,07	29,22	76,37	30,64	86,25	65,96
2016	7,13	29,91	75,85	32,95	87,46	65,54
2016-2	7,23	27,68	76,02	32,70	97,03	66,79
2017	7,46	27,05	76,74	32,03	95,92	65,50
2017-2	7,82	27,68	75,99	32,64	97,02	73,18
2018	8,05	27,32	75,44	36,65	102,94	74,35
2018-2	8,48	28,15	74,88	36,16	101,49	67,89
2019	9,02	28,01	74,32	34,51	98,09	67,62

Table 3. The Output Layer of Germany's Artificial Neural Network

Years	Quality of Life
2013	204,84
2014	192,69
2014-2	186,61
2015	195,94
2015-2	244,31
2016	199,70
2016-2	189,87
2017	189,74
2017-2	178,92
2018	190,04
2018-2	189,13
2019	187,05
2019-2	184,30

According to the designed ANN, 2013 was estimated with the input data of 2012, and 2014 was estimated with the input data of 2013. In this way, ANN, trained with 13-term data in this way, was simulated with the data of the 2019-2 period and reached the 2020 output data, that is, the quality of life index of the year 2020, when COVID-19 was not experienced.

The regression values of the training, testing, and verification stages of the ANN established for Germany are shown in Figure 3.

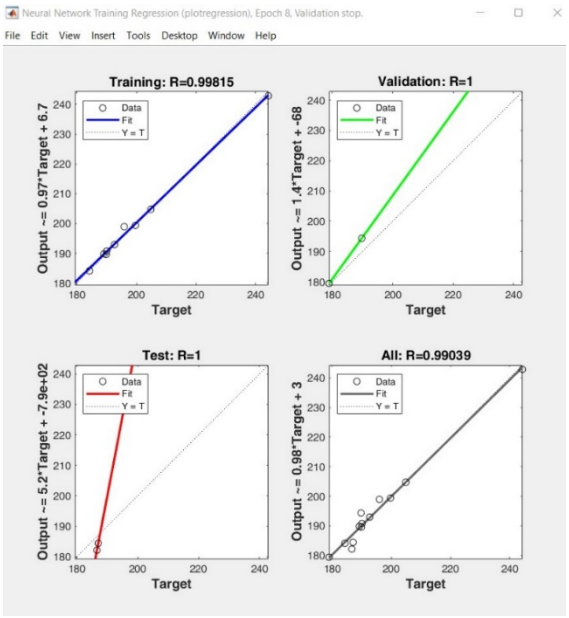


Figure 3. YSA Regression Results for Germany

When the trained ANN was simulated with 2019-2 input data, the quality of life of Germany in 2020 was estimated at 229,906 in the scenario where there is no COVID-19. In the presence of COVID-19, Germany's quality of life was 179.78. Figure 4 shows the retrospective estimates of the network. It is seen that all the historical forecasts are in agreement with the actual forecasts. The reason for the difference in 2020 is COVID-19.

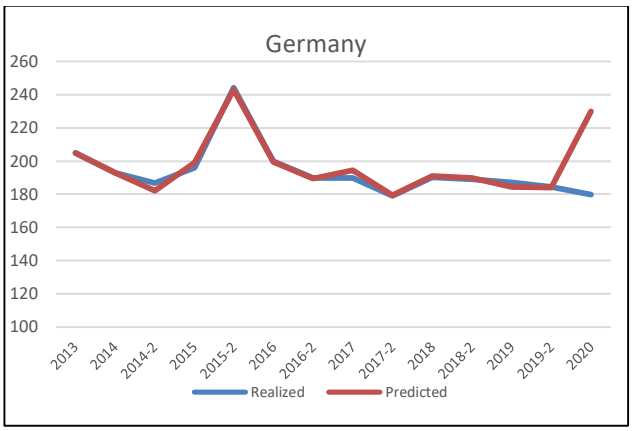


Figure 4. Predicted-Realized Comparison of Germany

Detailed knowledge of the trained network is explained by the example of Germany. In the continuation of the study, the outputs of the network trained for France, Italy, Turkey, and Greece will be given.

The regression values of the training, testing, and verification stages of the ANN established for France are shown in Figure 5.

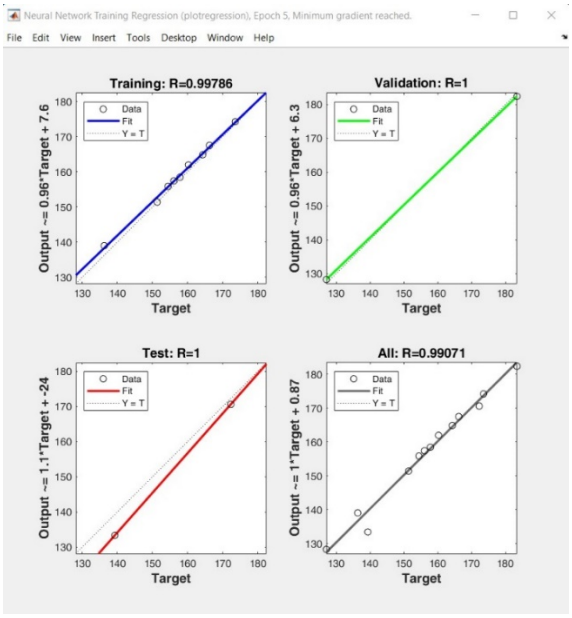


Figure 5. YSA Regression Results for France

As a result of the training, it was predicted that the quality of life index of France was 157.69 in the scenario where there was no pandemic. As a result of the pandemic, the quality of life index of France was published as 153.95. In Figure 6, retrospective estimates of the network are given.

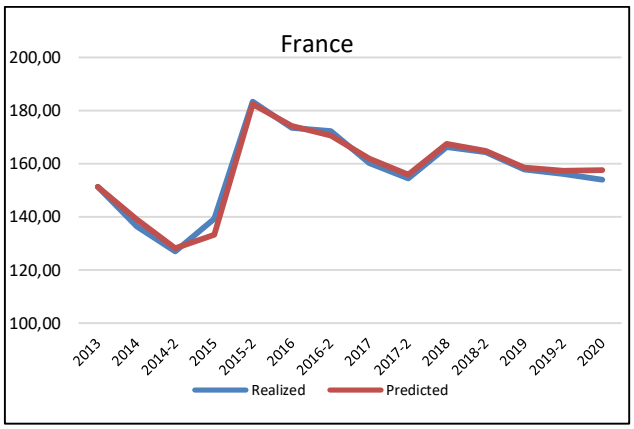


Figure 6. Predicted-Realized Comparison of France

The regression values of the training, testing, and verification stages of the ANN established for Italy are shown in Figure 7.

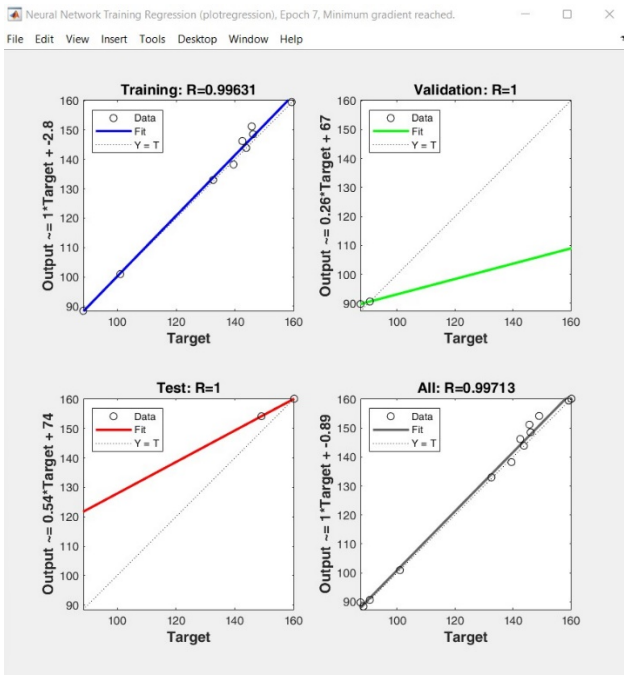


Figure 7. YSA Regression Results for Italy

As a result of the training, it was predicted that the quality of life index of Italy was 152.02 in the scenario where there was no pandemic. As a result of the pandemic, the quality of life index of France was published as 140.76. In Figure 8, retrospective estimates of the network are given.

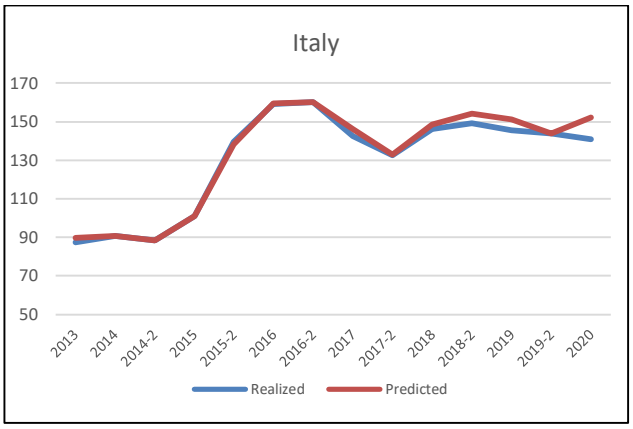


Figure 8. Predicted-Realized Comparison of Italy

The regression values of the training, testing, and verification stages of the ANN established for Turkey are shown in Figure 9.

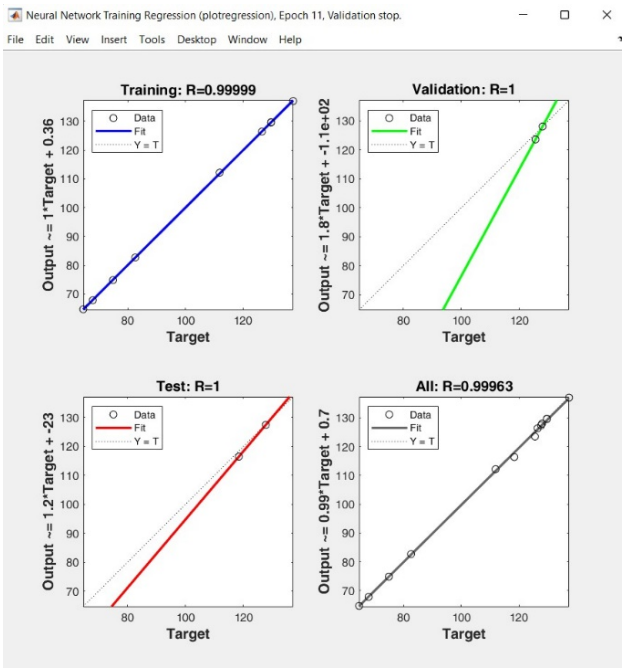


Figure 9. YSA Regression Results for Turkey

As a result of the training, it was predicted that the quality of life index of Turkey was 127.60 in the scenario where there was no pandemic. As a result of the pandemic, the quality of life index of France was published as 127.10 In Figure 10, retrospective estimates of the network are given.

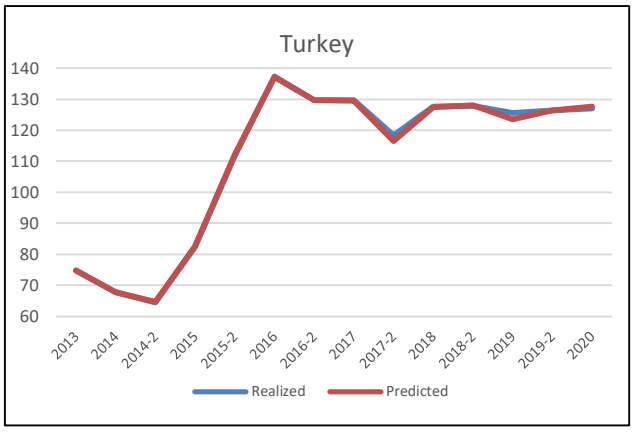


Figure 10. Predicted-Realized Comparison of Turkey

The regression values of the training, testing, and verification stages of the ANN established for Greece are shown in Figure 11.

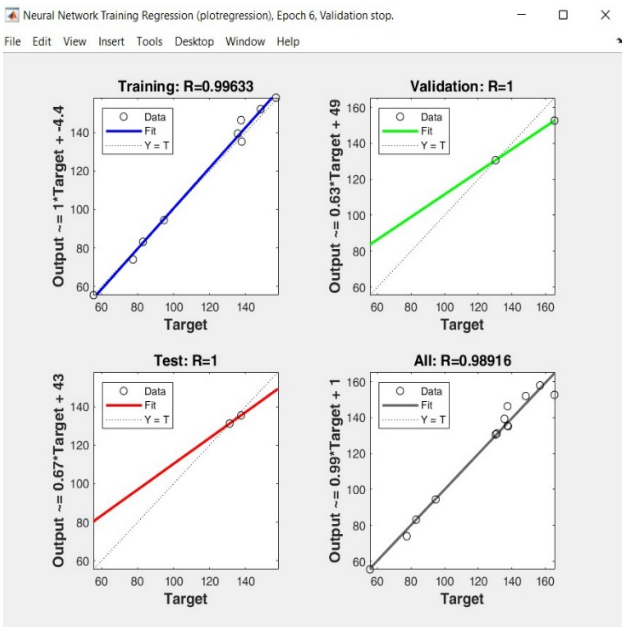


Figure 11. YSA Regression Results for Greece

As a result of the training, it was predicted that the quality of life index of Greece was 134.30 in the scenario where there was no pandemic. As a result of the pandemic, the quality of life index of France was published as 133.07 In Figure 12, retrospective estimates of the network are given.

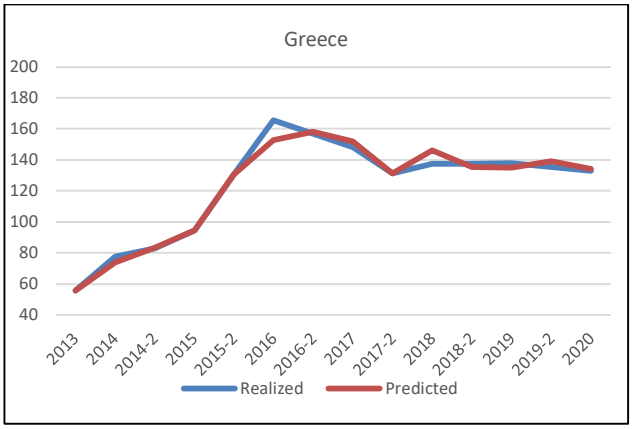


Figure 12. Predicted-Realized Comparison of Greece

3.3. Analysis of the ANN

The most accepted performance criteria for ANN analysis in the literature are R2, MSE, RMSE and MAPE values [15,16]. In this study, ANNs established with R, R2, RMSE and MAPE Criteria were tested. Table 4 lists the performance analyzes for five countries.

Table 4. ANN Performance Analysis by Country

Countries	R	R^2	RMSE	MAPE
Germany	0,99	0,9801	2,16	0,76
France	0,99	0,9801	2,1	1,03
Italy	0,997	0,994009	2,53	1,21
Turkey	0,999	0,998001	0,78	0,36
Greece	0,989	0,978121	4,75	2,21

As a result of the analysis, it was found that the outputs of the network give high accuracy.

The comparisons of the quality of life indexes of 5 countries, estimated by ANN and realized in 2020, and country rankings are shown in Table 5.

Table 5. Country Impact Rates from COVID-19.

Countries	Realized	Predicted	Difference	Difference (Percent)
Germany	179,78	229,906	50,12	27,88
Italy	140,76	152,024	11,26	8
France	153,95	157,69	3,74	2,42
Greece	133,07	134,302	1,23	0,92
Turkey	127,1	127,601	0,5	0,39

As can be seen from Table 5, by comparing the predicted and realized quality of life indices for 2020, it is seen that the country most affected by the pandemic in terms of quality of life is Germany. Germany is followed by Italy, France, Greece and Turkey respectively.

5. CONCLUSION

In a study conducted in 2017, the effectiveness of countries in health expenditures was investigated using data envelopment analysis. As a result of this research, Turkey and Greece were found to be effective in health expenditures, while Germany, France and England were found to be ineffective [10]. Demirci et al., in their study in 2020, stated that Turkey, Greece and Italy have efficient health systems, but Germany and France do not have an efficient health system [11]. The results obtained in this study are similar to the results of the two studies mentioned above.

Cinel stated in a 2020 study that the impact of pandemics on health is relatively limited and its economic consequences are more long-lasting and destructive [12]. Based on this discourse, the export difference of countries between 2019 and 2020 was investigated using data obtained from the OECD [13]. These export differences are calculated as a percentage. As a result of the ranking, it was seen that France was the country with the highest falling export rate. France was followed by Italy, Germany, Greece and Turkey, respectively.

It is seen that both the confidence in the health system and the economic indicators show similarities with the impact rate of the COVID-19 pandemic on the quality of life achieved as a result of this study.

Possible future scenarios can be revealed with different estimation methods, but in this study, alternative past estimation has been made, not future estimation. Just as people were not ready, states were caught unprepared for the pandemic. For this reason, the pandemic has caused both social and economic crises.

The quality of life consists of a general index containing six indices and countries are affected by these indices at different rates. As a result of this study, countries are advised to take measures to increase indices that reduce the quality of life and to be prepared for new pandemics that may occur. For other studies, researchers are advised to study countries separately under the indexes of real estate, pollution, health, crime, traffic and cost of living. In this way, the areas where countries have succeeded and failed within the scope of the fight against COVID-19 will be seen.

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