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Self-Organizing Maps Approach for Clustering OECD Countries Using Sustainable Development Indicators

Pakize YİĞiT [1]

Abstract

Sustainable Development concept (SD) aims to better life for future generations. However, the COVID-19 pandemic has caused tremendous effects on people's life in several areas. Therefore, the study aimed to investigate the impact of COVID-19 on the selected part of SD indicators in the OECD countries using Self-Organizing Map (SOM). SOM is a kind of artificial neural network (ANN) method, which is an effective clustering method to find hinder non-linear relationships between indicators. The data contained 38 OECD member countries for 11 variables for each country, covering three years (2019-2021). Firstly, descriptive statistics and Spearman rank correlation analysis were used for bivariate analysis. The coefficient of variation was also used to measure the convergence of indicators. Then, it was a two-stage clustering method using SOM and hierarchical clustering methods—the optimal cluster found according to the Silhouette Index and Davies–Bouldin Index, and as three. The convergence of gross domestic product increased gradually to 40.33% in 2019, 42.01% in 2020, and 43.69% in 2021, meaning increasing relative variability of OECD countries. While the mean of the life span was decreased, the share of health expenditure, health expenditure per capita, out-of-pocket health expenditure, and government health expenditure were increased in the study period. According to clustering analysis, the countries had similar characteristics within three years, except Colombia. Also, the USA distinguished very different characteristics from other OECD countries. Although the mean of study indicators varies due to the effect of the pandemic, the change within each OECD country showed mostly similar characteristics within three years.

Keywords: Sustainable Development, Self-Organizing Map, Life Expectancy, Health Expenditure, Consumer Price Index, Gross Domestic Product

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OECD Ülkelerinin Sürdürülebilir Kalkınma Değişkenlerine Göre Kendi Kendine Öğrenen Haritalar Yaklaşımı ile Kümelenmesi

Pakize YiĞiT [1]

Öz

Sürdürülebilir kalkınma kavramı gelecek nesiller için daha iyi bir yaşam sunmayı amaçlamaktadır. Ancak, COVID-19 pandemisi insanların yaşamında pek çok alanda muazzam etkilere neden olmuş, ülkelerin SK değişlenlerinin incelenmesi, ülkelerin politikalarını belirlemek için önemli hale gelmiştir. Bu nedenle, bu çalışmanın amacı, OECD ülkelerinde COVID-19 pandemisinin bazı SK değişkenleri üzerindeki etkisini Kendi Kendine Düzenleyen Haritalar kullanarak araştırmaktır. Yapay sinir ağlarının bir türü olan kendi kendine düzenleyen haritalar, değişkenler arasındaki doğrusal olmayan ilişkileri bulabilen etkili bir kümeleme analizidir. Veri 2019-2021 yıllarında 38 OECD ülkesine ait 11 sürdürülebilir kalkınma değişkenini içermektedir. Her bir sürdürülebilir kalkınma değişkeninin öncelikle ortalama, minimum, maksimum değerleri ve değişkenler arasındaki korelasyonu bulmak için parametrik olmayan Spearman sıra korelasyonu hesaplanarak yorumlanmıştır. Yıllar içerisinde ülkelerin birbirine göre gösterdiği farklılık, yakınsama katsayısı olarak kullanılan değişim katsayısı kullanılarak hesaplanmıştır. Sonrasında, iki aşamalı kümeleme analizi, kendi kendine düzenleyen haritalar ve hiyerarşik kümeleme analizleri kullanılarak uygulanmıştır. İdeal küme sayısı Silhouette indeksi ve Davies–Bouldin Indeksi kullanılarak üç elde edilmiştir. Gayri Safi Milli Hasıla yakınsama katsayısı yıllar içinde kademeli olarak artması, 2019'da %40,33, 2020'de %42.01 ve 2021'de %43.69, OECD ülkeleri arasındaki bağıl değişkenliğin arttığını göstermektedir. İncelenen çalışma yıllarında, ortalama yaşam süresi azalırken, kişi başına düşen sağlık harcamaları, sağlık harcamalarının payı, devlet sağlık harcamaları, ceptan yapılan sağlık harcamaları ortalaması artmıştır. Kümeleme analizine göre ise, Kolombiya hariç tüm ülkeler incelenen üç yıl için benzer özelliklere sahip olduğu bulunmuştur. Ayrıca ABD, OECD ülkelerinden çok farklı özellikler göstermektedir. Sonuç olarak, incelenen üç yıl içerisinde değişkenlerin ortalamaları pandeminin etkisi ile değişse de neredeyse bütün OECD ülkeleri kendi içerisinde benzer özellikler göstermektedir.

Anahtar Kelimeler: Sürdürebilir Kalkinma, Kendi Kendine Öğrenen Haritalar, Doğumda Beklenen Yaşam Süresi, Sağlik Harcamalari, Tüketici Indeksi, Gayrisafi Milli Hasila

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Introduction

There have been dynamic changes and rapid economic progress in the past few decades. While these developments have brought numerous benefits, they have also negatively affected both societies and the natural environment (Brodowicz & Stankowska, 2021, s. 646; Moraci vd., 2020, s. 2). Therefore, the concept of sustainable development has become prominent globally in recent years (Brodowicz & Stankowska, 2021, s. 646).

Sustainable development (SD) has described as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" to the 1987 in United Nations' Brundtland Report (WCED, 1987, s. 41). After that, the concept of SD has been increased worldwide and become one of the primary goal of policy documents of governments, business organizations and international agencies (Mebratu, 1998, s. 494).

In 2000, the United Nations's (UN) Millennium Declaration announced eight "Millennium Development Goals (MDGs)". They are reducing extreme hunger and poverty, providing primary education globally, supporting gender equality and power of women, decreasing child mortality, enhancing maternal health, combating diseases, providing environmental sustainability, and international collaboration for development. It was decided to achieve these goals by 2015 (United Nations, 2000, ss. 1–9). In 2015, the UN published a report of the MDGs indicating that during these 15 years, extreme hunger and poverty decreased, primary education became widespread, more girls enrolled in school, child and maternal mortality fell, the prevalence of HIV, malaria, and other diseases was reduced, the number of people accessing clean water was increased, and global agreements were made for the developments (Halkos & Gkampoura, 2021, s. 95; United Nations, 2015a, ss. 6–9). However, severe poverty, threatening ecosystems, the inequity between countries, with developing technologies, and governance challenges were still issues for the world, according to a UN report (Chopra vd., 2022, s. 1; United Nations, 2013). It is acknowledged that poverty is related to sustainable economic development and also associated with a wide range of social indicators like healthcare, education, social welfare, employment prospects, environmental preservation, and mitigation of climate change (Megyesiova & Lieskovska, 2018, s. 2; United Nations, 1992, 2023b).

UN established the 2030 Agenda for Sustainable Development with 17 SD goals and 169 associated targets in 2015, aiming "peace and prosperity for people and the planet, now and into the future" (United Nations, 2015b). They are given in Table 1. With this concept, SD prioritizes protecting natural resources and the environment while ensuring current and future generations' social and economic progress and well-being (Halkos & Gkampoura, 2021, s. 94; Hansmann vd., 2012, s. 451). Therefore, SD focused on three main pillars: social, economic, and environmental sustainability (Purvis vd., 2019, s. 494).

Table 1: Sustainable Development Goals (SDGs)

SDG1	No poverty
SDG2	Zero Hunger
SDG3	Good Health and well-being
SDG4	Quality Education
SDG 5	Gender equality

SDG6	Clean water and sanitation
SDG7	Affordable and clean energy
SDG8	Decent work and economic growth
SDG9	Industry, innovation, and infrastructure
SDG10	Reduced inequalities
SDG11	Sustainable cities and communities
SDG12	Responsible consumption and production
SDG13	Climate action
SDG14	Life below water
SDG15	Life on land
SDG16	Peace, justice, and strong institutions
SDG17	Partnership for the goals

The COVID-19 pandemic, a recent global health crisis, has become a significant public health concern, resulting in many fatalities worldwide. It started in December 2019; on January 30, 2020, the World Health Organization (WHO) designated it as a Public Health Emergency of International Concern (PHEIC), and on March 11, 2020 announced as a pandemic (WHO, 2023a). Therefore, countries started to take precautions to reduce the spread of the virus, like closing schools, social distancing, lockdowns, etc. As a result, governments have begun to face socio-economic and environmental hardship (Diffenbaugh vd., 2020, s. 470; Elsamadony vd., 2022a, s. 1; Nerini vd., 2020, s. 2). Diffenbaugh reported that it was reduced traffic congestion, better air quality, the encroachment of wildlife into human habitats, decreased mobility, and reduced greenhouse gas emissions due to restrictions during the pandemic. While many impacts may be perceived as advantageous for the environment, they also have growing adverse implications. These include cascading effects on poverty, food security, mental health, disaster preparedness, and biodiversity (Diffenbaugh vd., 2020, s. 470). Nerini found (Nerini vd., 2020, s. 3) that 90% of SD targets were negatively impacted whereas 40% of targets positive from the pandemic . They found that the most affected targets in this process are SDG3, "good health and well-being", and SDG1, "no poverty". In addition, Elsamadony et al. (Elsamadony vd., 2022a, s. 1) examined the quantitative impacts of COVID-19 for 72 countries and 17 SDGs. They found that SDG5 "gender equality", SDG7 "affordable and clean energy", SDG8 "decent work and economic growth", SDG11 "sustainable cities and communities", and SDG-12 "responsible consumption and production" were negatively effective by the COVID-19 pandemic.

The study aimed to investigate the impact of COVID-19 on the selected part of SD variables in the OECD countries. The study explained the difference with one dimensional (descriptive statistics), and multivariate analysis (clustering analysis). As a result, the study can also evaluate Turkey's changes in terms of SD indicators in other OECD countries.

The sections of the study organized in the following manner. Section-2 explains conceptual framework of the study. Sectin-3 offers the methods of the research and theorical description of SOM method. The section-4 presents findings as two parts: descriptive and multivariate. Section-5 provides conclusion and discussion.

1. Conceptual Framework

Due to the enormous impact of COVID-19 on the global world, investigating the impact

of the pandemic on countries' SDGs is essential for policymakers. A decrease of country's income due to the pandemic indicates that there will be a disruption in the UN's SDGs, and inflation is expected to cause the financial gap more (Elsamadony vd., 2022a, s. 2; Sachs vd., 2020, s. 3). In addition, the global impact of the COVID-19 pandemic has resulted in a severe economic recession comparable to the magnitude of the Great Depression (Ranjbari vd., 2021, s. 18). It is anticipated that the GDP per capita would experience a fall of 4.1% in the year 2020 and increased 5.0 % in 2021. Labour productivity also had a substantial decrease in 2020 due to pandemic (United Nations, 2023a). This crisis has led to a decreased unemployment rate globally, a peak of 6.9% in 2020 5.8% in 2022. In addition, the mean growth rate of government health expenditure per capita was 21% in 2020, 25 % in 2021 comparing to 2019 for 78 developing countries (The World Bank, 2023). There was an increase in health expenditures per capita and as a share of GDP in all income groups across countries in 2020 (World Health Organization, 2022) . Lifespan also decreased in pandemic crisis. In studies comparing countries' life expectancy at birth during the pandemic situation, it has been found that life expectancy at birth has fallen in developed countries (Aburto vd., 2022, s. 63; Schöley vd., 2022, s. 1649). Furthermore, power production or consumption data are used for association sustainable economic and social development by researchers. Total electricity consumption dropped and whereas renewable energy increased during the pandemic due to lockdown measures (Peng vd., 2022, s. 1206,1207). Their prices are also associated with consumer prices. Most countries have had increasing consumer prices, especially food, because of pandemic (United Nations, 2020).

Furthermore, the effects of the pandemic began to be felt in our country with the first case of COVID-19 appearing in March 2019. Although the pandemic was expected to affect the healthcare system the most, economic collapse and social disruptions began due to the quarantine measures implemented in Turkey like other countries. The Turkish economy experienced the lowest growth of the last 10 years in 2019 and 2020; showed 0.9% and 1.8% respectively due to pandemic(TURKSTAT, 2023). On the other hand, economic growth of the county in 2021 reached to 11%. Inflation was also increased 14.6% in 2020 and the highest inflation in 2021 was 36.1% (Akal & Bayram, 2022, s. 176). The impact of Covid-19 on unemployment in our country was felt most in 2020, unemployment rate were 13.2% in 2020 and 12% in 2021 (Akal & Bayram, 2022, s. 179). In addition to this, lifespan is getting shorter in Turkey according to TURKSAT statistics (TURKSAT, 2023). The lifespan was reported in Turkey as 78.6 in 2019-2019, 77.7 in 2019-2021, and 77.5 in 2020-2022. In addition to this, share of government health expenditure on GDP also increased in pandemic term as expected, reported as 3.6% in 2019 and 3.9% in 2020 (T.C Sağlık Bakanlığı, 2023, ss. 246–247).

Therefore, the study aimed to investigate the impact of COVID-19 on the selected part of SD indicators in the OECD countries. The study questions can be summarized as:

1) Do OECD countries differ according to SD variables in the examined period?
2) Which OECD countries have similar or different patterns in the examined period according to SD variables? What are these patterns?
3) In this period, what are Turkey's position and characteristics in OECD countries according to SD variables?

For this purpose, the SD variables examined both descriptive statistics and ANN based SOM clustering method. The study used a two-stage unsupervised SOM clustering

method which is more efficient unpervised clustering method comparing others (Arunachalam & Kumar, 2018). Also, the study might help policymakers to find effect of COVID-19 part of SDGs to enhance sustainable growth again.

2. Material and Methods

It has been more than 3 years since the COVID-19 pandemic began. Although the severity of the disease varies in each country, a total of 6, 596,900 people have officially died all over the world (WHO, 2023b, n. 09/10/2023). The aim of the study is to measure the variability of countries in terms of the examined SD variables during the pandemic (2020-2021) compared to the previous year (2019). For this aim, descriptive analysis and clustering analysis were used.

2.1. Data

The data was collected from 38 OECD member countries for 11 variables for each country, covering three years (2019-2021). The variables are part of sustainable development goals. A public database of OECD stat (OECD, 2023) was used to obtain data. It is a trustable database for data reliability, availability, and consistency. While selecting the variables and study years, careful attention was paid to ensuring that the variables and years were fully accessible for all member OECD countries and that there was no missing data. Therefore, all indicators are available for all OECD countries for the study years. The SD variables and their references considered in the study are as follows. Although the features were used before for several studies, the first nine indicators were mainly selected by the research of Megyesiova and Lieskovska (Megyesiova & Lieskovska, 2018, ss. 11–12).

1. Gross Domestic Product (GDP) per capita, USD, current prices, and PPPs (GDP)
2. The change of GDP per capita according to previous year (GDP change)
3. Current health expenditure per capita, current prices, and PPPs (CHEC)
4. The change of current health expenditure per capita (CHEC change)
5. Share of health expenditure of GDP (%) (SHE)
6. Government health expenditure as a share of the current expenditure on health (GEH)
7. Out-of-pocket payments on health for households, share of current expenditure on health (OPHE)
8. Female life expectancy (FLE)
9. Male life expectancy (MLE)
10. Unemployment rate (UR)
11. Consumer Price Index (CPI) change (CPI)

2.2. Analysis

Firstly, the study indicators investigated as their minimum, maximum, and average values. The study focused on the variability of the indicators in the COVID-19 years. For this reason, it was calculated coefficient of variation (CV) of indicators for each year. Because CV used as a measure of the convergence coefficient called sigma convergence coefficients (Das vd., 2016, s. 7; Megyesiova & Lieskovska, 2018, s. 3). The observation of decreasing CV means a good signal of convergence process of the OECD countries. Nonparametric Spearman Rank Correlation was also calculated to find relationship between variables.

Accordingly, it was used ANN based Kohonen SOM clustering analysis to perform clustering of the OECD countries using the SD variables. In clustering analysis, all years of 2019-2021 data were used to the difference better. Therefore, 114 units (38 OECD countries for three examining years) were used. The measuring of the similarities and differences across countries for the studied years indicated the influence of the COVID-19 pandemic on the SD indicators.

In the SOM clustering process, the data was initially normalized according to the mean of zero and standard deviation 1 method. Then, the data is transformed into the matrix form. In SOM analysis, the hexagonal topological order was used, as suggested by Kohonen (Kohonen, 2013, s. 55). Choosing number of nodes is another crucial step for SOM. It was selected as 5 √n rule (Bruwer vd., 2018, s. 358; Huiyan vd., 2008, s. 1197). It was chosen 7x7 SOM grid (49 neurons) with 5000 time iterations.

In SOM analysis, it is hard to determine distinct clusters with resulted maps. For this reason, Vesanto and Alhoniemi (Vesanto & Alhoniemi, 2000, s. 586) suggested "two-level approach" . In this approach, after SOM codes obtained by SOM method, then hierarchical or K means (one of the partitive clustering methods) used to cluster SOM codes. It provides more robust classifications. It was used 49 neuron SOM codes clustered by Ward's agglomerative linkage method. Silhouette Index and Davies–Bouldin Index were used to find the optimal clusters.

All analysis were performed using R studio 2022.07.2 and its Kohonen (Wehrens & Kruisselbrink, 2018), factoextra (Kassambara vd., 2017, s. 1), NbClust (Charrad vd., 2022, s. 1), clValid (Brock vd., 2008, s. 1), clustertrend (Wright vd., 2023, s. 1) packages.

2.2. Kohonen SOM Analysis

Artificial neural networks (ANN) are methods that make predictions using the way the human brain works. SOM, one of the ANN methods, is an unsupervised algorithm using clustering or dimension reduction method. It proposed by Kohonen (Kohonen, 1982, s. 59) so also called as Kohonen SOM map. SOM possess the ability to acquire knowledge from multi-dimensional data and subsequently convert it into a lower-dimensional representation, typically two-dimensional, while still maintaining the original topological relationships. The topological ordering map provides a clear visualization of the similarities among units based on their respective distances.

Similar to ANN approaches, it consists of neurons in the input layer that receive input data, as well as neurons in the output layer that are arranged in a topological order, which can be either a hexagonal or rectangular lattice. The neurons in the output layer are coupled to each neuron in the input layer using weight vectors. The SOM method can be described as five steps (Haykin, 2008, s. 436).

1 . Initialization: Select randomly assign values to the initial weight vectors $w_j(0)$. It is advised to choose small magnitudes for the weights.

2.Sampling: Generate a random sample, denoted as x, from the input space according to a specified probability distribution. The vector x corresponds to the activation pattern that is subsequently applied to the lattice. The dimension of vector x is equivalent to m.

3 . **Similarity matching:** To determine the most suitable neuron i(x) at time-step n, the minimum-distance criterion is employed to identify the best-matching (winning) neuron.

$$i(x) = \arg\min_j \left\| x(n) - w_j \right\|, \qquad j = 1,2,\dots,l$$

4 . **Updating:** The synaptic-weight vectors of all neurons that are in an excited state are changed by applying the update formula.

$$w_j(n+1) = w_j(n) + \eta(n) h_{j,i(x)}(n)\big(x(n) - w_j(n)\big)$$

5 . Continuation: Proceed with step 2 iteratively until there are no noticeable variations in the feature map.

There were various studies comparing SOM and other clustering techniques. They concluded that Kohonen SOM is more robust than other clustering methods because it is a non-linear ANN strategy so no need for any other statical assumptions and efficiently handling missing data (Arunachalam & Kumar, 2018, s. 11; Bloom, 2004, s. 724; Brida vd., 2012, s. 11349). Gue et al. (Gue vd., 2020, s. 1450) also suppressed that ANN methods have better predictive accuracy comparing to conventional techniques so it is highly advisable for analysis SD problems. Therefore, Kohonen-SOM was chosen in this study as a clustering tool.

3. Findings

In the first stage, descriptive statistics of the variables analyzed (Table1 and Table 2). It was showed min, max, mean and CV values of the study indicators and years.

There was an average decrease in GDP per capita in 2020, it increased in 2021 compared to 2019. Colombia had the lowest GDP per capita while the USA had the highest. The CV gradually increased 40.33% in 2019, 42.01% in 2020 and 43.69% in 2021. The observed increase in relative variability serves as a negative indicator of the convergence process in the GDP per capita within the OECD countries. The mean of CHEC increased steadily. Mexico exhibits the lowest CHEC whereas the USA demonstrates the highest. The CV of CHEC increased small amount 2019 to 2020 (49.19% to 49.59%) but dropped to 46.51% in 2021. The decreasing relative variability of CHEC is a good sign for convergence of OECD countries. Although the average of GEH increased over the years, the CV value of GEH decreased in 2021. It is a good sign of GEH for convergence process. Mexico had the lowest GEH whereas the USA had the highest. In addition to this, the relative variability of OPHE was increased by years. The lowest country that had the lowest OPHE was Luxemburg, the highest was Portugal for all three years.

Table 2: Descriptive Statistics of the Indicators-1

Variable	Year	Min	Max	Mean	CV
GDP	2019	16,485 (Colombia)	119,253 (Luxemburg)	47,973	40.33%
	2020	15,615 (Colombia)	119,883 (Luxemburg)	46,997	42.01%
	2021	17,645 (Colombia)	131,311 (Luxemburg)	51,101	43.69%
CHEC	2019	1,117 (Mexico)	10,853 (USA)	3,998	49.19%
	2020	1,227 (Mexico)	11,916 (USA)	4,274	49.59%
	2021	1,262 (Mexico)	12,197 (USA)	4,715	46.61%
SHE	2019	4.37 (Turkey)	16.67 (USA)	8.84	25.93%
	2020	4.62 (Turkey)	18.76 (USA)	9.64	26.69%
	2021	4.57 (Turkey)	17.36 (USA)	9.71	24.97%
GEH	2019	2.68 (Mexico)	13.78 (USA)	6.62	32.62%

	2020	3.29 (Mexico)	15.861 (USA)	7.40	32.73%
	2021	3.05 (Mexico)	14.522 (USA)	7.45	30.73%
OPHIE	2019	0.75 (Luxemburg)	3.725 (Portugal)	2.21	34.01%
	2020	0.704 (Luxemburg)	3.766 (Portugal)	2.23	34.71%
	2021	0.726 (Luxemburg)	4.098 (Portugal)	2.26	35.05%

The mean life expectancy of both females and males has been declining in recent years, with a greater reduction observed in male life expectancy compared to females. The mean LE for female was 83.60, 83.18 and 82.95, respectively for 2019, 2020 and 2021. The difference between mean of female and male LE was not change in examining years and found 5.3 years. In the years 2019 and 2020, the minimum life expectancy for females in Mexico was 78 and 78.1 years, respectively. In 2021, Hungary recorded a minimum life expectancy of 77.8 years for women. Conversely, Japanese women exhibited the highest life expectancy throughout these years. In the years 2019 and 2021, Latvia had the lowest LE for men among the countries under consideration, with Lithuania having the lowest LE in 2020. Also, the LE for Latvia in 2021 decreased to until 68.2 years for men. While the lowest UR in OECD countries was Czechia in years, the highest UR were Greece for 2019, and Costa Rica for 2020 and 2021. It was observed that the average unemployment rate increased to 7.41 in 2020, when the pandemic was at its most intense, and 6.80 in 2021 it was again higher than 6.08 in 2019. The convergence of UR had been declining over the years. Furthermore, the lowest CPI change was observed in Greece in 2019 and 2020 and in Switzerland in 2021, whereas the highest figures were observed in Turkey in all three years. On the other hand, the average CPI decreased to 1.25 in 2020, the highest convergence was observed this year (177.37%). Although the average CPI change in 2021 was observed to be higher than in 2019 (3.45, 2.09, respectively), the convergence value decreased (113.49%, 86.79%, respectively).

Table 3: Descriptive Statistics of the Indicators-2

Variable	Year	Min	Max	Mean
FLE	2019	78 (Mexico)	87.4 (Japan)	83.60
	2020	78.1 (Mexico)	87.7 (Japan)	83.18
	2021	77.8 (Hungary)	87.6 (Japan)	82.95
MLE	2019	70.9 (Latvia)	82.1 (Switzerland)	78.33
	2020	70.1 (Lithuania)	81.6 (Iceland)	77.81
	2021	68.2 (Latvia)	81.8 (Iceland)	77.63
UR	2019	2.02 (Czechia)	17.88 (Greece)	6.08
	2020	2.55 (Czechia)	19.61 (Costa Rica)	7.41
	2021	2.81 (Czechia)	16.43 (Costa Rica)	6.80
CPI	2019	0.25 (Greece)	15.18 (Turkey)	2.09
	2020	-1.25 (Greece)	12.28 (Turkey)	1.25
	2021	0.58 (Switzerland)	19.60 (Turkey)	3.45

Table-4 presented the correlation of SD indicators. There were strong, positive, and statistically significant relationship between SHE and GEH, GDP and CHEC, FLE and MLE (0.937; 0.929; 0.870, respectively). The correlation results showed moderate, positive, and statistically significant association of GDP with MLE, GEH, SHE and FLE (0.623; 0.571; 0.511; 0.459, respectively). There were negative, medium, and statistically significant relationship between CPI and FLE. CPI had a positive but modest correlation

(0.257) with CHEC. On the other hand, there were negative correlations seen between CPI and GDP, changes in GDP, CHEC, SHE, GEH, OPHE, and MLE.

Table 4: The Correlation of SD Variables

	GDP change	CHEC	CHEC change	SHE	GEH	OPHE	FLE	MLE	UR	CPI
GDP	-0.113	0.929**	-0.046	0.511**	0.571**	-0.204*	0.459**	0.623**	-0.272**	-0.202*
GDP change	1	-0.04	-0.291	0.153	0.125	0.07	0.026	0.024	0.014	-0.426**
CHEC		1	0.01	0.764**	0.779**	-0.046	0.456**	0.587**	-0.23*	-0.243**
CHEC change			1	0.008	0.01	0.021	-0.229*	-0.25	0.075	0.257**
SHE				1	0.937**	0.269**	0.355**	0.404**	-0.043	-0.302**
GEH					1	-0.039	0.291**	0.405**	-0.103	-0.205*
OPHE						1	0.105	-0.071	0.161	-0.223*
FLE							1	0.870**	0.009	-0.522**
MLE								1	-0.117	-0.393**
UR									1	-0.099

*p<0.05.; **p<0.01

Clustering Results

The assessment of SOM quality is conducted through visual examination of node counts, node quality (distance), and SOM neighbor distances plots (Arunachalam & Kumar, 2018, s. 23). They can be observed in Figure-1. The counts plot provides a visual representation of the frequency distribution of countries across different nodes. Each node contained between one and seven countries. The grey nodes indicate the presence of empty nodes. The quality plot illustrates the mean the mean distance between among the countries. The SOM neighbor distance plot, also known as the U-matrix, illustrates the distances between each node in a SOM and its neighboring nodes.

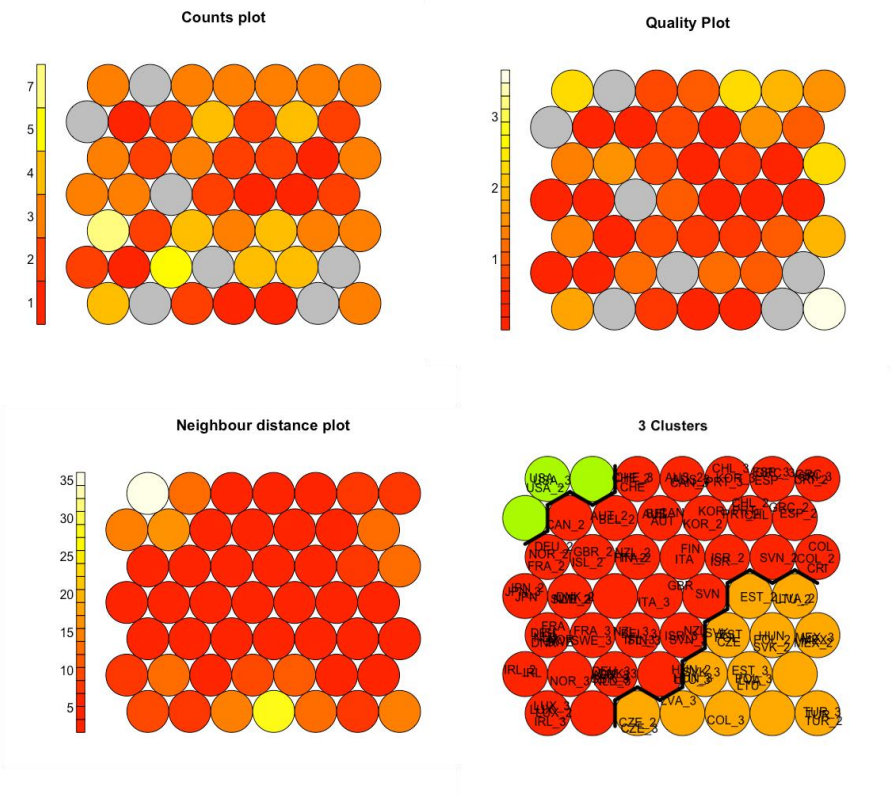

Figure 1 Counts , Quality, Neighbour distance and Cluster Plots of OECD Countries

According to SOM visualization, it can be seen that the USA was the most different country, Secondly, Latvia for 2021 also differed from other countries.

Table 5: Comparison of the Clustering Methods

Index	SOM+Hierarchical clustering	Hierarchical clustering	Hierarchical clustering with Factor Analysis
Davies–Bouldin Index	1.4308	1.8035	1.7342
Silhoutte Index	0.542	0.461	0.454

The optimal cluster found three with using Silhouette Index and Davies–Bouldin Index. It was also used hierarchical clustering and hierarchical clustering with factor analysis methods to evaluate the goodness of fit of the models. In the factor analysis, it was found four factors according varimax method. The methods were evaluated according to their Silhouette Index and Davies–Bouldin Index. Table-5 shows the indexes of three methods. According to result, SOM had better performance than hierarchical clustering and factor analysis with hierarchical clustering methods. Table 6 presented the allocation of the 38 countries into the three clusters based on their membership . Table-7 had the minimum, maximum and mean values of each cluster within the indicator.

Table 6: Clustered Countries

Cluster-1	Australia, Austria, Belgium, Canada, Chile, Colombia (2019 and 2020), Costa Rica, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxemburg, Netherlands, New Zealand, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom
Cluster-2	Colombia (2021), Czech Republic, Estonia, Hungary, Latvia, Lithuania, Mexico,Poland, Slovak Republic, Turkey
Cluster-3	USA

The first cluster consisted of 3 periods of 26 developed countries, 3 periods of Costa Rica and 2019 and 2020 values of Colombia from developing countries . The second cluster had undeveloped countries of Colombia for 2021, Turkey, Poland, Mexico, Hungary and developing countries of Czech Republic, Estonia, Lithuania, Latvia, Slovak Republic for the years examined. USA was identified as the third cluster within the analyzed time period.

Cluster-1 had the highest mean of life expectancy for females and males (84.39 and 79.77, respectively). The countries in this cluster also had the lowest CPI change. The countries in Cluster-2 had the lowest GDP, CHEC, SHE, GEH, OPHE, male and female LE and the highest CPI change, CHEC change. The third cluster had the highest GDP, CHEC, SHE, GEH, OPHE and the lowest CHEC change. In addition to this, GDP change, and unemployment rate were not statistically significant in separating these clusters.

Table 7: Clustered Statistics

SD indicators	Clusters	Mean	Minimum	Maximum
GDP	Cluster1	52,980	15,615	131,311
	Cluster2	34,107	17,645	44,813
	Cluster3	66,117	63,481	70,181
GDP change	Cluster1	0.97	0.80	1.14
	Cluster2	0.96	0.88	1.10
	Cluster3	0.96	0.90	1.02
CHEC	Cluster1	4,727	1,240	7,582
	Cluster2	2,365	1,117	4,303
	Cluster3	11,655	10,853	12,197
CHEC change	Cluster1	1.06	0.98	1.17
	Cluster2	1.10	0.99	1.40
	Cluster3	1.05	1.02	1.10
SHE	Cluster1	9.91	5.47	13.04
	Cluster2	7.00	4.37	9.49
	Cluster3	17.60	16.67	18.76
GEH	Cluster1	7.58	4.65	11.05
	Cluster2	5.09	2.68	8.20
	Cluster3	14.72	13.79	15.86
OPHE	Cluster1	2.32	0.70	4.10
	Cluster2	1.91	0.97	3.03
	Cluster3	2.87	2.84	2.90
FLE	Cluster1	84.39	79.90	87.70
	Cluster2	80.17	77.80	83.00

	Cluster3	80.20	79.30	81.40
MLE	Cluster1	79.77	73.50	82.10
	Cluster2	72.80	68.20	76.40
	Cluster3	74.67	73.50	76.30
UR	Cluster1	6.98	2.35	19.61
	Cluster2	6.22	2.02	13.81
	Cluster3	5.71	3.67	8.09
CPI	Cluster1	1.48	-1.25	4.52
	Cluster2	4.45	-0.44	19.60
	Cluster3	2.58	1.23	4.70

Discussion and Conclusion

The objective of this study was to examine the effects of the COVID-19 pandemic on SD indicators in a subset of OECD nations. Descriptive statistics and ANN-based SOM clustering analysis were employed in this study. The dataset used in this study contained 11 indicators from 38 OECD countries for three years from 2019 to 2021. It used two-stage clustering method, SOM, and hierarchical clustering. The Silhouette and Davies–Bouldin indexes were used to find the optimal number of groups.

The data set was grouped into three clusters. Cluster-1 consists of 28 counties, 26 of them developed countries for the three-year period and two developing counties: Costa Rica and Colombia (2019-2020). They had the highest life expectancy and the lowest CPI change. Cluster-2 consisted of five developing and five developed countries, including Turkey. They showed the lowest GDP per capita and health expenditures, male and female life expectancy and electric production, and the highest health expenditure per capita change. The USA forms a cluster independently and differs from other countries with the highest GDP per capita, health expenditures, and the lowest health expenditure per capita.

GDP is primarily indicator of SDG 8. However, there are several studies investigating GDP and other SGDs relationship (Adrangi & Kerr, 2022, s. 1; Coscieme vd., 2020, s. 1), it is not a proven study its significant relationship between all other goals, but it is still using in most SD studies to explain SD problems. In this study, all indicators (they are part of 2, 3, 7, and 8 SDGs) had high, medium, or weak significant correlation with GDP. Studies showed that GDP per capita was fallen in 2020 but increased in 2021. On the other hand, the convergence of GDP per capita is getting higher gradually in years within OECD countries so it means the difference between countries also getting increased.

Health expenditures data belong to the SDG 3. The goal justify that healthy people build the economically develop countries (United Nations, 2023b). Also, The COVID-19 fatality positively related with national health expenditure (Khan vd., 2020, s. 7). In this study, it was found that in 2020, when the impact of the pandemic was most intense, health expenditures increased suddenly compared to 2019. USA formed a cluster with the highest health expenditures. The USA had the highest mortality from COVID-19 for each year. Although, the country had the largest income country and high health expenditure, it did not perform well during the pandemic (Bollyky vd., 2023, s. 1342; Global Health

Security Index, 2020). In addition to this, Turkey's share of health expenditure was getting higher between years, but it had the lowest share of health expenditure of GDP between OECD countries in the study period.

It is also known that life expectancy of higher income countries are longer (Marmot, 2005). Preston showed that there was a logistic curve between life expectancy and national income (Freeman vd., 2020, s. 2; Preston, 1975, s. 235). It means that life expectancy increases with national income until some trim point than it decreases. As a result, some high-income countries had less life expectancy than expected. Freeman et al. (Freeman vd., 2020) showed that USA had 2.9 years less life expectancy than expected according to its GDP . It is also confirmed in this study that Luxemburg had the highest GDP but did not have the highest life expectancy according to descriptive statistics. USA had also the highest GDP per capita as a cluster, but it did not have the highest life expectancy. On the other hand, the lowest mean of GDP clustered countries had the lowest life span for both females and males. In addition to this, there were studies show that COVID-19 pandemic decreased life expectancy in countries (Aburto vd., 2022, s. 63; Marois vd., 2020, s. 1; Schöley vd., 2022, s. 1649). This study confirmed that the mean of life expectancy is decreased in OECD countries examining three years, Latvia interestingly had 68 years of life expectancy in males. Turkey's lifespan was also getting decreased in years.

The unemployment rate belongs to SDGs 8. Elsamadony (Elsamadony vd., 2022b, s. 1) reported that the goal of 8 effected by pandemics in all countries in spite of income level. It was found that the unemployment rate averagely increased in 2020 for OECD countries, but also mostly developed countries clustered had a higher unemployment rate than other clusters.

The consumer price index originally belongs to SDG 2; it also measures inflation and economical condition. It also affected from the pandemic and increased globally around the world. Turkey had the highest CPI in all OECD countries, and the including developing countries cluster had the highest CPI.

To sum up, the convergence of gross domestic product increased gradually in years, meaning increasing relative variability of OECD countries. While the mean of life span was decreased, share of health expenditure, health expenditure per capita, out of pocket health expenditure and government health expenditure, unemployment rate, consumer price index were increased in study period. The countries also had similar characteristics within three years, except Colombia. On the other hand, USA distinguished very different characteristics from other OECD countries. Although, mean of study indicators vary because of pandemic, the change within each OECD country showed mostly similar characteristics within three years.

There were several limitations of this study. Initially, the countries were limited with 38 OECD countries. Also, it was used indicators of part of SDGs 2,3, and 8 for three years. In addition to these limitations, the present study employed an artificial neural network-

based self-organizing map clustering technique to examine the variations of OECD countries in the SDGs during the COVID-19 pandemic. This approach was utilized to ensure the reliability and stability of the obtained outcomes. Further studies might need to analyze using more countries and SD indicators. Structural breaks also can be examined using time series data during the COVID-19 pandemic.

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Benzerlik Taraması	Yapıldı – Ithenticate
Etik Bildirim	itobiad@itobiad.com
Çıkar Çatışması	Çıkar çatışması beyan edilmemiştir.
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Plagiarism Checks	Yes - Ithenticate
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